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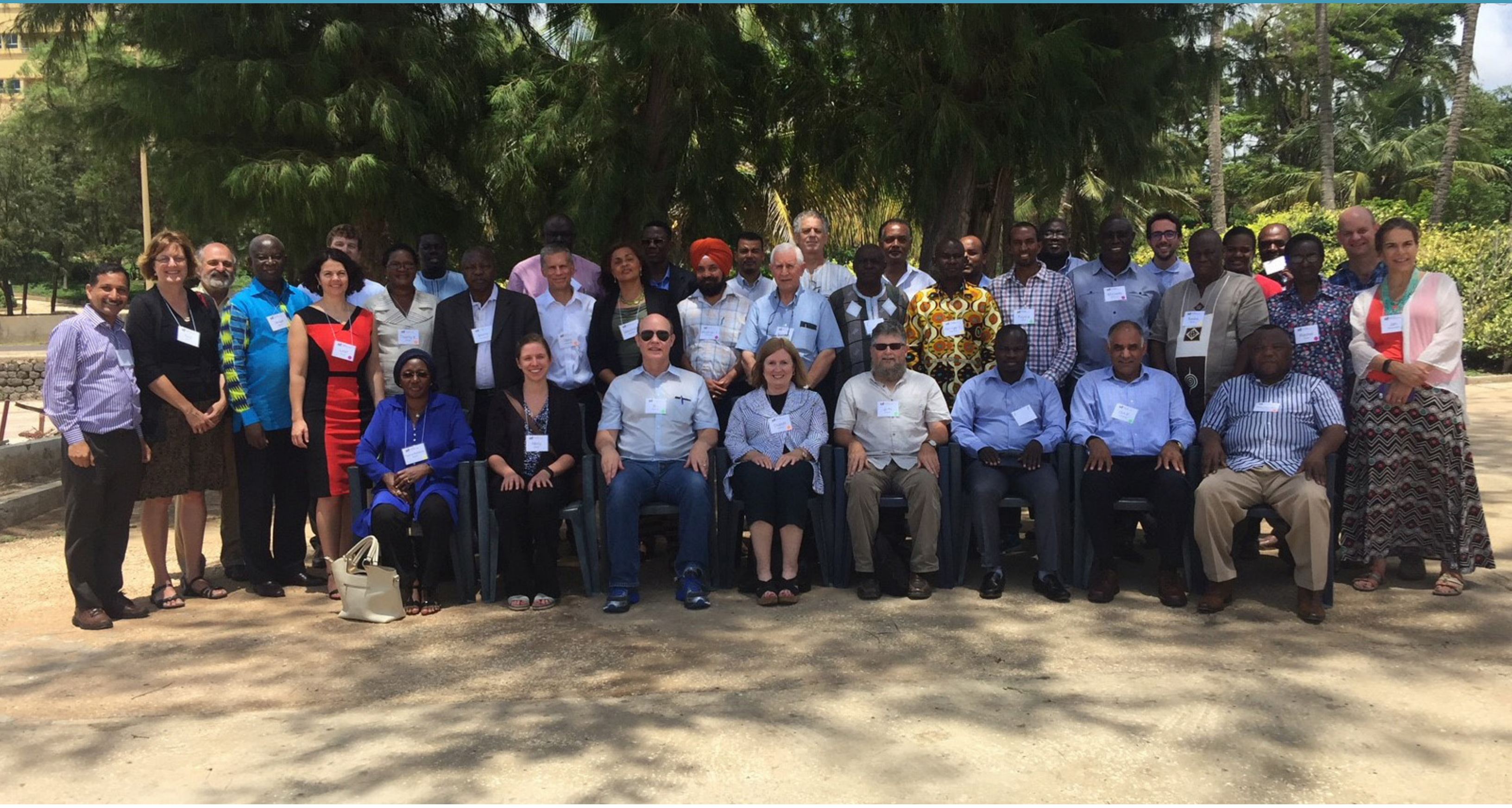

# SUB-SAHARAN AFRICA SOIL FERTILITY PRIORITIZATION REPORT

## II. SUMMIT RESULTS

USAID
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Feed the Future Innovation Lab
Collaborative Research on Sustainable Intensification

Kansas State University

# REPORT

**of the**

# Sub-Saharan Africa Soil Fertility Prioritization: II. Summit Results©

**Prepared by**

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## Executive Summary

This *Sub-Saharan Africa (SSA) Soil Fertility Prioritization Summit* was designed to better understand the perspectives of key leaders and actors from across the value chain from scholars to extension agents, and from biophysical to social scientists. Recognizing the need for a comprehensive view of the soil fertility landscape, the study aimed to incorporate elements across the entire soil fertility supply chain, being inclusive of multidisciplinary approaches (production, economics, social, regulatory/policy, environmental) to understand barriers to enhancing soil fertility and the establishment of evidence-based priorities to overcome these barriers.

The *SSA Soil Fertility Prioritization Summit* was the second phase of a multi-stage effort led by Kansas State University's Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification, (SIIL), which built upon results generated from the first phase, the *SSA Soil Fertility Prioritization Survey*. The first phase consisted of developing and administering a survey to multiple stakeholders working on soil fertility issues within Sub-Saharan Africa, including focus countries in West Africa, East Africa, the Great Lakes region and Ethiopia. While, the summit aimed to gather additional feedback from key stakeholders through a facilitated process designed to capitalize on the expertise of the participants and further explore the soil fertility limitations, solutions, barriers and strategies.

In August of 2017, the SIIL team convened 35 participants for the Sub-Saharan Africa Soil Fertility Prioritization Summit in Dakar, Senegal at the Hotel Ngor Diarama who were identified as key thought leaders on soil fertility issues in their respective regions. Participants represented IARCS, NARES, national universities, extension agencies, developmental agencies, agronomic/soils researchers, social scientists, regulatory agencies, private sector, and farmer organizations.

Participants were organized by regions based on their expertise and asked to identify solutions to the soil limitations prioritized across all regions in the survey (i.e. nitrogen deficiency, low soil organic carbon content, phosphorous deficiency, acidity, micronutrient deficiency, and low available water holding capacity). For each limiting soil factor, participants identified and prioritized solutions to overcome each limitation, barriers to overcoming the soil limitation, and strategies to overcome these barriers.

This facilitated activity captured a breadth of information. The summit results are complementary to the survey results and reinforced that there are key biophysical and socioeconomic barriers and strategies that can either create an enabling environment or hinder progress towards improving soil fertility across SSA. Inorganic fertilizer access, use, and related issues were prominent but many related biophysical (building soil organic carbon) and socioeconomic barriers (access to resources both financial and agronomic, and access to appropriate fertility recommendations and extension support) and solutions were identified as equally important to building soil fertility.

The combined biophysical and socioeconomic results provide a clear picture of the interdisciplinary and interconnected nature of priorities to improve soil fertility across each region. Thus, plans for improving soil fertility across SSA must take an integrated approach, inclusive of the identified biophysical and socioeconomic factors. Action plans that only focus on a singular or narrow factor such as inorganic fertility availability or mineral fertilizer recommendations alone will likely fall short of improving soil fertility. Each of these prioritized factors must be improved in such a way that no one of the identified priorities are limiting. For example, though it may be quite evident that the use of inorganic fertilizer can improve crop

yields, incorporating this approach exclusively - without the inclusion of appropriate recommendations, suitable extension services, access to financial resources, incorporation of organic amendments, and enabling policies will likely not be successful in improving soil fertility. A perspective of the current status of the soil fertility landscape and evaluation of the most limiting biophysical or socioeconomic factors in a given region is critical for recommending the appropriate action plan to improve soil fertility. Focusing only on inorganic fertilizer use alone without taking into consideration and addressing other biophysical or social constraints will fall short of improving soil fertility in most regions.

Please refer to the *SSA Soil Fertility Prioritization Final Report* for overall recommendations using a combined analysis of the *SSA Soil Fertility Prioritization Survey and Summit* results.

## Introduction

The health of our soils is the basis of the productivity of our farming systems, the food and nutrition security of our societies, and the improvement of livelihoods and poverty alleviation in our world. Soils of sub-Saharan Africa (SSA) are largely unhealthy due to years of nutrient mining and limited organic or inorganic resupply. As such, crop yields have stagnated and high levels of food insecurity and poverty persists. The World Bank (2013) estimates that over 80 percent of Africa's agricultural lands are degraded, having either biophysical or chemical constraints that limit food production. These degraded soils are estimated to affect 485 million Africans and cost the continent nearly US$9.3 billion annually (Thiombiano and Tourino-Soto, 2007). Without addressing soil health issues, smallholder farmers cannot benefit from yield gains offered by improved plant genetics and other associated agronomic practices. Limited by soil degradation, yield increases from improved crop varieties are estimated at only 28 percent in Africa as compared to 88 percent in Asia (IFDC, 2013).

Following the Green Revolution, SSA remains one of the only regions of the world where per capita food production has remained stagnant (Sanchez, 2002). However, there has been a renewed focus on soil fertility following the call of H. E. Kofi Annan for a "uniquely African Green Revolution." Soil fertility has been consistently identified as a primary limiting factor in SSA preventing the dramatic yield increases seen by the rest of the world. However, there are several obstacles in overcoming barriers to achieving healthy and fertile soils. Over thirteen years after H. E. Kofi Annan's call, and numerous activities and investments in SSA soil fertility, cereal yields still around 1.5 MT $ha^{-1}$ as compared with 3 MT $ha^{-1}$ in Latin America, and South Asia, 5 MT $ha^{-1}$ in China, and greater than 10 MT $ha^{-1}$ in North America, Europe, and Japan (AGRA, 2016). There is now a renewed sense of urgency in the need to refocus and prioritize sustainable soil fertility efforts in an inclusive and evidence-driven way that looks holistically at the barriers to improving soil health and productivity in SSA.

Soil and plant analysis, paired with hydro-agro-ecologically specific fertilizer response functions, is often the first step to producing evidence-based fertilizer recommendations for efficient crop response. Though this model has been attempted across SSA to varying effect, its self-sustaining business model and adoption by smallholder farmers has been limited. Further, past soil fertility improvement efforts have often focused on inorganic fertilizer use as the primary mechanism for improving soil fertility and improving crop yields; however, in SSA conditions where soils are already degraded (i.e. limited organic matter (OM) and organic nutrient pools), a focus on inorganic fertilizer use alone has had limited success in improving SSA soil fertility. Long-term solutions, such as approaches building OM and organic nutrient pools, and supporting inputs and management practices will likely be an essential component to achieving sustainable soil fertility in SSA. These past lessons have led to the need for a more inclusive evaluation of the soil fertility landscape aiming to evaluate the entire soil fertility supply chain; one that is inclusive of multidisciplinary approaches (production, social, regulatory/policy, environmental) to understand soil fertility barriers and the establishment of evidence-based priorities to overcome these barriers.

Based on this need, Kansas State University's Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL) led an inclusive process with the primary objective of identifying critical soil fertility priorities in SSA focused around key barriers (e.g. increasing soil organic matter, nutrient limitations – both macro and micro) and key sustainable priorities to overcome the identified barriers. This objective was realized through a multifaceted evidence-driven evaluations involving key leaders and actors from across international agricultural research centers (IARCS), national agricultural research and extension systems (NARES), national universities, extension agencies, developmental agencies, agronomic/soils researchers, private sector, social scientists, regulatory agencies, and farmer organizations to systematically identify soil fertility barriers and priorities to overcome these barriers. To accomplish this objective, SIIL developed a three-stage process that included the development and administration of a soil fertility survey (*SSA Soil Fertility Prioritization Survey Report*), followed by a cumulative prioritization summit (*SSA Soil Fertility Prioritization Summit* - the focus of this report), and concluded with a comprehensive analysis of the survey and summit to provide proposed recommendations to address key soil fertility issues within SSA (*SSA Soil Fertility Prioritization Final Report*). This multi-stage approach to identify key soil fertility priorities considered:

- Access to quality and standardized mineral fertilizers in the marketplace
- Suitability of available fertilizer blends (including micronutrients)
- Are technologies in place to maintain and build soil organic matter (OM) levels that would lead to improved crop response to fertilizer?
- Access to agroecologically appropriate fertilizer response curves and subsequent fertilizer recommendations.
- Are extension service providers in place to deliver appropriate, high-quality fertilizer recommendations to farmers?
- Access to quality soil and plant diagnostic laboratories
- Availability of high resolution soil maps
- Are strategies for integrated soil fertility management available and accessible to farmers
- Access to mechanization where appropriate (gender impacts)
- Effect of fertilizer regulations and subsidy programs
- Value and demand of the commodities produced
- Identification and development of market linkages
- Access to financial resources (gender equitable)
- Access to land tenure (gender equitable)
- Effect of intrinsic soil properties (e.g. parent material)
- Effect of environmental or climate constraints

The *SSA Soil Fertility Prioritization Summit* was the second phase of the three-stage effort that built upon results generated from the first phase, the *SSA Soil Fertility Prioritization Survey*. This phase consisted of developing and administering a survey to multiple stakeholders working on soil fertility issues within Sub-Saharan Africa. The results from the survey, (found in the *SSA Soil Fertility Prioritization Survey Report*), served as the foundation to the summit activities.

The summit aimed to gather feedback from key stakeholders through a facilitated process designed to further explore the soil fertility limitations, solutions, barriers and strategies to capitalize on the expertise of the participants. Participants were invited based on their expertise and extensive knowledge of the following four focus regions:

- West Africa region: Senegal, Burkina Faso, Ghana, Niger, Mali
- East Africa region: Tanzania, Kenya
- Great Lakes Area: Rwanda, Uganda, Burundi, Malawi
- Ethiopia (kept separate due to its unique agroecology)

The survey and summit specifically addressed the following:

- Understanding overall constraints associated with soil fertility to minimize yield gaps.
- Understanding the geographic distribution and area impacted by those constraints.
- Prioritizing, by region, efforts to overcome constraints in order to maximize the area positively impacted by research, extension, and potential adoption of improved soil management practices.
- Establishing research needs for soil and crop management, and nutrient recommendations for smallholder farmers.
- Exploring and prioritizing barriers to the use of soil and nutrient management (including analytical and diagnostic tools; and simulation models) information in making crop production management decisions by smallholder farmers.
- Exploring opportunities and innovations (e.g. production, market, financial, social, policy) for overcoming these barriers.

Distinct priorities for overcoming the identified critical soil limiting factors identified in the survey (i.e., N deficiency, low soil organic carbon content, P deficiency, acidity, micronutrient deficiency, and low available water holding capacity) were identified for each region. Results from the process and summit discussions produced strong commonalities across the SSA. Therefore, the focus of the report is on the unified barriers and strategies. Regionally unique barriers and strategies are interjected and discussed where appropriate.

This summit report provides a robust and diverse set of solutions, barriers and strategies for overcoming the primary soil limitations identified in each region and for the SSA, as a whole. The report is organized by a methodology, results, observations and conclusion section, in addition to the appendices with supporting documentation. The first five appendices are organized by each soil fertility limitation and include results from each of the four regions in the following order: Ethiopia, Great Lakes, East Africa and West Africa. The final two appendices include the summit agenda and participants' name and organization.

1. Appendix A: Full Results for Nitrogen (N) Deficiency

2. Appendix B: Full Results for Low Soil Organic Carbon (SOC) Content

3. Appendix C: Full Results for Phosphorous (P) Deficiency

4. Appendix D: Full Results for Acidity

5. Appendix E: Full Results for Micronutrient Deficiency

6. Appendix F: Soil Fertility Prioritization Summit Agenda

7. Appendix G: Soil Fertility Prioritization Summit Participants

## Methodology

On August 14th and 15th of 2017, the SIIL team convened 35 participants for the Sub-Saharan Africa Soil Fertility Prioritization Summit in Dakar, Senegal at the Hotel Ngor Diarama who were identified as key thought leaders on soil fertility issues in their respective regions. Participants represented international agricultural research centers (IARCS), national agricultural research and extension systems (NARES), national universities, extension agencies, developmental agencies, agronomic/soils researchers, social scientists, regulatory agencies, private sector, and farmer organizations. The summit built from the survey results and was designed to further explore the soil fertility limitations, solutions, barriers and strategies to overcome these barriers through a facilitated process to capitalize on the expertise of the participants.

Participants were separated into regions based on their expertise and asked to identify solutions to nitrogen deficiency, low soil organic carbon content, phosphorous deficiency, acidity and micronutrient deficiencies since these were the top soil limiting characteristics identified in the Sub-Saharan Africa Soil Fertility Prioritization Survey (See *SSA Soil Fertility Prioritization Survey Results Report*) across all regions. Each region had between seven to nine participants. For each limiting soil factor, each region separately identified their top solutions to overcome this limitation through participatory. team effort and consensus. Solutions were recorded on flip charts. Each participant was given four large Post-its and asked to write two biophysical and two socioeconomic barriers to these solutions. All Post-its were read aloud and posted for all to see. Participants organized the barriers into clusters and titled the clustered barriers by theme and gave a title or named the theme. Participants then developed strategies to overcome the named clustered barriers and the strategies were recorded on flip charts. This process occurred from start to finish for each limiting soil characteristic and separately for each region.

The following day, all solutions were displayed for everyone to review. After reviewing all solutions and strategies across the regions, all participants convened as a group and through consensus, identified common solutions identified by all regions. These common solutions across all regions were titled as a group and posted for ranking or prioritizing. Each participant was given two dot stickers and were asked to place their sticker by the solutions that they felt would provide the largest breadth and depth in addressing soil fertility issues in the Sub-Saharan Africa Region. All the regions completed the process for the first four identified soil constraints (nitrogen deficiency; low soil organic carbon content; phosphorus deficiency; and acidity). One group completed all five constraints. Due to time limitations, the last item 'micronutrient deficiency' was given as a take home assignment to the four groups that could not complete this topic. All the members provided the solutions, barriers and strategies to overcome these barriers and they were summarized and provided in Appendix E.

## Results

The summit provided a rich and diverse view of solutions, barriers and strategies for overcoming the primary soil limitations identified in each region and for the SSA, as a whole. This section attempts to summarize that diverse input although the reader is referred to Appendices A to E for a complete presentation of the results and description. Critical analyses and review of detailed results is strongly encouraged when considering projects or initiatives in a specific region covered by the survey and summit. Issues that were not identified frequently during the summit are not presented in this section.

### Soil Limitation: Nitrogen (N) Deficiency

*Solutions*: For N deficiency as a limiting soil factor, responses across the regions had many common themes including the addition of inorganic fertilizer, the addition of carbon-rich sources of N, such as manures and composts, utilizing legumes in crop rotations or as cover or inter-crops, and other variations on integrated soil fertility management (IFSM). Agroforestry was mentioned as a solution for both East Africa and West Africa. Improved knowledge and training was unique to Ethiopia and the use of N efficient crops/varieties/hybrids was unique to the Great Lakes region.

*Barriers and Associated Strategies by Cluster*: The clustering exercise produced very similar concepts across all regions. Clusters were identified for costs/financial aspects, new data, improved dissemination of existing information, and the availability and quality of fertilizers and other N sources.

Results clearly indicate that knowledge development/sharing and capacity building are essential strategies in reducing N deficiencies. There is a strong need for more qualified professionals, supplied with location specific information on N fertility, working directly with farmers to have a significant impact on this soil limitation. This would require investment in the number and training of people providing recommendations to farmers and applied research to support their efforts. Many comments suggested extension services, specifically; but such needs could also be met with international agricultural research centers (IARCS), national agricultural research and extension systems (NARES), national universities, developmental agencies, NGO's, the private sector, and farmer organizations. The use of smart phones and other technologies is strongly encouraged. Applied research would cover issues including fertilizer recommendations, soil testing, plant analysis, developing fertilizer response curves, alternative crops and forages, crop selection for efficient N use, and, in general, all aspects of integrated soil fertility management (ISFM).

Lack of availability and affordability of quality inorganic fertilizers was consistent across all regions as was the financial resources or credit to purchase fertilizers regardless of cost. There was widespread willingness to consider sources of N other than inorganic fertilizers which included multiple forms of organic materials. For inorganic fertilizers and alternative N sources, many barriers addressed a general lack of knowledge, including farmer acceptance, the absence of crop-specific recommendations, the lack of adequate extension systems and personnel, the lack of soil testing, and the lack of composition data for manures and composts. A lack of policies supporting the use of carbon-rich sources of N and management of crop residues is also a common barrier, particularly with regard to the use of such materials as fuels and livestock feed. In addition, free grazing of animals was a constraint for leaving crop residues in the field. Addressing financial issues is equally as important and includes developing and implementing well-designed voucher or subsidy programs with an exit strategy, the encouragement of microfinancing programs, farmer's coops, and crop insurance programs. Policies at the country and regional levels more favorable to the use of C-rich soil amendments and retaining crop residues on the soil would be very beneficial. This could include specific regulations governing farmer practices as well as the development of alternative feed and fuel sources to reduce demand of crop residues and manures for these uses. Such actions would need to be regional in nature to account for local factors, such as the type and population of livestock, locally adapted forage crops, and locally available alternative fuel sources.

Lack of appropriate scale mechanization was noted as a barrier in Ethiopia and the Great Lakes Region. Land tenure was noted as a barrier in Ethiopia and West Africa, as well. Ethiopia was the only region that identified the need for adequate soil testing facilities. For some barrier clusters, strategies were not developed due to time constraints.

**Soil Limitation: Low Soil Organic Carbon (SOC) Content**

*Solutions*: Across all regions, solutions directly or indirectly suggested increasing C to the soil through the addition of C-rich materials such as manures or composts, retention of crop residues, cover crops or green manures, or use of inorganic fertilizers to increase biomass production. Ethiopia and the Great Lakes and East Africa regions listed solutions that are consistent with ISFM, including crop rotations, cropping systems, optimizing C:N ratios through improved crop-livestock-soil management, and improved information and recommendations on soil fertility management. All regions listed components of conservation agriculture and improved agriculture practices related to reducing soil erosion and use of no-till practices. Agroforestry was suggested for West Africa. The option of adding biochar was specifically mentioned for West Africa.

*Barriers and Associated Strategies by Cluster*: More than any other soil limitation; the need for basic and applied research was a clear need in all regions. Applied research on crop residue management, tillage, soil erosion, cropping systems, cover crops, and soil compaction were specifically mentioned. For basic research, soil microbial processes as related to soil health and nitrogen fixation, biochar, use of soil applied polymers, and the optimization of C and nutrient flows were highlighted. Similar to N deficiency, policy and development issues that would encourage the application of C-rich materials and retention of crop residues to/on the soil were strongly emphasized.

Clusters were also identified in all regions that related to acquiring new knowledge and capacity building and the lack of availability of appropriate mechanization. Strategies for acquiring new knowledge and capacity building are equally applicable for soil organic carbon (SOC) and were covered under the soil limitation of N deficiency. Strategies for appropriate mechanization related to providing appropriate scale planters (hand-held or 2-row drawn by animals or single-axle tractor) and other equipment needed for conservation agriculture practices.

Issues related to cover crops as components of conservation agriculture and ISFM were identified for the Great Lakes, East Africa, and West Africa regions. Strategies included capacity building within extension services, the availability of suitable seed for cover crops, and improved ways to demonstrate the cost-benefit relationships for using cover crops. Land-tenure and labor issues were mentioned in Ethiopia and West Africa and are essential for long-term strategies for soil improvement. Strategies included policies related to grazing, land ownership, and the promotion of soil quality improvement. Labor included the availability of labor at critical times, as well as training needs that would help develop a skilled work force to service agriculture in general. Issues related to engaging women and youth were also included in the strategies related to labor. Socioeconomic issues were specifically mentioned in the Great Lakes region and were implied in the other groups. It was suggested that there may be cultural issues against the adoption of improved management practices; however, it would be necessary to explore this topic more thoroughly to confirm this sentiment. Other barriers discussed were the need for additional research, improved policies for grazing practices, development of alternative fuel sources, and the additional work needed to identify the connection between mechanization and health issues.

Issues related to burning of brush and crop residue, and the use of biochar was unique to West Africa. Strategies to address these issues involve the need for policies on the use of prescribed burning and research exploring the production and use of biochar.

**Soil Limitation: Phosphorus (P) Deficiency**

*Solutions*: The addition of P fertilizers and soil pH management were provided as essential solutions across all four regions. The use or promotion of soil microorganisms that increase soil P solubility were mentioned for Ethiopia, Great Lakes and East Africa regions with mycorrhizae specifically called out for two of those regions. Increased availability and use of soil testing as a solution for Ethiopia and East Africa with the additional and related need for improved P fertilizer recommendations mentioned for Ethiopia. The addition of C-rich materials to soils and the use of crops adapted to low soil P conditions were identified as solutions for the Great Lakes and West Africa regions. Addressing soil compaction was mentioned for East Africa while the use of rock phosphate is a potential solution for West Africa.

*Barriers and Associated Strategies by Cluster*: Clusters for cost and availability of P fertilizers were identified for all four regions, as was the need for research on proper P management practices. Strategies included policies promoting the use of P fertilizers, including risk management approaches such as crop insurance, the development of locally available P sources, and overall capacity building to improve research and extension capabilities. Issues related to the availability of cost of lime for soil pH management was also common across all four regions and will be described in more detail in the next section. Access to an improved soil testing procedures, both in the lab and in the field, was identified as a cluster or within a cluster for three of the regions (with an exception of Great Lakes). Similar to the previous soil limitation, cultural pressures may hinder the adoption of improved practices such as the use of P fertilizers. Finally, equipment and transportation limitations were identified as clusters for the Great Lakes region. Research on appropriate scale mechanization and policies for improving infrastructure such as roads were listed as strategies.

**Soil Limitation: Acidity**

*Solutions*: Liming or partial liming (increasing soil pH to overcome serious limitations such as Al toxicity but not as high as would provide optimum plant nutrient availability) were identified as solutions in all four regions. Similarly, the use of acid-tolerant plant species was also identified in all regions. A combination of solutions that includes the addition of C as manures or biochar, or using ashes or burning to produce ashes, was also common to all regions. Adding C or biochar can help alleviate Al toxicity and biochar and ashed are enriched in basic cations that can help improve base saturation and increase soil pH. Solutions that involve fertilizer selection and management were identified in the Ethiopia and the Great Lakes region discussions. This would include fertilizers with a low potential for acidifying the soil or band placement of P fertilizers to provide a zone of soil more favorable for root development. Water management practices, soil testing, and agroforestry were unique solutions for Ethiopia, East Africa, and West Africa, respectively.

*Barriers and Associated Strategies by Cluster*: Three clusters were common to all four regions: availability of liming materials and associated infrastructure issues; cost issues; and a lack of research on both the development of liming recommendations for soil and the identification and improvement of crop genetics that facilitates acid soil tolerance. Barriers and strategies for the availability of lime ranged from subsidies for transporting liming materials from distance sources to policies that promoted the development of locally available liming materials. Strategies for addressing the barriers to the availability of liming materials would likely alleviate some cost issues. Absent that, subsidies were mentioned as a strategy for soil limitations described previously and were referenced in this section. Enhanced soil testing capabilities was identified as a need for Ethiopia and the East and West Africa regions. Improved extension services and the associated capacity building strategy were identified for the Great Lakes and East Africa regions. Mechanization issues were mentioned as barriers for the Great Lakes region and included topics such as equipment suitable for spreading large amounts of liming materials and also equipment that could apply subsurface bands of lime in the soil. Biochar was mentioned as a strategy within clusters across three of the four regions. The apparent interest is driven by the possibility of such materials delivering stable C and having a liming effect simultaneously. Much work is needed in this area including identifying feedstocks, production, and potential benefits for crop production.

Somewhat surprisingly, land tenure was not addressed within any of the regions. It may probably considered intrinsic to the problem. Liming acidic soils is expensive and treatments are generally effective for multiple years, hence land tenure would be an important consideration before such an investment in soil improvement is made.

### Soil Limitation: Micronutrient Deficiency

*Solutions*: Solutions were the use of blended fertilizers, manures, soil testing and plant analysis, liming soils to increase the availability of cationic micronutrients, and foliar feeding of micronutrients. Overall, the status of micronutrient fertility is in need of significant investigation.

*Barriers and Associated Strategies:* Barriers and associated strategies were similar to what was found for other soil limitations. There is a strong need for research to identify what crop/soil/micronutrient combinations would be responsive followed by the growth and development of public and/or private extension services to disseminate that information. The lack of availability of micronutrient fertilizers is a significant limitation and blending with existing N-P-K formulations would seem to be the best way to increase micronutrient availability to crops, other than foliar feeding. However, fertilizer blends with micronutrients must be based on research that indicates response and not simply low soil or plant tissue concentrations. Without first establishing research indicating micronutrient response, the addition of micronutrients to fertilizer blends will only increase the fertilizer costs of responsive macronutrients and reduce economically optimum returns to fertilizer use. Across all regions, there was a need to provide more education, information, and develop a systematic method of disseminating information related to micronutrient and its relationship to soil fertility.

*Note*: A limited amount of information was obtained for micronutrient deficiency for the Great Lakes region due to time constraints.

**Prioritization of Soil Fertility Solutions for SSA**

In order to prioritize soil fertility issues across the SSA, regional solutions for each soil fertility limitation were captured and displayed for all participants review and reflection. The exercise was designed to synthesize the solutions across regions in an effort to focus on solutions that would provide the largest breadth and depth in addressing soil fertility issues within the Sub-Saharan Africa. Through a consensus process, participants identified nine common solutions and ranked them for prioritization purposes to identify the most important ones.

Participants identified the following priorities across all regions (participant vote tallies follow each priority in brackets): apply inorganic nitrogen and phosphorous (24), incorporation of organic resources (20), increase integration of legumes in crop systems (focus of biological $N_2$ fixation) (17), conservation agriculture practices (where appropriate) (11), liming acid soils (11), diversification of cropping system (7), use of acid tolerant crop varieties (2), and consider biochar where appropriate, economical, and environmentally feasible (1),and promoting the proliferation of beneficial microorganisms (0).

## Observations

Although the summit results generated data at the regional level, the following common themes were identified across all four regions from discussions.

- Solutions, barriers, and strategies were interrelated and applicable among and between the identified soil fertility limitations characteristics (e.g., strategies to overcome N deficiency were applicable to low SOC content, and P deficiency given the need to develop strategies that embrace a ‘systems’ approach to soil health)
- Need for expanded research, leading to improved/updated recommendations for site- and region-specific conditions
- Need for education, communication, and training for farmers with a focus on peer-training and on-farm demonstrations
- Need to build the capacity of extension service providers
- Need to strengthen knowledge transfer among and between researchers, extension service providers, and farmers (both large and smallholders)
- Socioeconomic factors need to be explored and more social scientists need to be involved in developing solutions related to the soil fertility issues

## Conclusions

The following discussion is based solely on the results obtained from the *SSA Soil Fertility Prioritization Summit* and does not include discussion of results from the *SSA Soil Fertility Prioritization Survey*. Please refer to the *SSA Soil Fertility Prioritization Final Report* for a combined analysis and recommendations.

This *SSA Soil Fertility Prioritization Summit* was designed to systematically identify evidence-driven soil fertility barriers and strategies to overcome these barriers specifically focused on overcoming the prioritized soil limiting factors identified in the *SSA Soil Fertility Prioritization Survey* (i.e., N deficiency, low soil organic carbon, P deficiency, acidity, and micronutrient deficiency). These summit specific results in combination with the survey results guided the development of recommendations and a proposed action plan for stakeholders, research and development, policy makers, funding organizations, and the scientific research community as well. Distinct priorities were identified for each region, though unified priorities across regions were also developed and were prominent. For the purpose of this discussion, soil fertility is defined as the ability of the soil to provide adequate amounts of essential plant nutrients to sustainably produce plant biomass (both grain and fodder) to meet anthropogenic requirements.

The facilitated process implemented during the summit captured a breadth of information. The summit results are complementary to the survey results and indicate that there are key biophysical and socioeconomic barriers and strategies that can either create an enabling environment or hinder progress towards improving soil fertility across SSA. Inorganic fertilizer access and use, availability and use of organic materials and related issues were prominent, but many related biophysical barriers (e.g., building soil organic carbon) and socioeconomic barriers (access to resources both financial and agronomic, access to appropriate fertility recommendations and extension support) and solutions were identified as equally important to building soil fertility.

The combined biophysical and socioeconomic results provide a clear picture of the interdisciplinary and interconnected nature of priorities to improve soil fertility across each region. Thus, plans for improving soil fertility across SSA must take an integrated approach, inclusive of the identified biophysical and socioeconomic factors. Action plans that only focus on a singular or narrow factor such as inorganic fertility availability or mineral fertilizer recommendations alone will likely fall short of improving soil fertility. Each of these prioritized factors must be improved in such a way that no one of the identified priorities are limiting. For example, though it may be quite evident that the use of inorganic fertilizer can improve crop yields, without the inclusion of appropriate recommendations, suitable extension services, access to financial resources, incorporation of organic amendments, and enabling policies, improving soil fertility will likely not be successful. A perspective of the current status of the soil fertility landscape and evaluation of the most limiting biophysical or socioeconomic factors in a given region is critical for recommending the appropriate plan of action to improve soil fertility. Focusing only on inorganic or organic fertilizer use alone will fall short of improving soil fertility in most regions.

Overall, recommendations used a combined analysis of the *SSA Soil Fertility Prioritization Survey and Summit* have been developed and are articulated in the *SSA Soil Fertility Prioritization Final Report*.

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## Appendix A - Soil Fertility Prioritization Summit Results – Nitrogen Deficiency

### I. Ethiopia – Barriers and Associated Strategies by Cluster - Nitrogen (N) Deficiency

*Solutions:*

1. Improved crop, livestock, and soil management practices.
2. Increase availability and access to organic sources of N.
3. Increase availability and access to inorganic sources of N.
4. Improved information and recommendation for appropriate N use and application.

*Information, Education, and Dissemination - Barriers*

- Empirical response curves (big, messy, geo-referenced data)
- Small-scale innovative soil testing facilities
- Local, possibly informal extension
- Widely disseminated market information (smart phone) to small scale farmers
- Lack of extension education
- Gap between research and applications at farm level
- Lack of efficient extension and research system
- Wrong understanding of N role by extension and farmers
- Lack of proper crop rotations (+ legumes/ Forages)
- Lack of recommendable agronomic practices
- Inadequate support for public extension and research
- Lack of information documentation and sharing
- Limited awareness of farmers on the appropriate use of N-fertilizer and right recommendation scheme

*Information, Education, and Dissemination - Strategies*

- Build capacity of the extension system (e.g., human resources, facilities, etc.)
- Develop recommendable technology practices
- Critical reassessment of the role of the extension system (must address the vehicle of information)
- Strengthen Ethiopian’s existing system to improve dissemination, education, and information
- Strengthen the relationships and linkages between research ↔ extension ↔ farmers ↔
- Leverage information technologies for dissemination
- Strengthen farmer service centers
- Who is responsible for quality control? (farmer service centers)

*Access to Finance and Resources - Barriers*

- Access to credit funds
- Limited access to finance to purchase in-organic fertilizer sources
- Unaffordable fertilizers
- Lack of access to financial sources
- Credit
- Transportation Access
- Affordability and accessibility of organic and inorganic N sources

*Access to Finances and Resources- Strategies*

- Strengthen farmer service centers
- Offer low interest rate loans for small holder farmers via microfinancing
- Empower woman in finance and resource management
- Share cropping

- Making subsidies available, where appropriate
- Scale-up and strengthening the input voucher systems
- Insurance for crop and livestock
- Strengthen farmer Coops

*Organic Input Issues - Barriers*

- Lack of alternative energy sources crop residue/animal manure
- Competitive use of organic manures for fuel sources, and limited production and supply of bio-fertilizers
- Lack of integrated (crop-livestock-natural resources) research and management
- Competing uses of organic materials
- Competing interest for crop residue as livestock feed and retention on field
- Lack of alternative feed sources, other than crop residue, for livestock
- Limited availability of organic inputs

*Organic Inputs Issues - Strategies*

- Crop livestock integration and management
- Biomass recycling
- Develop alternative sources (e.g., solar, etc.)
- Increase forage production (e.g., green manure) to increase biomass
- Agroforestry
- Understanding barriers to adoption
- Incentives to better manage organic inputs (e.g., policy, financial, etc…)
- Better management of common pool resources

*Agroecology and Soil Management Issues - Barriers*

- Water logging-in the case of highland vertisols
- Soil spatial variability
- Challenging inherent soil conditions (Sloping, erodible, texture)
- Diverse agroecology requires diverse packages

*Agroecology and Soil Management Issues - Strategies*

- Soil and water conservation
- Develop decision support tools that are site specific recommendations for farmers for better decision-making

*Small Farm Issues - Barriers*

- Lack of affordable and small scale mechanization tools
- Lack of mechanization at small scale farms
- Small and/or fragmented land holding
- Lack of appropriate mechanization
- Small farm size and limited economic opportunity

*Small Farm Issues - Strategies*

- Land consolidation within families and farmer groups
- Improve appropriate small-scale mechanization

**II. Great Lakes – Barriers and Strategies for Associated Clusters - Nitrogen (N) Deficiency**

<u>*Solutions*</u>**:**

1. Apply inorganic fertilizer
2. Use of legumes
3. Apply manures + C-rich materials
4. ISFM (Integrated Soil Fertility Management)
5. Select N efficient crops/varieties/hybrids

*Cultural - Barriers*

- Who? Gender
- Mentality/ Acceptability
- Cultural constraints/inhibitions
- Negative cultural perception that fertilizers damage the soil

*Cultural - Strategies*

- Gender weight, draft power, fencing
- Extension – crop inputs do not make product inferior
- Encourage privates to provide extension
- Encourage Agribusiness to do demonstrations
- Knowledge of risk/insurance
- Market for ↑ production

*Access - Barriers*

- Barriers of availability
- Barriers to inorganic fertilizer/access to fertilizer
- Accessibility and availability of correct fertilizer formulation
- Inaccessibility of N-fertilizers in rural areas
- Unavailability of fertilizer

*Access - Strategies*

- District availability
- Improve transport from district to farm
- Use private sector for transport and distribution
- Appropriate size packaging to farmer gender considerations
- Timeliness – not too late!
- Cooperatives
- Extension
- Border security

*Cost - Barriers*

- Barriers to apply inorganic fertilizer. 1) Financial Constraints
- Barriers to inorganic fertilizer –fertilizer quality –price profitability
- Profitability
- Barriers to applying inorganic fertilizers 1) cost/availability
- Affordability (credit for inputs)
- High cost of fertilizers
- Lack of funds

*Cost - Strategies*

- Well designated and implemented subsidies (exit strategy, etc.) access
- Government policy promoting improved agriculture practices (organic farmers, link to market)

- In-country production/blending
    - Tech solutions to scale

*Quality and Use - Barriers*

- Barriers to inorganic fertilizer / Poor fertilizer grade
- Fertilizer improved formulations (balanced crop nutrition)

*Quality and Use - Strategies*

- Private extension
- Public extension
- Utilize mobile technology
- Soil fertility recommendations crop/location specific
- Best application technology
- Use crop modeling with local weather/climate
- Fertilizer testing – private
    - quality / composition
- Uniform standards and testing for fertilizers (apply to all countries) (blending for local needs)
- Fertilizer recommendation specific to soil test results and locally available fertilizer
- Consider other soil fertility diagnostics (in relation to other productivity restraints)
- Comparison of methods for assessing soil fertility status in field, spectral, wet chemistry, plant tissue, geospatial
- Nutrient balance approach

*Additional Barriers for all Solutions*

*How to apply - Barriers*

- Equipment
- Knowledge of proper N use
- Lack of information on fertilizer recommendations for specific areas
- Knowledge about how and what
- Barriers to inorganic fertilizer.
- Lack of crop specific N recommendations
- Poor extension services-information of merits of fertilizers
- Lack of good practices - application –timing – placement –amount

*Cost of Production - Barriers*

- Cost/economical constraints
- Transportation of manure/waste
- Communication / Economics, trade in manure organic waste as commercial product
- Transportation of manure
- Seed cost
- Cost
- Cost
- Costs
- Labor for manure application
- Seed cost and availability

*Manure Composition - Barriers*

- Competition for manure (heating, etc.)
- Manure nutrient composition

- Quality (nutrient) of manure
- Stage of decomposition composting
- Composition/contents (nutrients)
- Quality of manure

*Market Use of Legumes - Barriers*

- Value of legumes (use of legume)
- No market for legumes
- Perceived value if not harvested
- Limited market for legumes
- Market for legumes
- Cultural barriers no use value of legumes

*Knowledge/Research - Barriers*

- Extension-delivery Integrated Soil Fertility Management (ISFM) knowledge-agronomic practice-how to apply-complete/knowledge intensive
- Barrier ISFM lack of knowledge
- State of knowledge
- Limited research of hybrids
- Lack of soil fertility recommendations
- Need for basic agronomy research
- Good/efficient cropping systems with legumes
- Few tested N-efficient varieties/hybrids

*Availability - Barriers*

- Barriers to selecting N use efficient crops Accessibility
- Barriers for applying C materials Availability of manure
- Lack of seed
- Barriers to ISFM availability of organic and inorganic inputs
- Barr manure availability (limited production) manure and/or waste
- Seed availability
- Availability
- Availability of quality manure
- Seed availability
- Manure availability
- Quality seed improved
- Unavailability of proper seeds
- Barriers to manure/cropping/ Quality
- Access

*Production – Barriers*

- Poor production
- Effective inoculants for various crops
- Crop variety selection for N fixation
- Legume rotation fit with overall crop production strategies
- Feasibility
- Cropping system how to use intercrop arrange rotations green manures
- Probability of legumes in crop rotation

- Inoculant availability (rhizobium)
- Availability of P fertilizers and other nutrients (secondary micro) and lime
- Legumes that produce well in acid soil
- Poor responsive soils soil/land mechanization
- Absence of crop-livestock integration
- Capacity to implement ISFM
- Timing/crop succession

*Climate - Barriers*

- Climate (sustainability)

*Information Extension - Barriers*

- Lack of information on N-efficient crops
- Limited land (farmers prioritize other crops)
- Necessity/understanding
- Farmer type specific recommendations
- Information on combined use of inorganic and organic fertilizer for specific sites
- Information/extension
- Poor execution services
- Lack of information on non-food legumes

*Additional Strategies for Solutions 2-5*

- DVP of book values for manure composition
- Education on handling/diet effects on manure quality
- Promote dual application of manures/fertilizers
- Step-wise improvement in soil fertility (site specific)
- Encourage legumes for human consumption
- Weed suppression with legumes

### III. East Africa – Barriers and Strategies for Associated Clusters - Nitrogen (N) Deficiency

<u>*Solutions*</u>:

1. Management/Agronomy
2. External Inputs – N
3. Legume Incorporation/crop rotation farming systems
4. Integrated Crop Livestock (OM management) → manures → residues
5. Agroforestry / Modeling Training

*Soil Testing and Recommendation* - *Barriers*

- Lack of appropriate N recommendations and its paper extension
- Regular soil testing for recommendations
- Recommendation tools
- Optimization of recommendations
- Soil testing (reliability)
- No standardization of recommendations

*Environmental Sustainability* - *Barriers*

- Goal: economic empowerment
- Economic return given by fertilizer

*Extension and Capacity Building* - *Barriers*

- Participatory technology development
- Sufficient capacity to manage N-fertilization
- Capacity of implementers to apply solutions
- Farmer education
- Communication
- Capacity building

*Organic Input Availability and Use* - *Barriers*

- Organic inputs not enough
- Competition for farm resources
- Competition for use of farm residues

*Access to Finances* - *Barriers*

- Access to financial sources
- Financing to enable inputs to be affordable
- Access to finance
- Access to external N input sources
- External input access and affordability
- Availability/access to external inputs
- Cost of fertilizer and efficiency
- Socioeconomic 2 Farm operation

*Combined Strategies for all Barriers*

- Farmer organization
- Development of affordable fertilizers
- New soil testing models
- Targeted subsidies
- Targeted fertilizer blends
- Emerging extension technologies

**IV. West Africa – Barriers and Strategies for Associated Clusters - Nitrogen (N) Deficiency**

Solutions:

1. Use of mineral fertilizers
2. Organic matter (OM) input (manure + livestock)
3. Cover crops + green manuring
4. Cereal - legume intercropping and crop rotations
5. Agroforestry + legume trees

*Nutrient Loss - Barriers*

- Erosion (Climate)
- Soil Quality
- Use of Min. Fert (High Mobility in Soils)
- Leading of N. Fertilizers
- Soil Quality (Leaching Runoff)
- Runoff

*Nutrient Loss - Strategies*

- Reduce nutrient losses
  - Vegetation barriers / soil cover / cover crops
- Soil and water conservation (tied ridging, blends, contours
- Appropriate application of fertilizer (timing, placements, type, quantity)
- Increase nutrient holding capacity (e.g., CEC)

*Acceptability - Barriers*

- Perception that minerals fertilizer use is not profitable
- Farmers willingness

*Acceptability - Strategies*

- Demonstration using FFS
- Awareness raising/sensitization
- Farmer-to-farmer communication

*N-Use Efficiency - Barriers*

- Lack of adequate recommendations for N
- Too broad recommendation
- Inappropriate use of Fertilizers
- Use of mineral fertilizer (Low Efficiency of Use)
- Poor N fertilizer application methods

*N-Use Efficiency - Strategies*

- Site specific recommendation
- Timing of fertilization application (4 R – time, method, amount, type)
- Improve water and nutrient management
- Breed for varieties with ↑ NVE
- Increasing SOM
- ↑ Soil information services / data (promotion of digital soil mapping) to improve recommendations

*Cost - Barriers*

- Poor farmers
- Cost

- High cost of mineral fertilizers
- Access to financial resources
- High cost of mineral fertilizers
- Lack of finance
- Use of Min. Fert (Unaffordability)
- High Prices of Fertilizers to Farmers
- Lack of Inorganic N Fertilizer at affordable prices
- Financial
- Availability/ Price

*Cost - Strategies*

- Smart subsidies
- Improve awareness of local availability
- Improve availability
- Creating farmer organization
- Enhance farmer loans…
- Open the fertilizer market

*Availability - Barriers*

- Access to fertilizers/availability
- Not available
- Not accessible by farmers’
- Unavailability of mineral fertilizers
- Demography
- N Deficiency (Use of Mineral Fertilizer- unavailability)
- Unavailability of fertilizers at farmers’ level
- Demography

*Availability - Strategies*

- Enhance infrastructure (roads)
- Promote small scale input dealers in rural areas
- Regulating exports to prioritize local or our country
- Better organize farmers to negotiate or collective bargaining
- Awareness about /appropriate transport and storage at community level.

*Fertilizer Quality - Barriers*

- Fertilizer Quality
- Poor quality of fertilizer sold in market
- Good quality fertilizer
- Quality Fertilizer

*Fertilizer Quality - Strategies*

- Regional policy for quality control (implementation)
- Systematic Lab analysis of fertilizer samples from the market
- Promote reference lab for quality control (independent)

*Knowledge - Barriers*

- Lack of Knowledge
- Lack of Extension Service
- Lack of knowledge of N fertilizer use among factors
- Lack of Knowledge in Crop Livestock Integration

- Low Efficiency of Organic fertilizer
- Lack of Knowledge on the importance of OM among farmers
- Lack of Knowledge to produce compost
- Lack of information on importance of SOM
- Lack of information on composition of organic materials

*Knowledge - Strategies*

- Training/capacity building
- Availability of appropriate training materials
- Appropriate housing of animals
- Community composting (training)…
- Demonstrations… (FSS, …etc…)
- Communication of information/knowledge (e.g., radio, TV, Extension materials – technical sheets)

*Cultural - Barriers*

- Willingness of farmers
- Culture
- Perception of farmers on the use of O.M

*Culture - Strategies*

- Education
- Sensitization
- Use of acceptable practices
- Minimize burning

*Climate - Barriers*

- Drought (livestock reduction)
- Climate/ Height Mineralization/ Temporal Cure

*Climate - Strategies*

- Promotion of climate resilient practices
- Appropriate variety of ….
- Conservation agriculture
- Agroforestry

*Availability of Organic Inputs - Barriers*

- Quick depletion of organizer matter
- Culture of burning and uncontrolled bush burning
- Unavailability of manure and other organic inputs
- Problems with retention of crop residue on soil due to free roaming livestock and bush fires
- Other uses for crop residues
- Low biomass production of cropping system
- Unavailability
- Alternative of crop residues
- Annual bush fires
- Availability of manure
- Crop resides
- Availability
- Practice of burning biomass and crop residues

- Lack of organic matter sources
- Multiple use for crop residues
- Livestock Cost
- Manure Shortage
- Bulky, difficult to transport

*Availability of Organic Inputs - Strategies*

- Training on composting, where appropriate
- Provide alternative energy sources
- Develop strategy for crop residue management
- Minimize or control bush fires
- Crop livestock integration
- Waste management
- Management and application of OM
- Human waste management
- Promotion of biogas (management)
- Integration of organic & inorganic fertilizer
- Awareness raising

*Livestock Management - Barriers*

- Land Pressure
- Transhumance/ Mobility of livestock
- Uncontrolled livestock grazing
- Conflict with animals

*Livestock Management - Strategies*

- Specific forage crops for livestock
- Controlled grazing
- Encourage housing of animals
- Manage the number of livestock
- Improve feed lots
- Silage of forages/fodder

*Quality OM - Barriers*

- Compost
- Hygiene
- Use of chicken manure to promote increased use of waste
- Quality OM

*Quality of OM - Strategies*

- Technical training
- Choosing appropriate OM
- Enhancing availability
- Storage and management and handling of OM

*Soil Quality - Barriers*

- Poor Soil Quality
- Soil Quality

*Soil Quality (Poor) - Strategies*

- Improve soil health
- Add organic matter
- Add fertilizer → improve biomass

- Inoculation of legumes
- Symbiosis… $N_2$ fixation…
- Enhance agroforestry…
- Minimize use of acid forming fertilizer

*Additional Barriers for All Solutions*

*Competition - Barriers*

- Lack of suitable leguminous species for agroforestry
- Lack of types of trees for cropping (competition tree/crop.)
- Competition between crop and association legumes
- Tree compete with annual food crops for growth factors

*Water Availability - Barriers*

- Water availability out of raining season
- Water access
- Short and unreliable rainy season
- Difficulty in fitting cover crops or green manuring into cropping calendar

*Management Issues - Barriers*

- Bush fires can burn cover crop limiting other effects
- Uncontrolled burning
- Uncontrolled grazing of livestock
- Soil type/quality
- Cultural
- Low soil fertility
- Cultural Barriers
- Low contribution of legumes because of removal from fields
- Low N-fixation by legumes in farmers' fields because of nutrient deficiencies especially
- Low contribution of legumes because of low densities in typical/tradition intercropping systems
- Lack appropriate plant density for legume intercropping
- Difficulty in managing some cover crop
- Bush burning and grazing by animals of cover crops
- Risk of snakes associated with cover cropping

*Financial Resources - Barriers*

- High cost of cover crop seeds
- Financial Resources and Material Resource
- Time demanding
- High labor requirement for managing some intercropping plants
- High cost
- Farmers especially (women farmers) not willing to invest in agroforestry

*Knowledge - Barriers*

- Lack of Knowledge
- Lack of Knowledge of biodiversity on farms
- Lack of Knowledge
- Lack of Knowledge
- Lack of Knowledge
- Weak extension services
- Lack of knowledge of importance of intercropping and rotation

- Little knowledge sop-agroforestry integration

*Land Tenure - Barriers*

- Cover crops take up useful space
- Access to land
- Lack of land for rotation (cash crop)
- Insecure land tenure may affect agroforestry scheme
- Limited land availability for crop rotation
- Land Tenure
- Limitation of agricultural land

*Policy - Barriers*

- Access to market and spoilage for legumes
- Weak implementation of policies

*Appropriate Species - Barriers*

- Some cover crops are not edible e.g., mucuna
- Lack of appropriate cover crop seeds
- Lack of improved cover crop seeds
- Availability of some cover our species
- Common cover crops not edible and so not attractive to farmers
- Availability of green manure

## Appendix B - Soil Fertility Prioritization Summit Results – Low Soil Organic Carbon (SOC) Content

### I. Ethiopia– Barriers and Strategies for Associated Clusters - Low SOC Content

Solutions:

1. Optimize C:N ration through improved crop livestock and soil management.
2. Increase availability and access to organic inputs to soil to the extent possible.
3. Increase availability and access to inorganic fertilizers to increase biomass.
4. Improved information and recommendation for appropriate use and application of fertility inputs.

*Organic Resources Management - Barriers*

- Promote residue management
- Competing uses for organic materials
- Soil reaction affect the microbial activity
- Develop alternatives for building materials, fuel, and energy
- Lack of adoption of alternative sources of energy (e.g. Solar)
- Apply animal manure and crop residue
- Balance organic and inorganic fertilizer use
- Lack of SOC sources
- Competitive use of organic sources

*Organic Resources Management - Strategies*

- Falls into management practices and tools as well.
- Develop alternatives for the non-soil use of organic materials
- Emphasize methods and practices to build soil microbiota to encourage farmers
- Goal is to increase OC input to improve soil fertility and SOC

*Information, Education, and Dissemination (Target audience is farmers, service providers, extension systems, and researchers) - Barriers*

- Develop and disseminate feasible composting practices
- Unbalanced nutrients (more out than in)
- Better science-based information via extension
- Nutrient composition of composts is not known
- Education and support for agroforestry adoption
- Awareness creation on the use/importance of SOT
- Lack of research/study on how to optimize C:N ratio
- Limited awareness and lack of information about the fact on the ground (C: N ratio)
- More research and extension programs on conservation tillage

*Information, Education, and Dissemination (Target audience is farmers, service providers, extension systems, and researchers) - Strategies*

- Refer to solutions for N deficiency for common strategies (e.g., I)
- Inform, educate, and disseminate information for farmers about soil health, organic materials, and soil fertility (e.g., health card)
- Provide reliable soil testing services (e.g. mobile Labs, etc.)
- Encourage entrepreneurship for soil informatics and soil testing
- Develop packages related to SOC enhancement technologies (e.g., composting, standards, zero tillage, agro-forestry) → all things related to enhancing SOC.
- Using technologies to educate farmers to increase quality and reliability

- Strengthened relationships of the farmers ↔ extension ↔ researchers ↔
- Soil health card

*Management Practices and Tools - Barriers*

- Tillage
- Extensive tillage
- Concern disseats associated with crop residue retention and lack of chemicals to control them
- Increase biomass production
- Erosion
- Availability and adoption of soil conservation practices
- Conventional agronomic practices
- Lack of tools for no tilling (reduce tilling practices)
- Eliminate or control free grazing
- Limited/short crop rotations
- Low soil productivity

*Management Practices and Tools - Strategies*

- Very related to increasing availability and access to organic inputs to soil in regard to training and education
- Promote/support community based water shed development and management (e.g. terracing practices, agro-forestry, etc…)
- Promote improved agriculture practices
- Simulation models & decision-support tools – meant for researchers' engagement
- [Conservation Agriculture] in the context of Ethiopia, means zero tillage, minimum tillage, crop rotation + crop residue retention. * This is a clarification point.

*Land Use/Tenure Policy - Barriers*

- Develop and enforce land use policy
- Develop incentive for OM increase
- Land tenure system
- Better policy for land tenure and common-pool resources to provide incentives for SOC management
- Provide incentive for manure/compost application
- Free grazing

*Land Use/Tenure Policy - Strategies*

- Reform grazing practices
- Develop and enforce land use policies
- Develop incentives to improve soil quality for land tenants

*Labor Issues - Barriers*

- Shortage of farm labor during critical times
- Labor resources/limitation
- Access to credit and resources

*Labor Issues - Strategies*

- Labor and resources sharing at the right time with the right skill sets
- Entrepreneur approaches and/or opportunities, especially for women and youth
- Create a larger demand for markets from the farms
- Enhancing and scaling appropriate mechanization to address these labor issues, also to benefit women

- Increase cropping intensity which will demand trained labor for the farm that leads to the desirable jobs
- Organize youth to provide services for farmers (e.g., men and women)

**II. Great Lakes– Barriers and Strategies for Associated Clusters - Low SOC Content**

<u>*Solutions*</u>:

1. Manure/Fertilizers
2. Cover crops
3. Rotations/cropping systems
4. No-till/weed control/burn
5. Crop residue

*Socioeconomic - Barriers*

- Cultural resistance to change
- Labor constraints
- Crop rotation → adoption constraints for small holder farmer →all crops need to generate benefits
- →Cover crops difficult to accept by farmers →additional cost/no benefits
- →Little economic alternatives to burning→ for clearing and weed control
- Still competition for crop residues
- Farmer's perceptions
- Resistance to technology adoption
- Crop residue →competing to crop residue harvest too low to make a difference
- Crop residues used as animal feed, fuel, wood, etc.
- Alternative uses for crop residue

*Socioeconomic - Strategies*

- Return all C-waste back to soil (manure, etc.) by policy
- Confined grazing for manure distribution
- Alternative fuels/feeds - consider CA
- Connection of mechanization with health issues and availability of labor
- Crop rotation/cover crops for small holders
  - Income year-to-year
  - Cover crop cost/benefit
- Need research
- Extension/capacity building

*Basic Research - Barriers*

- Fit with farmers' practice and established cropping systems
- Basic cropping systems research
- Lack information on how to use systems
- →Long time needed to restore SOM (5 years- 10/ha)
- No till effect on SOC not clear if till needed for weed management

*Basic research - Strategies*

- Sustainable cropping systems designed for ↑ SOC/economically viable
- ↑ Soil quality
- Farming systems incorporating livestock
- Optimization C/nutrient flows
- N fixation tropical soils
- Soil conditions / polymers, biochar

*Mechanization/Equipment - Barriers*
- Equipment for no till/reduced tillage
- Planting equipment for no-till systems
- Lack of suitable no-till equipment

*Mechanization/Equipment - Strategies*
- Hand-held planting equipment for no-till
- 2 – row planters – tractor or animal drawn
- Spraying equipment
- Gender sensitive
- Keep residue on soil
- Local control of grazing (chief)
- Economic analysis of alternatives

*Additional Barriers for All Solutions*

*Economic Cost - Barriers*
- Availability of inputs
- Manure/fertilizer cost
- Cost of fertilizer
- Cost
- Cost of cover crop seed
- Seeds
- Cost of application
- Barriers accessibility, affordability, profitability > cost of inputs

*Availability - Barriers*
- Seed for cover crops not readily available
- Manure availability

**III. East Africa – Barriers and Strategies for Associated Clusters - Low SOC Content**

Solutions:

1. Residue/organics management
2. ↑ Inorganic fertilizer to increase yields = ↑biomass
3. Crop diversity
4. ↓ Erosion
5. Reduced tillage (CA)

*Diversification - Barriers*

- Cover Crops
- Diversification
- Mono-cropping
- Right biomass varieties
- Lack of new markets
- Access to seed variety
- Value of cash crops
- Food habits
- Initial challenge to establish new crops

*Resource Availability and Management - Barriers*

- Better soil management needed (tools, sensing, etc.)
- Labor intensive
- Soil compaction
- Insufficient water
- Low availability of tillage services
- Low levels of residues/organics
- Land availability

*Policy - Barriers*

- No carbon incentives
- Climate change
- Incentive to increase SOC

*Crop/Livestock Competition - Barriers*

- Crop/livestock integration
- livestock

*Extension and Capacity Building - Barriers*

- Conservation agriculture awareness
- Capacity to implement
- Lack of training

*Combined Strategies for all Barriers*

- Improved crops/livestock integration
- Mechanization and farmer organizations (contract services)
    - Private sector engagement
- Better knowledge of cropping systems (research)
    - Funding private & NGOs – need for field trials
- Implement relevant policies
    - Supporting farmer ownership & decision making land
- Embrace new communication technologies

## IV. West Africa– Barriers and Strategies for Associated Clusters - Low SOC Content

<u>*Solutions*</u>:

1. Organic matter input (including biochar)
2. Agroforestry
3. Cover cropping + green manuring
4. Use of inorganic fertilizers to ↑ biomass (+ organic, bio-fertilizer…+enriched organic fertilizer)
5. Promote conservation agriculture

*Burning - Barriers*

- Uncontrolled bush fires
- Uncontrolled burning

*Burning - Strategies*

- Sensitization of burning
- Re-enforcement by-laws
- Compensation for no-burning (create incentives) …

*Equipment - Barriers*

- Lack of Ca equipment
- Lack of appropriate tools to practice NT

*Equipment - Strategies*

- Design & test appropriate tools for planting mulch
- Appropriate spraying equipment
- Appropriate spraying and preparation
- Appropriate training on equipment
- Harvesting equipment (for cover crops…)
- Harvest crops and leave the residue…

*Low Productivity - Barriers*

- No tillage- not appropriate with some root crops
- Low productivity
- Lower yield/ minimum fertility

*Low Productivity - Strategies*

- Adapt CA & fertilizer
- Integrated organic + inorganic
- Integrated soil fertility management
- Crop rotation (appropriate)

*Land Tenure - Barriers*

- Land Tenure
- Land Tenure

*Land Tenure - Strategies*

- Appropriate technology (short-term) …
- Policy on land tenure… (ownerships…)

*Knowledge - Barriers*

- Lack of technical knowledge
- Knowledge about the technic

- Lack of knowledge
- Lack of technical knowledge
- Lack knowledge on CA
- Lack of Knowledge
- Farmers Acceptance
- Lack of Knowledge
- Knowledge
- Lack of knowledge on biochar
- Limited Knowledge on biochar
- Knowledge
- Knowledge sf bio-char
- Knowledge Rate/ Food Stock Value

*Knowledge - Strategies*

- Extension education
- Farmer training; FSS
- Profiling & identifying needs of farmers
- Soil testing… of fields
- Policy briefs (to control quality, e.g., training manuals (extension services)

*Climate & Water - Barriers*

- Water availability
- Climatic Constraints

*Climate & Water - Strategies*

- In-situ water harvesting
- Identify specific cropping system
- Supplemental irrigation
- Mulching & OM improvement; etc.….
- Relay – cropping…

*Resources - Barriers*

- Multiple use for crop residues
- Multiple crop use
- Lack of materials for soil cover
- Appropriate cover crop spp
- Problem with maintaining permanent soil cover
- Need residue management strategies
- Appropriate cover crops
- Accessibility of herbicides (appropriate) for NO-TILL Agriculture
- Use of crop residues
- Requires a huge amount of time
- Material Resources
- Insect and Termite Development
- Technical Feasibility does not work everywhere
- Labor demanding
- Fuel wood demanding

*Resources - Strategies*

- High biomass cover crops (identify/use) → (research/extension)
- Cover crops not edible by animals

- Make seeds of cover crops available
- Training on use of cover crops
- Proper selection sites for conservation agriculture
- Knowledge sharing
- Appropriate use and knowledge of herbicides
- Herbicide tolerant seeds/crops
    - Selective herbicide use

*Additional Barriers for All Solutions*

*Soil Quality* - *Barriers*
- Continuous tillage
- Too low initial soil fertility does not support CA
- Soil quality

*Grazing* - *Barriers*
- Free grazing by animals
- Uncontrolled grazing
- Destruction by recovering animals

*Availability* - *Barriers*
- Availability
- Availability (5f bio-char)
- Availability of lead stock material

*Research* - *Barriers*
- More scientific evidence needed
- Little Research on biochar
- Limited research information on biochar
- Making technic (biochar)
- Long term effects
- Application Frequency
- Technology not easily accessible

*Resources* - *Barriers*
- Unavailability of p fertilizers
- Mineral p fertilizers not accessible
- Availability x2
- Lack of p mineral fertilizer only
- Non-availability of inoculum sources
- Availability of rock phosphate
- Availability of P mineral fertilizer
- Availability and access to fertilizer and amendments

*Additional Strategies for All Barriers*

*Competition* - *Strategies*
- Conduct research (local/regional)

*Appropriate SPE & Seeds* - *Strategies*
- Identify suitable cover crops
- Improve availability of seeds
- Community seed production

- Input suppliers
- Creation of market demand for SP/seeds
- Research/Extension

++ *Management Issues* - *Strategies*

- Creation of fire belts
- Suitable cover crops fitting the typology
- Knowledge on timing of planting/density
- ++ all management practices

## Appendix C - Soil Fertility Prioritization Summit Results – Phosphorous (P) Deficiency

**I. Ethiopia – Barriers and Strategies for Associated Clusters - Phosphorous (P) Deficiency**

<u>*Solutions*</u>:

1. Testing/mobile services for crop-specific recommendations.
2. Encourage adoption of management practices for soil pH.
3. Encourage practices to proliferate mycorrhiza with P deficient soils.
4. Increase availability and access to inorganic sources of P.
5. Improved information and recommendation for appropriate P use and application.

*Affordability/Cost - Barriers*

- Lack of local sources
- Lack of subsidies for P fertilizer
- Importation/ P. sources
- Lack of Indigenous P sources
- High transport costs
- High cost of P. fert.
- Improved access to p-fertilizer/right time delivery
- Limited access and less affordable inorganic P sources (fertilizers)
- Few incentives to reduce P loss
- High cost and access to p-fertilizers
- pH modification is not affordable by SHF
- Affordability for testing services

*Affordability/Cost - Strategies*

- Bulk purchases through groups
- Apply 4 Rs [Right time, Rate, Right form, Right placement] – fertilizer 101
- Smart subsidies to reach the right target, as some subsidies have had mixed results
- Improved infrastructure to reduce transport costs
- Free market for price competition
- Soil & crop management practices to reduce P losses
- Availability & affordable testing solutions, (e.g., soil testing Labs)
- Other issues similar to #1, 2, & 3 in I and II

*Research Management - Barriers*

- Right application time, method, and amount for p-fertilizers
- Limited knowledge about microbes importance and use
- Location-specific recommendations
- Acid soil management for small-holder farmers
- Inadequate soil test based recommendation
- Full package nutrient management practices should be put in place
- Lack of improvised crop and soil management practices
- Lack of soil and crop specific P rate
- No crop specific nutrient critical levels for P
- P crop efficient
- Conduct from P response in different agroecologies
- Limited understandings by famers about soil pH’s effect on P

- Low soil pH
- Lack of strategies to manage soil PM

*Research Management - Strategies*

- Develop soil, crop agroecology, specific P recommendations
- Select and develop P efficient crop or cultivars
- Better collaboration and coordination with the national and international scientists
- Develop liming recommendations for low pH soils

*Testing & Recommendation Services - Barriers*

- Lack of sufficient soil testing labs
- Inadequate soil testing lab
- Lack of reliable nutrient testing
- Access to reliable testing services
- Lack of knowledge/ cultural practices

*Testing & Recommendation Services - Strategies*

- Train Lab technicians and ↑ salaries
- Increase the number and quality of nutrient, soil, P, N, pH, etc. testing Labs and services (e.g., soil health card)
- Explore alternative models for addressing testing (e.g., soil fertility kits, RS, GIS and remote sensing (RS) options, → getting relevant, reliable, information to the farmer in a timely manner)

**II. Great Lakes – Barriers and Strategies for Associated Clusters - Phosphorous (P) Deficiency**

<u>Solutions</u>:

1. Addition of P fertilizer
2. Manure/bio-solids/urban waste
3. P Solubilizing micro-organisms/plants
4. Liming
5. Crops tolerant of low P

*Availability - Barriers*

- Availability of manure/biosolids/urban waste quality of product
- P-fertilizers availability
- Availability of P locally
- P solubilizing micro. →Availability as a commercial product (effectiveness) – inoculant
- Availability of fertilizers/lime
- Lime availability
- Lack of commercial p-products (bio-fertilizers in the market)

*Availability - Strategies*

- Work toward utilizing locally available P sources (P rock)
- Alternate formulations – multi-element with higher P content, not equal N-P-K
- By product or waste P sources for large scale crop production (not veggies)
- Bio-solid/fertilizer combinations

*Infrastructure - Barriers*

- Lack of equipment to apply P
- How to transport and apply 3 tons lime/ha
- No processing plants of urban waste

*Infrastructure - Strategies*

- P application equipment

*Basic Research - Barriers*

- Low crop responses to applied P
- State of knowledge
- Efficiency of P fertilizer use
- No proper recommended atoms? For lime and P-fertilizers
- Research on economic feasibility of nutrient recycling (manure, bio solids, urban waste)
- Lack of knowledge o tolerant p-crops
- Closing P cycle
- Fertilizer balance
- Lack of research on crops that grow in low P conditions
- Lack of P and low P tolerant crops

*Basic Research - Strategies*

- Explore P efficient crops
- Develop locally available P deposits (economics first)
- P solubilizing microbes – feasibility?
- P calibration/response curves
- P cycling – waste products closing P cycle

*Additional Barriers for All Solutions*

*Socioeconomic - Barriers*

- Perception of bio-solid use in food production
- Cultural acceptance of recycled nutrients including P
- Limited acceptability of using urban waste
- Human health issues on use of waste

*Cost - Barriers*

- Cost
- Cost
- Lime cost
- High cost
- Lime-agricultural→cost→availability
- Cost of P fertilizers and lime

**III. East Africa – Barriers and Strategies for Associated Clusters - Phosphorous (P) Deficiency**

<u>*Solutions*</u>:

1. Managing Soil Acidity (liming - acid-tolerant crops)
2. Biological Management (Mycorrhiza)
3. Add P & P management
4. Reducing soil compaction
5. Soil testing

*Access to Right P Sources - Barriers*

- Non-availability of P nutrient sources
- Access to local rock phosphate
- Lack of affordable fertilizer
- Expensive P fertilizer
- Expensive P nutrient fertilizers
- High costs of mechanization (soil compaction)
- Availability of biological agents (PSB's)
- Expensive biological products
- Access to right P sources

*Access to Right P Sources - Strategies*

- Use of non-conventional P sources (e.g. Tithonia)
- Financial resources
- Soil testing/recommendations – targeted to local level
- Crop/Livestock integration

*Product Development - Barriers*

- Lack of engagement of the private sector
- Heavy metal content of P sources

*Product Development - Strategies*

- Creation of research platform (farmers, researchers, industry)
- Economic forecasting to target future work
- Data sharing/collection e.g. soil mapping to meet industry & policy needs
- Donor connected to end user through projects

*Lime - Barriers*

- Low availability of lime
- High amounts of lime needed
- High cost of lime
- Lime availability
- Large amounts of lime required to reduce acidity

*Lime - Strategies*

- Acid tolerant crops
- Lime granulation/tech.
- Lime subsidies
- Soil testing/recommendations

*Risks (intrinsic) - Barriers*

- Poor P and h20 management

- Poor quality soils

*Risk (intrinsic) - Strategies*

- Crop insurance with weather indexing

*P Management - Barriers*

- Lack of knowledge in P management
- Improper P management (first lime, then P)
- Adequate P management strategies
- Sustainable soil management
- Availability of biological management strategies
- It is difficult to integrate P management with other nutrients/issues (lime, water, PMN, etc.)
- Poor technology uptake

*P Management - Strategies*

- 4Rs of P use
- Demo trials of new products (farmer field schools)
- Participatory Extension
- Communication technologies – e.g. videos

**IV. West Africa – Barriers and Strategies for Associated Clusters - Phosphorous (P) Deficiency**

<u>*Solutions*</u>:

1. Addition of mineral P fertilizers
2. Soil amendments using OM
3. Overcoming P-fixation
4. Use of P-efficient crop varieties
5. Use of rock phosphate

*Resources - Barriers*

- Unavailability of p fertilizers
- Mineral p fertilizers not accessible
- Availability x2
- Lack of p mineral fertilizer only
- Non-availability of inoculum sources

*Resources - Strategies*

- Development of private sector
- Organize farmers in local communities
- Have policy to make available "P" sources
- Provide evidence that "P" is deficient
- Develop soil testing facilities
- Promote band application of "P" fertilizer

*Research - Barriers*

- P-efficient crop varieties not commonly available
- P efficient crop varieties not available for poor farmers
- Soil condition (PH)
- Research capacity
- Little research on P efficient crop varieties

*Research - Strategies*

- Conduct basic research on placement (local/band…), and promotion
- Development of P-efficient varieties
- Explore new local sources of "P"
- Methods to determine "P" deficiency
- How to solubilize "P" to make it available
- [Acidification of soil]

*Quality of "P" Source Barriers*

- Quality of P.
- Low solubility of rick phosphate
- High P. fixation power of some soils
- Increasing ratios between P. available and Total P.
- Quality of P fertilizer

*Quality of "P" Source - Strategies*

- Facilitate use of inoculum
- Fertilizer testing lab for quality
- Approximate processing of rock "P"

*Policy - Barriers*

- Lack of policy that promotes the use of phosphate rock as soil amendment
- Sustainability
- Grazing and burning of crop residue

*Policy - Strategies*

- Need for subsidy for P fertilizer (e.g., Ghana)
- Promotion of Rock “P”, where available
- Policy to encourage use of [e.g., mycorrhiza] & soil amendments, bio-fertilizer

*Additional Barriers to All Solutions*

*Knowledge - Barriers*

- Technical knowledge
- Lack of knowledge
- Limited knowledge on appropriate application rate and method of P fertilizer
- Lack of awareness on the importance P for plant growth and development
- Lack of knowledge
- Lack of knowledge on strategies to improve P availability
- Lack of knowledge

*Finances - Barriers*

- Cost
- High Cost P fertilizers
- Lack of resources/finances
- High cost In P fertilizers
- High cost of straight P mineral fertilizer
- Cost of rock phosphate
- P mineral more costly than blend
- Cost of soluble p fertilizer
- High cost of P fertilizer
- High cost of fertilizer and amendments
- Limited financial capacity of farmers

## Appendix D - Soil Fertility Prioritization Summit Results – Acidity

**I. Ethiopia– Barriers and Strategies for Associated Clusters – Acidity**

Solutions:

1. Lime application to neutralize soil pH (e.g. liming, creating lime value supply chain).
2. Soil-specific practices for water management.
3. Select acidity tolerant crops/cultivars.
4. Increase SOM (e.g., bio-char, household ashes).
5. Use appropriate fertilizer sources to minimize soil acidification.

*Value Chain Issues - Barriers*

- Bulkiness of lime application
- Hi capital and labor costs for lime
- Cost/affordability of lime application
- Accessibility of lime and transportation
- Costly transport and application costs
- Lime transportation cost
- Inefficient distribution systems
- High cost of lime
- Highly labor intensive
- Insufficient lime production
- Shortages of lime supply

*Value Chain Issues - Strategies*

- Build capacity of existing lime crushers
- Explore and develop additional lime resources and establishing new crushers
- Testing quality and reactivity of lime
- Provide incentives for ag-lime production, transportation and 'last mile' delivery to farmers
- Facilitation of 'on-farm' application

*Germplasm - Barriers*

- Lack of cultivar options
- Availability of germplasm
- Inadequate acid tolerance/crops/ cultivars
- Lack of appropriate soil management and acid tolerant crops
- Limited crop options for acidic soils
- Lack of research knowledge of acidity tolerant crops/ cultivars
- Acid- tolerant crop species and cultivars

*Germplasm - Strategies*

- Select and develop appropriate cultivars
- Evaluate alternative crops (e.g., acid tolerant)

*Access to Soil Testing and Recommendation Services - Barriers*

- Liming information
- Reliable soil testing service access
- Lack of site specific lime recommendations
- Lack of information for site specific application rates
- Inadequate soil testing services

*Access to Soil Testing and Recommendation Services - Strategies*

- Train Lab technicians and ↑ salaries
- Increase the number and quality of nutrient, soil, P, N, pH, etc. testing Labs and services (e.g., soil health card)
- Explore alternative models for addressing testing (e.g., soil fertility kits, RS, GIS and remote sensing (RS) options, → getting relevant, reliable, information to the farmer in a timely manner)

*Soil Management - Barriers*

- low biomass/competing uses for biomass
- land fragmentation/physiography
- lack of low PM/acid soil/management strategies
- limited sources of SM fertilizers for PM management
- lack of identifying fertilizers which doesn't increase soil pH
- Sustainable production of enough biochar

*Soil Management - Strategies*

- Improving the affordability of lime, organic matter, crops, and fertilizer formulas
- Developing appropriate packages for small-holder farmers - (asset soil management)

**II. Great Lakes– Barriers and Strategies for Associated Clusters - Acidity**

*Solutions*:

1. Liming/Partial liming
2. Acid tolerant plants
3. Manure application
4. Burning/biochar
5. Band application lime/P fertilizer

*Research and Extension - Barriers*

- Targeted recommendations for partial application
- Knowledge of acid tolerances and access to seeds
- Research on acid tolerant crops
- Research needed on acid tolerant crops
- Recommended lime rate
- Research needed on lime bonding rates to avoid A/toxicity
- Research acid-tolerant varieties
- Do we have acidity tolerant crops?
- Research status on acid tolerant crops
- Information on acid tolerant crops
- Research needed on biochar/P/pH interactions

*Research/Extension - Strategies*

- Lime particle size studies
- Low input liming studies
    - Rate
    - Directed placement
- Biochars – sources, rates
- Acid tolerant crops and species, breeding for tolerance

*Sources of Lime/Biochar - Barriers*

- Availability lime/manure
- Local available lime material
- Unavailability of biochar/lime
- Lack of quality lime resources

*Socioeconomic - Barriers*

- Acceptability of Biochar
- Cultural constraints/acceptability
- Competition for organic inputs (residue manure) that can improve pH

*Socio-economic - Strategies*

- Is biochar acceptable?

*Mechanization/Equipment - Barriers*

- Equipment for band application of lime/p-fertilizers
- Equipment/mechanization
- Technical consideration for band liming (equipment)
- Equipment needs for lime application
- Equipment requirements

*Cost - Barriers*

- Cost
- Cost of lime
- Cost, transport, application, lime
- High cost of lime
- Cost of lime and application
- Availability and cost of lime
- Transport of lime

*Cost - Strategies*

- Pool resources within a region or district to save some costs, also, cooperatives
- Lime policy – cost/benefit
- Subsidies – different then fertilizers
- Feasibility study

*Policy - Barriers*

- Lack of subsidies for lime produce
- Need to overcome lime application logistics

*Policy - Strategies*

- Government role in developing local lime sources

## III. East Africa– Barriers and Strategies for Associated Clusters - Acidity

<u>*Solutions*</u>:

1. Liming the soil
2. Acid tolerant crops
3. Soil testing
4. Manuring
5. Biochar / Phosphate rocks

*Crop Selection - Barriers*

- Tolerant crops vs diversification
- Awareness on acid tolerant crops
- Crop breeding for tolerance
- Align acid tolerance with cultural/food needs

*Crop Selection - Strategies*

- Contextualized crop selection
- Acid tolerance breeding

*Access to Lime - Barriers*

- Adequate lime sources
- Access to liming materials
- Biochar availability
- No multifunctional fertilizer is available
- Lime not locally available
- Cost of lime (transport)
- Lime low demand no private sector engagement

*Access to Lime - Strategies*

- Subsidies
- Private sector engagement

*Economic Efficiency - Barriers*

- High buffering soils-large amounts of lime
- High buffering capacity of soils
- Large capital outlay for acidy remediation
- Expensive mgs of biochar and soil amendment

*Economic Efficiency - Strategies*

- Micro-dosing
- Granulation
- Access to finance

*Soil Testing and Recommendations - Barriers*

- Access to regular soil testing
- Lack of affordable soil testing

*Soil Testing and Recommendations - Strategies*

- Contextualized recommendation
- Spectral soil testing

*Knowledge Gap - Barriers*

- Acidity management
- Knowledge of application
- Recommendations for manure/bio-char for alleviating acidity
- Strategies for sustainable long-term acidity management
- Risk of over P fertilization
- Lacking methods to remove sub-soil acidity
- Lack of reliable data on biochar and soil amendments

*Knowledge Gap - Strategies*

- Demo plots/field days
- Private and public sector engagement
- Dedicated research studies

**IV. West Africa– Barriers and Strategies for Associated Clusters - Acidity**

<u>*Solutions*</u>:

1. Liming
2. Use of acid-tolerant crop varieties
3. Use of organic matter
4. Use of biochar
5. Use of agroforestry (e.g., Gliricidia, species)

*Research* - *Barriers*

- Appropriate liming recommendations
- Lack of calibration/guidelines on proper use of liming materials
- Research capacity
- Large quantities of liming materials are required-labor intensive
- Long term required for breeding acid-tolerant varieties
- Little research on biochar
- Little research on liming
- No immediate effect
- Timing can be long
- Lack of adapted technologies

*Research* - *Strategies*

- Soil testing / identify problem
- Specifically focus on soil pH
- Liming recommendation (quantity…)
- Make lime available
- Quantify impact of acidity on crops (yield/quality)
- Breed for acid tolerant varieties
- Research on biochar (type, quantity fortification, quality: timing…)
- Use of locally available materials (e.g., oyster shells), bones, ashes…

*Resources* - *Barriers*

- Availability of resources
- Availability of acid tolerant varieties
- Availability of lime at local level
- Availability of materials
- Unavailability of suitable acid-tolerant crop varieties
- Few acid-tolerant crop varieties
- Availability of appropriate agroforestry species
- Ca fertilizers are unavailable
- Availability of tree species for agroforestry
- Few agroforestry species
- Availability of OM sources
- Lack of liming materials (availability)
- Liming materials not in the market

*Resources* - *Strategies*

- Promoting liming materials
- Making, seed available and tolerant varieties
- Encourage research on local source of liming materials
- Use of organic matter

- Promote use of crop residues
- Use rock-P to improve soil acidity
- Use calcareous materials (locally available)
- Use of appropriate fertilizer (esp., SSP vs. others)
- Use of kitchen wastes/ashes…

*Additional Barriers for All Solutions*

*Finances* - *Barriers*

- High cost of liming
- Cost
- Labor demanding
- Liming is costly
- Cost-benefits of biochar and liming
- Lack of funding for research

*Knowledge* - *Barriers*

- Technical knowledge
- Lack of knowledge
- Lack of knowledge on liming
- Quick testing of soil acidity not widely promoted
- Non-awareness of acidity as a problem
- Lack of knowledge
- Inappropriate practices

## Appendix E - Soil Fertility Prioritization Summit Results – Micronutrient Deficiency

**I. Ethiopia– Barriers and Strategies for Associated Clusters – Micronutrient Deficiency**

*Solutions*:

1. Improve SOM content of the soil
2. Improve pH conditions
3. Improve the soil to enhance availability of micronutrients
4. Promote effective micronutrient application methods and form of fertilizers
5. Apply micronutrients in the form of chemical fertilizers

*Barriers*:

- What was proposed for SOC and Acidity work here
- Low biomass to produce composts that has significant effect in increasing micronutrients
- Blending micronutrients with 1° and 2° nutrients may not be efficient form and application method to address their deficiency
- Extreme of soil reaction (salinity) and (acidity) has paramount challenge in ensuring their availability

*Strategies*:

- Refer to SOC and Acidity improvement and management
- Alternative ways of micronutrient fertilizer forms and application methods

*Solutions*:

1. Update fertilizer recommendations to include micronutrients
2. Promote chelated forms of nutrients
3. Soil pH maintenance near neutrality

*Barriers*:

- Lack of knowledge
- Unavailability of micronutrients containing fertilizer
- Recommendations not available
- Economic considerations
- Soil pH effect

*Strategies*:

- Promoting poultry manure
- Promoting balanced fertilizer formulation
- Foliar spray of chelated micronutrients
- Nutrient recycling, organic inputs

*Solutions*:

1. Conduct soil testing to determine micronutrient deficiencies
2. Make micronutrient – containing fertilizers/blends available
3. Conduct sensitization exercise to link crop and human micronutrient requirements

*Barriers*:

- Lack of information on soil micronutrient deficiencies
- Lack of localized research on micronutrient deficiency impacts on crop productivity
- Limited/no availability of micronutrient-containing fertilizers

*Strategies*:

- Establish site-specific research on micronutrient impacts on crop quality and yield
- Increase/improve availability of micronutrients containing fertilizers/blends

*Solutions*:

1. Soil management practices to improve micronutrient levels and availability
2. Lower soil pH/Rhizosphere zone pH to increase micronutrient – bioavailability (e.g. soil amendments)
3. Soil fertilizer / apply micronutrient fertilizer
4. Adoption/utilization of improved crops/cultivar efficiency in extracting and up-taking micronutrients

*Barriers*:

- Access to affordable fertilizers
- Soil testing
- Lack of comprehensive knowledge/education about fertilizer application issues (avoiding over or under fertilization)
- Lack of knowledge and research of micronutrient efficient crops/germplasm

*Strategies*:

- Improve and strengthen extension education system & dissemination
- Provide affordable and faster (timely manner) soil testing services to farmers (e.g. mobile labs, private vendor service providers)
- Integration of research and extension for developing and adopting improved cultivars/germplasm
- Incorporate inter-cropping and crop rotations

*Solutions*:

1. Apply efficient micronutrients
2. Maintain soil pH at required level so that micronutrient availability is not effected
3. Use crop-rotation and apply organic & sources (e.g., residues)

*Barriers*:

- Lack of quality laboratory to control soil and plant tissue analysis
- Lack of skilled manpower for lab analysis
- Lack of residue
- Soil acidity and alkalinity

*Strategies*:

- Conduct field research to identify deficiency of micronutrients
- Apply liming or leaching
- Capacity building (both for manpower and laboratory facilities)
- Apply maize-legume intensification

**II. East Africa– Barriers and Strategies for Associated Clusters – Micronutrient Deficiency**

*Solutions*:

1. Fertilizers blending/coating
2. Manure
3. Soil testing / plant analysis
4. pH management
5. Foliar feeding

*Research - Barriers*

- Lack of crop response data
- Technology delivery (folia feeding)
- Difficulty to decrease pH

- Managing soils (pH) for m-nutrient availability
- Unpredictable behavior of availability from soils
- Unreliable data sets
- Competition with uptake of other cation/anion

*Research - Strategies*

- Crop nutrient response trials
- Nutrient emission trial/limiting nutrient trial
- Macro & micro response interactions
- Research agronomic biofortification for human health & animal health

*Access - Barriers*

- Not enough manure on farm
- Access to blended/cooked fertilizers
- Access to foliar feeds
- Access to micronutrient inputs
- Private sector engagement
- Developing affordable fertilizer

*Access - Strategies*

- Cheaper product development subsides (targeted soil test based)
- Blending

*Management Knowledge Gap - Barriers*

- Crop/micronutrient relationship
- Problem with proper application
- Targeted recommendations for MN application
- Knowledge gap on micronutrients
- Knowledge gap

*Management Knowledge Gap - Strategies*

- Framework of site selection – graduate degrees on Micros
- Applications methods

*Soil and Plant Testing & Recommendations - Barriers*

- Lack of reliable testing labs
- Plant analysis expensive/non-available
- Recommendations for fertilizers/manures
- Accurate soil testing (special protocols)
- Access to soil/plant testing
- Soil testing for micronutrient availability

*Soil and Plant Testing & Recommendations - Strategies*

- Acidity effects on micronutrient available
- New analysis techniques

**III. West Africa– Barriers and Strategies for Associated Clusters – Micronutrient Deficiency**

<u>*Solutions*</u>:

1. Organic matter inputs
2. Use of fertilizers combining micronutrients
3. Application of chelates
4. Early diagnosis of symptoms

*Barriers*:

- Farmers not aware of importance of micronutrients
- Plant availability depending on soil pH
- Deficient LAB conditions for testing micronutrients
- Visual symptoms may be misleading
- Research capacity
- Availability of fertilizers combining micronutrients

*Strategies*:

- Farmers awareness on importance of micronutrient
- Improve capacity for soil testing
- Conduct site specific research on micronutrients interaction with soil conditions
- Capacity building for field technicians
- Improve market availability of fertilizers combining micros

<u>*Solutions*</u>:

1. Trainings
2. Research
3. Local sourcing
4. Mix with other methods/approaches

*Barriers*:

- Soil quality/type
- Technical knowledge
- Availability on the market
- Application

*Strategies*:

- Organize working groups and sharing experiences at the local level
- Early soil quality detection/assessment →Research
- Set production units at local level
- Have strong policy/regulation framework and implementation tools

<u>*Solutions*</u>:

1. Application of mineral fertilizer containing micronutrients
2. Use of fertilizers with micronutrients
3. Addition of organic amendments
4. More awareness on their utility

*Barriers*:

- Small quality research
- Differences on the need from site to site
- Evidence based results
- Profitability and feasibility
- Fertilizers with micronutrients are not available
- No micronutrient recommended application rates

- Small quantities required
- Limited knowledge in application to get uniformity
- High cost associated with foliar sprays

*Strategies*:

- Incorporating in manufactured fertilizer
- Testing of products
- Apply micronutrients in foliar sprays
- Incorporate micronutrients with granular fertilizers
- Soil testing to access level of availability or accumulation to toxic levels
- Include sticker-spreader in foliar sprays to improve adherence of the spray
- Seed treatments for molybdenum application
- Site-specific nutrient management
- The 4Rs for fertilizer application (rate, time, type, and placement)

*Barriers*:

- Mineral fertilizers containing micronutrients not commonly available on the market
- When available, usually more expensive
- Low awareness of micronutrients limitation as a problem
- High cost of testing for micronutrients in soil and plant material

*Strategies*:

- Intensive soil testing for micronutrients deficiencies
- Research on crop responses to micronutrients additions to come out with recommendations
- Formulation of fertilizers to contain micronutrients for all crops not only for cotton
- Subsidies for fertilizers containing micronutrients

<u>Solutions</u>:

1. Use of micronutrient fertilizer
2. Use of organic matter input, especially animal manure
3. Use of appropriate rock powder input
4. Use of micronutrient tolerant crop varieties

*Barriers*:

- Poor micronutrient management
- Poor soil quality due to poor soil parent materials
- High cost of lab testing of micronutrients
- High cost of research on micronutrients

*Strategies*:

- Soil and plant testing to set the level of deficiencies
- Applying micronutrient fertilizers by broadcasting, banding foliar (better mixed with other fertilizer)
- Diagnose the deficiencies also from leave colors

<u>Solutions</u>:

1. Organic Matter inputs
2. Use of micronutrient inputs
3. Use of micronutrient crop varieties
4. Liming
5. Soil testing

*Barriers*:

- High cost of micronutrient fertilizers
- Lack of availability of micronutrient fertilizers

- Lack of knowledge among farmers of the importance of micronutrients
- Little research in micronutrient tolerant crop varieties

*Strategies*:

- Addition of organic matter inputs (fishmeal, seaweed, compost, etc.)
- Use of landraces that are tolerant to micronutrient deficiency
- Breed micronutrient tolerant crop varieties
- Use of appropriate fertilizer blends that contain both macro and micronutrients
- Foliar application

## Appendix F – Sub-Saharan Africa Soil Fertility Prioritization Summit Agenda

| **August 14, 2017 - Hotel Ngor Diarama, Dakar, Senegal - August 14-15, 2017** | | |
|---|---|---|
| 08:00h | Registration | All participants |
| 08:30 – 08:40h | *Welcome Remarks*:<br>Director of the Sustainable Intensification Innovation Lab and USAID Representative | Dr. Vara Prasad<br>Dr. Jerry Glover |
| 08:40 – 08:50h | Introduction of participants | All participants |
| 08:50 – 09:00h | *Setting the Stage*: Sub-Saharan Africa Soil Fertility Prioritization Highlights | Dr. Gary Pierzynski |
| 09:00 – 09:15h | *Program Overview and Plan of Action*:<br>- Why are we here?<br>- What are you being asked to do?<br>- What will be the results from our time together? | Dr. Jan Middendorf<br>Dr. Zach Stewart |
| 09:15 – 10:00h | *Regional Focus*: Soil Fertility Prioritization Exercises<br>- Interactive session to identify solutions, barriers and strategies | SIIL team facilitators |
| 10:00 – 10:30h | Coffee break | All participants |
| 10:30 – 12:30h | *Regional Focus*: Soil Fertility Prioritization Exercises<br>- Interactive session to identify, solutions, barriers and strategies | SIIL team facilitators |
| 12:30 – 13:30h | Lunch break | All participants |
| 13:30 – 16:00h | *Regional Focus*: Soil Fertility Prioritization Exercises<br>- Interactive session to identify solutions, barriers and strategies | SIIL team facilitators |
| 16.00 – 16:30h | Coffee break | All participants |
| 16:30 – 17:00h | *Regional Focus*: Soil Fertility Prioritization Exercises<br>- Interactive session to identify solutions, barriers and strategies | SIIL team facilitators |
| 17:00 - 17:30h | Reflections and plan for the next day | Dr. Vara Prasad |
| 17:30h | Adjourn | |
| 18:30h | Dinner | All participants |
| **August 15, 2017** | | |
| 08:30 – 08:45h | *Recap of Day 1*: Review of strategies and sharing highlights from each region | Dr. Vara Prasad |
| 08:45 – 10:00h | *Sub-Saharan Focus:* Soil Fertility Prioritization Exercises<br>- Interactive session to identify commonalities, gaps, & priority areas | Dr. Jan Middendorf and SIIL team |
| 10:00 – 10:30h | Coffee Break | All participants |
| 10:30 – 12:30h | *Sub-Saharan Focus:* Soil Fertility Prioritization Exercises<br>- Interactive session to identify commonalities, gaps, and priority areas | Dr. Jan Middendorf and SIIL team |
| 12:30 – 13:30h | Lunch | All participants |
| 13:30 – 14:30h | Closing Activity and Remarks | Dr. Vara Prasad |
| 14:30h | Finalize reimbursements and wrap up | All participants |

## Appendix G - Soil Fertility Prioritization Summit Participants

| N | Participant | Institution, Country |
|---|---|---|
| 1 | Abdullah Jaradat | USDA-Agricultural Research Service, USA |
| 2 | Alassane Maiga | Institut d'Economie Rurale, Male |
| 3 | Aliou Faye | Institut Sénégalais de Recherches Agricoles (ISRA), Senegal |
| 4 | Augustine Obour | Kansas State University, USA |
| 5 | Bhupinder S. Farmaha | Clemson University, USA |
| 6 | Bill Payne | University of Nevada, USA |
| 7 | Charity K. Kruger | Centre for Environment, Agricultural Research and Advocacy (CEARA), Botswana |
| 8 | Davide Ciceri | Massachusetts Institute of Technology, USA |
| 9 | Debbie Hellums | International Fertilizer Development Center (IFDC), USA |
| 10 | Ekwe Dossa | International Fertilizer Development Center (IFDC), Togo |
| 11 | Feyera Liben | University of Nebraska-Lincoln, USA |
| | Gary Pierzynski | Kansas State University, USA |
| 12 | Geoffrey Omuron | The National Agricultural Research Organization (NARO), Uganda |
| 13 | George Y. Mahama | CSIR-Savanna Agricultural Research Institute, Ghana |
| 14 | Isaurinda Baptista | INIDA, Cabo Verde |
| 15 | Jan Middendorf | Kansas State University, USA |
| 16 | Jeremy Cordingley | Crop Nutrition Laboratory Services Limited, Kenya |
| 17 | Jeroen Huising | The International Institute of Tropical Agriculture (IITA), Nigeria |
| 18 | Jerry Glover | United States Agency for International Development (USAID), USA |
| 19 | Jesse B. Naab | West African Science Service Center for Climate Change & Adapted Land Use (WASCAL), Burkina Faso |
| 20 | Liesl Wiese | Food and Agriculture Organization of the United Nations (FAO), South Africa |
| 21 | Martin Yemefack | The International Institute of Tropical Agriculture (IITA), Cameroon |
| 22 | Mateete Bekunda | The International Institute of Tropical Agriculture (IITA), Tanzania |
| 23 | Mulugeta Demiss | Agricultural Transformation Agency (ATA), Ethiopia |
| 24 | Neal Eash | The University of Tennessee, USA |
| 25 | Nsalambi Nkongolo | ARC-Institute for Soil, Climate and Water, South Africa |
| 26 | Om Parkarsh | University of Massachusetts, USA |
| 27 | Ousseynou Ngom | Development Gateway, Senegal |
| 28 | Rachel Opole | Kenya Agricultural and Livestock Research Organization, Kenya |
| 29 | Saaka Buah | Savanna Agricultural Research Institute (CSIR-SARI), Ghana |
| 30 | Sam Gameda | International Maize and Wheat Improvement Center (CIMMYT), Ehiopia |
| 31 | Tegbaru Bellete | Ethiopian Agricultural Transformation Agency (ATA), Ethiopia |
| 32 | Vara Prasad | Kansas State University, USA |
| 33 | Yacine Badiane Ndour | Institut Sénégalais de Recherches Agricoles (ISRA), Senegal |
| 34 | Ysuf Assen Mohammed | Montana State University, USA |
| 35 | Zach Stewart | Kansas State University, USA |