TAAT Technology Toolkits and their Strategic Deployment

TAAT Clearinghouse

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TAAT Technology Toolkits and their Strategic Deployment

The Technologies for African Agricultural Transformation (TAAT) is funded through a grant from the African Development Bank and is implemented by the International Institute of Tropical Agriculture (IITA) in close collaboration with other centers of the Consultative Group for International Agricultural Research (CGIAR) and specialized institutions such as the African Agricultural Technology Foundation (AATF), the Forum for Agricultural Research in Africa (FARA) and the International Fertilizer Development Center (IFDC) and others. For more information, contact *Mp.Bokanga@cgiar.org or plwoomer@gmail.com*.

Front cover photographic credit: TAAT's Cassava Technology Toolkit: high yielding, disease resistant varieties and the multiplication systems needed to disseminate them (upper left); opportunities for mechanization include machine stem planters (top center) and weeders (upper right); diseases are identified through mobile apps (lower left); storage life is lengthened by tuber waxing (bottom center); and processing technologies include production of export-quality starch (lower right).

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Background. The African Development Bank recently launched Feed Africa: A Strategy for Agricultural Transformation in Africa. This loan program is intended to unlock Africa's agricultural potential and boost job creation with a view to diversifying African economies and to better meet the Strategic Development Goals related to poverty reduction and ending hunger and malnutrition. Technologies for African Agricultural Transformation (TAAT) is a flagship program within the Feed Africa Strategy aimed at modernizing African agriculture through the advancement of agricultural technology in a way that improves the business of agriculture across Africa, thus raising agricultural productivity, mitigating risks and promoting sustainable enterprise diversification.

To achieve these goals, TAAT focuses upon the identification, promotion and dissemination of proven technologies and management innovations. It is led by the International Institute of Tropical Agriculture (IITA) and structured as a series of Value Chain Compacts, each with its own Technology Toolkits, impact targets and partnership arrangements. The TAAT Clearinghouse was established in Cotonou, Benin to oversee technology selection and to coordinate efforts between Compacts and across Africa. The Program Management Unit operates at IITA to ensure timely technical and financial reporting. TAAT presently operates in 31 African countries.

The principle of designing and deploying Technology Toolkits is established within the framework of TAAT as a mechanism to extend cohorts of proven technologies to African farmers. Toolkits are defined as *"an assemblage of proven core technologies needed to close productivity gaps that are mobilized during country-level technology deployment but then interpreted and advanced in a wider developmental context".* They are necessarily holistic. For example improved crop varieties alone are not able in themselves to increase yields without accompanying technologies related to soil fertility, pest control, and water management. The same holds true for animal breeds without veterinary services and improved feed systems. Toolkit composition begins with proven production inputs and management innovations, but also operates along the entire commodity value chain in a transformative manner.

These toolkits provide the capacity for farmers to double yields, achieve food and nutritional security, increase farm household incomes above poverty levels, create employment and build agricultural exports. For crop enterprises these toolkits include improved varieties and their seed systems; land preparation; management of nutrients, water, weeds, pests and diseases; labor saving and ergonomic tools and machinery; harvest and post-harvest operations; and processing and marketing opportunities. For animal enterprises they include stock improvement and rearing; containment and housing; feed and health systems; harvest, processing and marketing operations; and integration into larger farming systems and landscapes. The following is a summary of these Technology Toolkits followed by their deployment strategy and implications within the wider TAAT and Feed Africa Programs. While each toolkit is presented as a dissemination product of the nine TAAT Commodity Value Chains, it must be noted that their more precise composition varies within different partnership arrangements and that various TAAT Enablers also contribute to their design and implementation as specialized service providers.

The Rice Compact Technology Toolkit

Photo Gallery 1. TAAT's rice technology toolkit includes a diverse selection of improved rice varieties (upper left) including biofortified "golden rice" (center top); RiceAdvice decision support (upper right); deep nitrogen placement (lower left); mechanical weeders (bottom center); and the ASI thresher (lower right).

This effort is coordinated by AfricaRice with partnership in 16 countries, mostly in West Africa where massive importation of rice occurs. It is based upon the dissemination of three varietal lines: New Rice for Africa (NERICA), Advanced Rice Varieties for Africa (ARICA) and ORYLUX (aromatic) varieties; with over 68 varieties released to date. These varieties include both wet and upland varieties and biofortified "golden" rice. Also under development is hybrid seed. These lines are promoted through commercial licensing of foundation and certified seed. Land preparation is facilitated through engineered irrigation surfacing. Fertilizer interventions include climate-smart urea deep placement for greater nitrogen use efficiency and the application of foliar micronutrients where needed. Water management is guided by the "Smart Valley" concept, the development of site-specific irrigation kits, and where required efficient water lifting technologies. Weeding operations are assisted through the use of motorized weeders that cut, uproot and bury weeds between crop rows. Crop management is further guided by RiceAdvice decision support; an application tool providing farmers with guidelines for specific field conditions via "smart phones". Separation of the grain from the cut plant is assisted by an Axial Flow Thresher that may either be purchased or manufactured locally. Processing technologies result in "import-quality" polishing, rice flour and its products, and uniform steam (GEM) parboiling. The main goal of this Compact is to greatly reduce the massive imports of rice into Africa.

Photo Gallery 2. The TAAT wheat toolkit includes several newly-released heat, drought and disease resistant varieties (top left); engineered irrigation (top center); raised bed culture (upper right); management of stem rust (lower left); mechanized planting and harvesting (bottom center); and compact milling systems (lower right).

The Wheat Compact Technology Toolkit

This partnership is coordinated by the International Center for Agricultural Research in the Dry Areas with

activities in seven countries including the East African Highlands, Southern Africa Plateau and Sahel. Activities in the Sahel are of particular importance as the development of new crop varieties permits irrigated wheat production during its cool season. This toolkit features many new wheat varieties with heat and drought tolerance, and stem rust resistance. These traits allow for expansion of wheat production in Africa, including the Sahel during its cooler "winters". It is fast-tracking this next generation variety release through national programs. It offers expertise in land preparation including raised beds, furrow and deficit irrigation, and sprinkler systems. It promotes low-cost mechanized planting within conservation agriculture. Soil fertility is managed through specially-blended pre-plant fertilizer and legume rotation. Weeds are managed through pre-emergent herbicides. Pests and diseases are managed through early planting, and bred resistance to the Hessian fly and stem and yellow rust as well as strategic release of biocontrol agents for insect pests. This Compact embodies the greatest level of mechanization within TAAT, and expansion of contract planting and combine harvester fleets are essential to its overall success. At the same time it promotes smaller-scale out-grower technologies that can accommodate wheat rotation into existing cropping systems. The Compact rationale is intended to develop greater self-sufficiency in Africa's wheat production to reduce the current massive imports. This strategy includes the Compact's flour milling systems and development of wheat's many value-added food products.

The Maize Compact Technology Toolkit

This Compact is coordinated by the African Agricultural Technology Foundation and IITA with partnership in 12 countries located in Sub-humid climates of Central, East, Southern and West Africa. This effort is driven by the availability of three recently-developed traits; drought tolerance, imazapyr resistance, and Vitamin A biofortification. Drought tolerance mitigates risk of climate change, imazapyr resistance reduces the threat of the striga plant parasite and biofortification contributes to nutritional security. Varieties championed by AATF are promoted by the TEGO seed licensing mechanism and these and other improved varieties and hybrids are becoming widely marketed through commercial seed suppliers. Land preparation is advanced through contract mechanization, such as the award-winning Hello Tractor initiative, and increased availability of hand tractors. Integrated Soil Fertility Management incorporates pre-plant fertilizer blends, N top dressing, crop residue and manure management, and legume rotation and intercropping strategies. Drought Tolerant Maize for Africa (DTMA) signals a breakthrough in water management and is best accompanied by water conservation features such as tie ridges and contour cropping. Weeds are better managed through the use of pre-emergent herbicides, including those suitable for maize-legume intercrops. Parasitic striga can

Photo Gallery 3. TAAT's maize toolkit includes an array of new maize varieties (upper left) including those mobilized through the TEGO mechanism (top center); greater access to mechanization services (upper right); and technologies that counter threats from parasitic striga (lower left), health-threatening aflatoxins (bottom center) and the recent invasion by Fall Army Worm (lower right).

finally be eliminated from maize croplands using a combination of technologies including Strigaway. The recent invasion of Africa by the Fall Armyworm may also be controlled through IPM and rapid curative response, and is the focus of another TAAT Enabler Compact. So too, varieties are identified that offer tolerance to Maize Lethal Necrosis Virus. Aflatoxins are reduced through the application of AflaSafe, a technology that introduces non-toxic fungi and greatly improves food safety where applicable. Harvest labor is greatly reduced through mechanical and motorized shellers that remove grain from cobs. Maize is a major component of processed animal feeds and this deepens maize markets to accommodate anticipated surpluses. Stover is also valuable as livestock feed. Improved maize production offsets grain importation, and cereal banking assists in protecting prices during peak supply.

Photo Gallery 4. TAAT's Fall Army Worm Rapid Response toolkit focuses upon mobilized operators offering efficient and affordable control services to invasion of cropland (above); applicator safety is a major consideration (lower left); youth-led operators have customized their cargo tuk tuks in a way that popularizes their businesses as well as TAAT as a whole (lower right).

Fall Armyworm Rapid Response

This action operates through one of the TAAT Enablers and is specifically intended to counteract the biological invasion of Fall Army Worm across Africa. It is led by IITA with strong partnership by several Advanced Institutes, starting with five piloting countries located in East, Southern and West Africa in 2018. It is closely allied with the Maize Compact. Fall Army Worm *(Spodoptera frugiperda)* is suddenly a major threat to food security in Africa. This highly destructive pest is native to Tropical America and first detected in Africa in January 2016 in Nigeria. It has since spread to 38 countries across Africa and exhibited a wide host range of over 80 plants with preference for cereal crops, particularly maize. Included within this Enabler strategy is the FAW Rapid Response for which a toolkit was devised and distributed. This action links youth, product manufacturers and agrodealers to the war on FAW by providing practical, mobile solutions to invasion outbreaks, and offers a business model for diversification of agribusiness services in maize production areas. It establishes Rapid Response units operating out of commercial locations and community-based

An offer for FAW Rapid Response services by an Agripreneur Group in Kenya.

organizations, with each unit consisting of two to four trained youth. The toolkit consists of a customized cargo tuk-tuk, power sprayers, state-of-the art safety equipment, bio-rational pesticides, farmer information materials and communication tools. These units work in conjunction with local agrodealers, farmer groups, county extension and local representatives of input distributors. Training is an important element of this toolkit so a one-day course on FAW Rapid Response was developed that contains seven modules: 1) Fall Army Worm control as a business opportunity; 2) Understanding the Fall Army Worm invasion; 3) Control options and access to rapid response equipment and supplies; 4) Operation and maintenance of control equipment; 5) Commercial partnership and enterprise establishment; 6) Costs and expected returns; and 7) Agripreneur youth as rapid responders within local communities and agrodealer networks. These courses have proven to not only prepare operators for efficient and safe FAW control, but also galvanize local commitment and investment in this toolkit. FAW control services are offered for about $45 to $55 per ha and initial demand for them is very strong among farming communities severely affected by FAW invasion. But an unresolved issue remains, to what extent should these costs be borne by individual farmers as opposed to wider programs that view FAW suppression as a necessary public good? A key emerging technology is seed treatment with Fortenza Duo insecticide that provides several weeks' protection to young maize plants, a strategy recently launched in Southern Africa.

The Sorghum-Millet Compact Technology Toolkit

This Compact is coordinated by the International Crops Research Institute for the Semi-Arid Tropics with national partnership in seven countries of the Sahel. Its toolkit supports two indigenous cereals essential to the food security across African drylands: sorghum and millet. It is based upon the development of many new improved varieties of both crops and their rapid release through national programs. As both of these crops are open pollinated, they are well suited for dissemination by community-based seed production actors, but at the same time mechanisms for production of foundation and certified seed are under development. Water harvesting is a necessary component of this toolkit and is achieved by established soil preparation techniques including "Zai" pits, tie ridges and contour bunds that eliminate runoff during heavy seasonal rains. Labor savings is achieved through the promotion of hand-pushed planters. Soil fertility is managed through fertilizer micro-dosing, a technique that increases nutrient use efficiency and applies inputs in proportion to demands

Photo Gallery 5. TAAT's sorghum and millet toolkit includes an array of new sorghum (upper left) and millet (top center) varieties; water harvesting (upper right) and fertilizer micro-dosing (lower left) are essential accompanying technologies; sorghum and millet are processed into nutritious foods. Crop residues are an extremely important organic resource throughout the Sahel.

created by seasonal rainfall. Legume rotation with groundnut and cowpea are important features of this cropping system, and so too are interactions with livestock as virtually all stover is fed to farm animals during the long dry season. Sorghum is attacked by parasitic striga and innovations leading to its control, including release of resistant varieties, are also included. Release of a parasitoid wasp is being considered for control of head miner, and sorghum disease control is promoted through the release of rust resistant varieties. Models for commercialized rearing of these control agents are available from elsewhere in Africa. Stover management includes the promotion of mobile choppers so that crop residues may be better processed into livestock feeds. The importance of these two crops across the Sahel cannot be understated as they provide the main staple cereal to most people, and the organic resources they offer are even used for dwellings and fences. There is also huge scope for further value-added processing of sorghum and millet as well because these grains are extremely nutritious and useful in barley and wheat substitution. An innovative community-based cereal banking system, known as "warrantage" is being employed as a combined food security and marketing mechanism.

The Cassava Compact Technology Toolkit

This Compact is coordinated by IITA with partnerships in 15 countries in Central, East, Southern and West Africa. Because cassava is suited to a wide range of climatic conditions, its toolkit approach varies across agro-ecological zones. Africa is the world's leading cassava producer but the crop is widely regarded as a food for the poor rather than a substrate for value-added food and industrial starch production. As a result few cassava products from Africa are traded on world markets and this Compact seeks to rectify this shortcoming by intensifying cassava's production and processing. Stalling cassava's progress was its susceptibility to a number of serious virus diseases but after decades of research tolerant varieties and management systems are now in place. These new varieties are also selected on the basis of their higher dry matter and starch contents and some represent biofortified yellow (vitamin A) traits. Cassava is propagated by stem cuttings and technologies are now available to rapidly multiply and commercially disseminate these improved varieties. This "seed" system includes laboratory propagation using Semi Autotrophic Hydroponics technology, distributing these plantlets to commercially- or- community-operated fields producing stem cuttings, and then selling these cuttings to farmers employing other modern farming techniques. This dissemination is advanced through mechanized stem cutters and planters among larger-scale producers. Soil fertility is managed through sequential addition of fertilizers based upon the stage of crop development and culminates in the addition of a specialized fertilizer blend rich in potassium (e.g. RFC-Root), a nutrient in high demand by the crop during tuber fill but not sufficiently available through current

Photo Gallery 6. TAAT's cassava toolkit includes high yielding, disease resistant varieties and the multiplication systems needed to disseminate them (upper left); opportunities for mechanization include machine stem planters (top center) and weeders (upper right); diseases are identified through mobile apps (lower left); storage life is lengthened by tuber waxing (bottom center); and processing technologies include production of export-quality starch (lower right).

agrodealer networks. Cassava is resilient with regard to its water relations and can be grown across semi-arid to humid climates, but drought tolerant varieties are now available and are being disseminated where needed. Cassava is a longer duration crop with potential to accumulate weeds, pests and diseases during its growth. Competition with weeds greatly reduces cassava yields and established mechanized tools including rotary and paddle weeders are being promoted, as well as wider use of pre- and post-emergent herbicides. So too, established IPM systems that reduce virus vectors are disseminated through extension providers in a way that compliments disease management through improved access to virus-free planting materials. Disease diagnosis is assisted through use of a mobile phone application. Owing to cassava's large stature and deep tubers, mechanized harvest "lifting" operations are difficult, but are under consideration as well. A simple "waxing" technology that improves shelf life of tubers is being promoted. Processing technologies focus upon the production of high quality flour and industrial grade starches, as well as use of peels as animal feed. Indeed, the potential for greatly increased production of cassava exists through application of this toolkit and increased processing capacities are needed to translate these surpluses into exports.

The Sweet Potato Compact Technology Toolkit

This Compact is coordinated by the International Potato Center (CIP) with partnership in eight countries located in Central, East, Southern and West Africa. It is based upon the widespread release and popularization of the Orange-Fleshed Sweet Potato (OFSP), a color that signals its Vitamin A content. This vitamin is deficient in many diets across Africa, in part due to shortcomings in access to assorted vegetables, resulting in a Compact primarily focused upon nutritional security in both rural and urban areas. Much progress was made in developing sweet potato technologies in past years, but incomplete consumer experience was achieved with the earliest "softer" varieties but now firmer textured traits are available as well. Sweet potato is propagated by vine cuttings and a system to deliver disease-free propagules is in place. First national authorities maintain virus-free germplasm banks for distribution to both commercial and community-based multipliers growing OFSP primarily for cuttings. These cut vines are sold to farmers and planted for tuberous root production.

Photo Gallery 7. TAAT's Orange-Fleshed Sweet Potato toolkit includes high yielding varieties (upper left) rich in Vitamin A (top center); rapid dissemination of improved varieties (upper right); proven management technologies (lower left); integration with livestock systems (bottom center); and processing options with proven profitability (lower right).

The profitability of this propagation system is well established. The vines are planted on hills or raised beds fertilized with mineral and organic fertilizers that improve recovery of roots. Small-scale tillers and paddle weeders assist in bed preparation. As tubers fill, a specialized fertilizer blend (RFC-Root) meets the crops changing nutritional needs, particularly increased demand for potassium. For such a succulent plant, sweet potato exhibits surprising resistance to short-term drought, a trait that is being improved through the release of new drought tolerant varieties. Because of the crop's trailing habit, raised beds and hills are spaced far apart, offering an entry for weeds but this is reduced through mulching and the use of mechanical weeders. IPM technologies are available that reduce vectors of virus disease, particularly the Feathery Mottle Virus. Producers that maintain crop sanitation measures are able to produce their own cuttings, and to distribute them to neighbors, greatly accelerating dissemination. Upon harvest, both the tubers and green shoots have value, the latter as livestock feed. Silage technologies are available for this second purpose. Several processing opportunities exist for OFSP, particularly as puree for addition to processed foods, including baked products. The tubers may also be processed into snacks. OFSP offers a breakthrough in Africa's nutritional security, in large part through its ready introduction into small scale-farming systems and its compatibility within both traditional and modernizing diets.

The Bean Compact Technology Toolkit

This Compact is coordinated by the International Center for Tropical Agriculture (CIAT) through partnership in eight countries located in upland areas of Central, East and Southern Africa where bean production offers greatest opportunity. It is driven by the development of biofortified bean varieties rich in iron and zinc and lines increasingly resistant to root disease. It includes both bush and climbing varieties. These varieties are disseminated by both commercial and community-based seed production. Seed dressing containing insecticide and fungicide, and inoculation with elite rhizobia are important accompanying technologies. Land preparation is improved through the use of small-scale mechanization, and for climbing varieties through low-cost staking strategies employing locally gathered materials. Soil fertility is managed through the application of specialized fertilizer blends with little or no nitrogen and manures. Beans require cooler, moist climates and planting on raised beds for rapid drainage is encouraged. Weed management is improved through the use of pre-emergent herbicides and the use of hand-operated mechanical weeders. Integrated Pest and

Photo Gallery 8. TAAT's bean toolkit contains several new biofortified crop varieties (upper left) including climbers (top center); application of legume inoculants (upper right) and seed dressing; specially blended fertilizers (lower left); and hermetic grain storage (lower right). Special attention is paid to modernizing traditional bean intercropping systems (bottom center).

Disease Management is well developed for bean and these tools are being compiled and distributed through extension mechanisms. Grain is separated from cut plants by commercially-available mechanical threshers and protected from weevils through use of PICS hermetically-sealed bags. Beans are an important protein source, but one with a lengthy cooking requirement that is being more conveniently processed for consumers by pre-cooking and milling, and several new products are entering urban markets. This Compact is primarily intended to improve Africa's nutritional security and is targeted toward domestic markets such as local supermarkets.

The Fish Compact Technology Toolkit

This Compact is jointly led by WorldFish and the IITA Youth Agripreneurs through activities in five countries offering greatest opportunity and infrastructure to greatly expand and improve aquaculture. It serves to modernize fish farming with focus upon tilapia and the African catfish. It is introducing improved breeds of fish by establishing broodstock centers and facilitating cross-border movement of these elite fish. It is developing low-cost hatcheries where male mono-sexed fingerlings and juveniles are produced under sanitary conditions and distributed with low mortality. In many cases it will establish certification standards where none exist. A variety of production systems are being promoted including improved ponds but also rearing in tanks and cages. Pond design includes liners for improved water retention and drainage to facilitate fish harvest and pond maintenance. Needs for improved water quality and distribution are being addressed. Clustering production through the establishment of commercial "aquaculture parks" is one means to develop critical mass for fish production technologies. This Compact is assisting in efforts to develop feed systems based upon locally-produced, higher protein feeds with improved buoyancy characteristics manufactured through small-scale pelleting and extrusion technologies. So too, the Compact recognizes the need for providing incentives for millers currently engaged in pelleted livestock and poultry feed production to include fish feed within their product lines. Fish health is also being promoted through protection of water quality, particularly its aeration, and the exclusion of predators and poachers. Harvest technologies achieve complete recovery through nets or drainage with no carryover of adults that feed upon subsequently introduced juveniles. Value-adding fish processing technologies such as drying and smoking based upon consumer preference are being facilitated, as are "white butcheries" where first-stage processed fish products remain refrigerated or frozen as they reach consumers. Fish farming and processing is viewed as viable enterprises for youth in rural areas. In many cases, fish ponds are integrated with crop production and the value of pond effluent for irrigation and nutrient supply is being considered. Ultimately, this effort serves to offset diminishing catches from inland fisheries, and to reduce fish imports to Africa of cultivated fish produced elsewhere.

Photo Gallery 9. TAAT's fish farming toolkit includes improved tilapia stock (upper left); low-cost hatcheries (top center); modern pond design (upper right); localized feed production (lower left); youth-led production and harvest technologies (bottom center); and value-added processing (lower right).

The Poultry Technology Toolkit

This effort represents one of two commodity value chains within the Small Livestock Compact coordinated by the International Livestock Research Institute (ILRI) through strategic partnership in seven countries. Its approach serves to modernize poultry production at a variety of production scales through improvements in flock breeds, feeds, health care and marketing innovation. It addresses stock improvement of both meat and layer breeds including greater access to hardy duo-purpose birds among smaller-scale producers. It recognizes the importance of heat tolerance of improved poultry suited to the tropics. Rearing systems include low-cost, semi-automated local hatcheries raising chicks for one to 21 days based upon farmer preference and delivering them with greatly reduced mortality. It recognizes a shift to full-time containment within poultry houses offering lighting, continuous water and more efficiently utilized feed. At the same time, it recognizes the advantage of part-time feed scavenging within smaller-scale production systems and is designing poultry sheds accordingly. Feeds represent the largest investment in poultry raising and intensified production requires that affordable feeds be available for different stages of meat and egg production. Feed costs are becoming reduced by stimulating local feed production, pelleting for greater feed efficiency, and inclusion of grain surpluses and crop byproducts such as cassava peels and soybean press cake. In this way, producers' access to improved poultry feeds interacts with the successes of several of TAAT's priority crop value chains and also reflects the need to include soybean among them. Improved poultry health involves universal vaccination of chicks against Newcastle virus, and preventive antibiotics in drinking water. Wider access to veterinary services is viewed as critical to human bio-security in Africa considering the avian-related disease outbreaks experienced elsewhere in the world. Movement toward more commercialized production involves staggering production batches, slaughter to industrial standards, mechanized de-feathering and reliable egg grading. Larger-scale producers are encouraged to advance beyond first-stage processing of whole birds, but to offer poultry parts as well. Smaller-scale operations are organized into producer and marketing hubs to benefit from scale of production and conduct collective sales. Poultry production is seen as an important entry point to youth-led enterprise. Poultry manure is an important organic and nutrient resource and is being processed accordingly in a manner that reduces gaseous loss to the atmosphere. Ultimately this Compact toolkit serves to improve household protein consumption by both rural and urban consumers while eliminating poultry product importation into Africa.

Photo Gallery 10. TAAT's poultry technologies include improved duo-purpose breeds (upper left); modern incubation and hatcheries (top center); intermediate-scale poultry houses (upper right); veterinary support access (lower left); mechanized plucking (bottom center); and hygienic processing systems (lower right).

The Small Livestock Technology Toolkit

This effort represents the second commodity value chain within the Small Livestock Compact coordinated by the International Livestock Research Institute (ILRI) through multi-stakeholder actions in seven countries located in Central, East, Southern and West Africa. It relates to sheep and goats and the need to intensify production practices that transition their rearing from subsistence to commercial operations. It is based upon promotion of proven technologies that can improve small livestock genetics, feed, health, production systems and marketing. Localized herd improvement results from introducing improved animal breeds through community-based breeding. While the benefits of open grazing are recognized, so too are the advantages of part-time containment in protective sheds and zero-grazed fattening in the final stages of meat production. Designs of low-cost animal pens are available. This toolkit includes a variety of feed systems that include improved pastures, cut and chopped fodder, preserved feeds and supplemental grain during fattening. Pasture improvement results from introduction of both forage grasses and legumes. Feed quality improvement also results from reliance upon dual-purpose crop cultivars with improved residue production and quality. Feed is preserved through hay and silage making advanced through use of mechanical choppers. Improved animal health results from vaccination campaigns relying upon thermostable PPR vaccines and greater access to veterinary services. Animals may be marketed live to take advantage of their mobility or through affiliation with local slaughterhouses that certify and protect meat quality. Short-term fattening operations represent a viable value-addition option, and may be conducted as a bridging enterprise between producers and market. In some cases, value is added through the availability of shearing equipment for sheep and the grading and baling of wool. So too, new processing options are available for hide curing and secondary leatherworks, and this offers an avenue for youth-led agribusiness development. Small livestock are often raised as a component within mixed farming systems and many opportunities exist for improved crop management through application and processing of manures resulting from crop residues used as forage and feed. The toolkit recognizes that overgrazing has resulted in widespread land degradation, particularly in drylands, and guidelines for rangeland rehabilitation are available. In this way, this Compact is closely associated with food security and environmental protection in the Sahel, but also offers improved livelihood options across Africa, particularly in association with maize and legume based cropping systems.

Photo Gallery 11. TAAT's sheep and goat technologies include herd improvement (upper left); pen design (top center); improved feed production and preservation (upper right); greater access to vaccines (lower left), fattening enterprise (bottom center); and value addition to animal products (lower right).

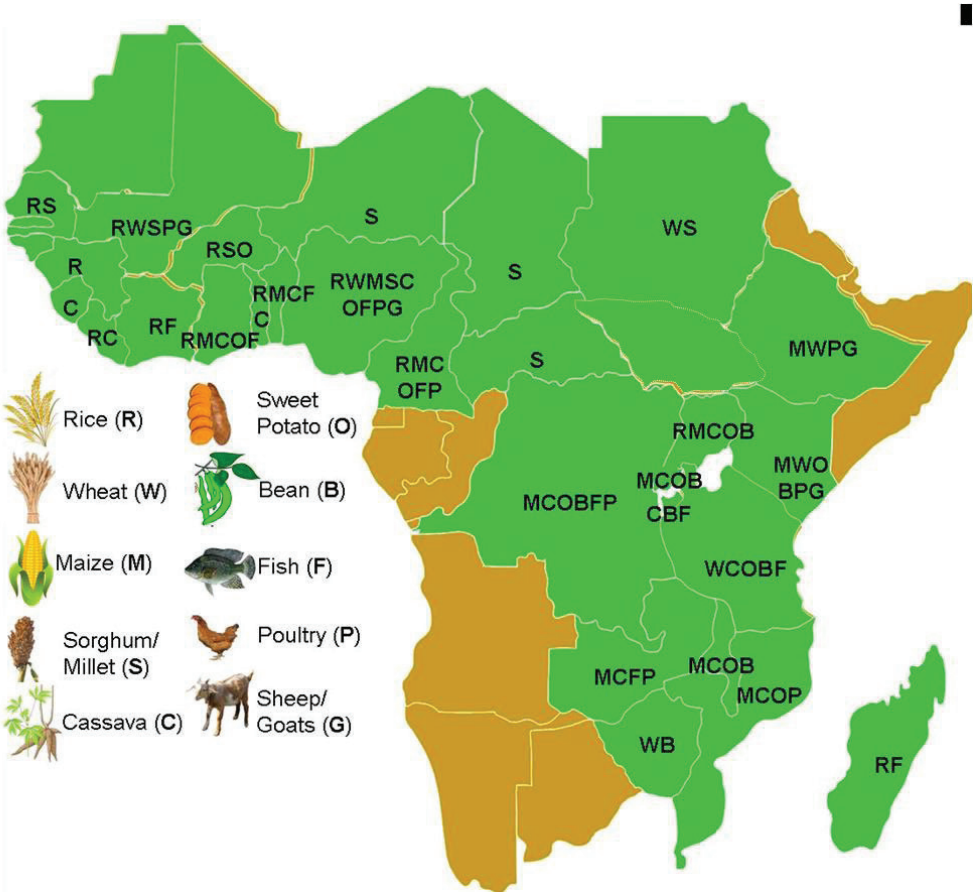

Figure 1. The geographic distribution of TAAT toolkit deployment in Africa results in 86 interventions in 27 countries. Note that Guinea Bissau, Gambia, Mauritania and South Sudan are newly admitted to TAAT.

Toolkit Deployment

The Technology Toolkits described in this report are being developed, adapted and deployed by their respective Commodity Value Chain Compact partnerships. Award of these Compacts resulted from a careful vetting process by IITA that first considered numerous technologies and identified which were worthy and ready for scaling. At the same time, The African Development Bank announced its intention to form TAAT as a technology backstopping flagship to its Feed Africa loan program among Regional Member Countries, and conducted investigation missions to learn expectations of such a facility. Then selected lead institutes were offered the opportunity to develop a Compact application for submission to the TAAT Clearinghouse following a standard template developed by the TAAT Program Management Unit and these applications were submitted to it. The Clearinghouse then commissioned both in-house and external reviews of these applications and forwarded its recommendations to the TAAT Program Steering Committee (PSC). The PSC either approved the Compact applications for funding or placed conditions upon their revision. In all, 15 Compacts were commissioned; nine relating to Commodity Value Chains and six providing Enabler backstopping services. It is these Commodity Value Chains that then prepared the more generalized Technology Toolkits described in this report and went on to adapt and deploy them at country levels through a series of implementation workshops and site-specific partnership actions.

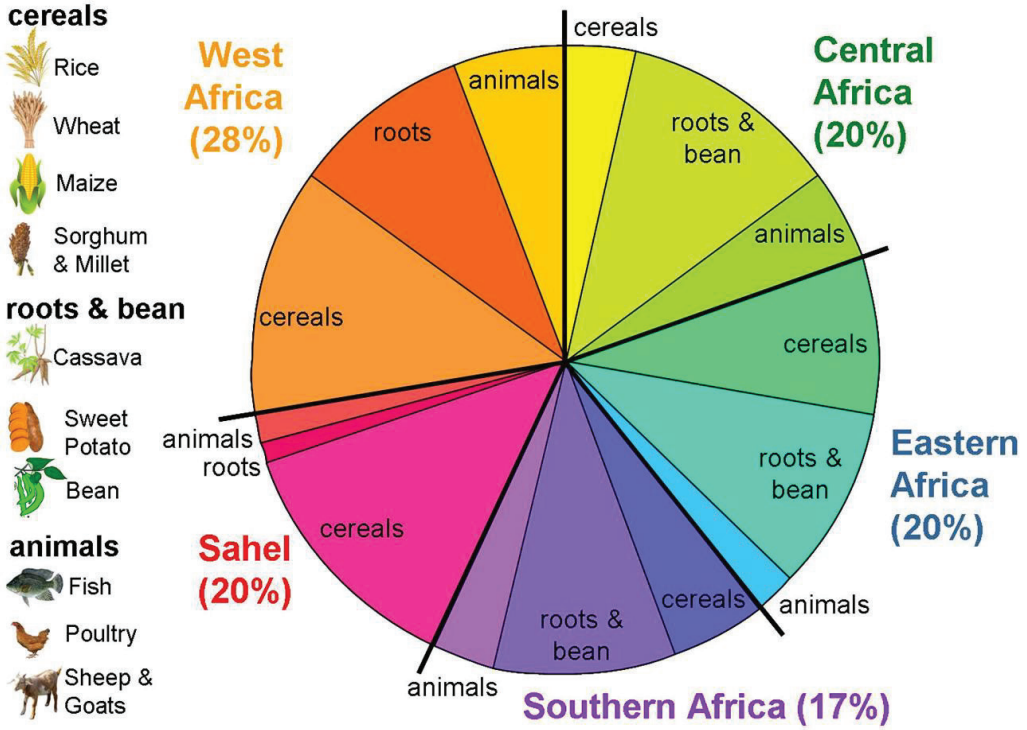

Figure 2. Distribution of Compact toolkits grouped by function indicates even overall distribution across five African sub-regions but that some important interventions should be better represented.

Countries selected for toolkit deployment were identified in the Commodity Value Chain Compact applications, and in some cases were recommended through Clearinghouse and PSC review, based upon which ones are best suited to host which Compacts. In some cases, Compact activities were clearly defined by agro-ecological conditions, as with the Sorghum-Millet Compact and its importance across the Sahel. In other cases it was largely determined by the need to reduce massive food imports of staple commodities, particularly rice and wheat, and which countries are best positioned to join in that effort. Considerations for nutritional security through accelerated deployment of recently-development biofortified crops, particularly Orange-Fleshed Sweet Potato and High Iron Beans, were also factored into country selection. The net result was the establishment of 86 toolkit interventions in 27 African countries during 2018-2019 (Figure 1).

A binomial matrix of planned toolkit interventions by participating countries was constructed consisting of 243 cells containing 86 positive events and subjected to various analyses. Note from Figure 1 that participation in East and West Africa is complete but some gaps appear in Central and Southern Africa. There is an average country participation of 3.2 interventions per country, ranging from only one (Chad, Guinea Conakry, Liberia, Niger and Togo) to eight (Nigeria, all but bean). Participation in TAAT continues to grow, with four countries recently admitted (Gambia, Guinea Bassau, Mauritania and South Sudan) but not yet assimilated into the Value Chain Compacts. Additional information on Compact and country-level activities is available from the TAAT Clearinghouse Partnership Management Office. The effectiveness of Compact operations and the performance of their toolkits will undergo continuous Monitoring and Evaluation by the TAAT Clearinghouse and this will become the topic of a future Clearinghouse Technical Report.

Table 1. Regional participation and thematic distribution of TAAT commodity toolkits.

Region	Participating Countries	Total Toolkits	Cereals	Roots & Bean	Animals	Comments[1]
	------ number ------		---------- frequency[2] ----------			
Central Africa	4	17	0.18	0.59	0.24	wheat & sorghum poorly suited
Eastern Africa	4	17	0.41	0.47	0.12	good balance but sorghum absent
Southern Africa	5	15	0.27	0.53	0.20	good balance but sorghum absent
Sahel	6	13	0.85	0.08	0.08	no maize, cassava, bean or fish
West Africa	8	24	0.46	0.33	0.21	strong balance, bean poorly suited
Program-wide	27	86	0.43	0.40	0.17	average 3.2 toolkits per country

[1] Comments refer to the balance and exclusion of commodities within region. [2] Cereals group the rice, wheat, maize and sorghum/millet compacts; Roots & Bean group the cassava, orange-fleshed sweet potato and high iron bean compacts; and Animals include fish, poultry, goats and sheep.

Participating countries were assigned to one of five sub-regional locations; Central, Eastern, Southern and West Africa, and the Sahel. Also the Value Chain Compacts were grouped in a functional manner as cereals, roots and bean, and animal enterprises. Strong balance exists among the sub-regions (Figure 2) with participation ranging between 17% (Southern Africa) and 28% (West Africa). There is a strong regional component to value chain toolkit intervention as well with cereals most important in Eastern and West Africa, and the Sahel. Root crops have greater importance in Central, Southern and West Africa. Animal enterprise includes fish, poultry and small livestock and is underrepresented as a whole, particularly in the Sahel where the integration of dryland cropping and livestock is an extremely important livelihood strategy.

Regional participation ranges from four (Central and Eastern Africa) to eight countries (West Africa) hosting between 13 to 24 toolkit interventions (Table 1). Again the balance of the three commodity chain categories is revealed. Cereals emerge as most important followed by root crops and bean; the former

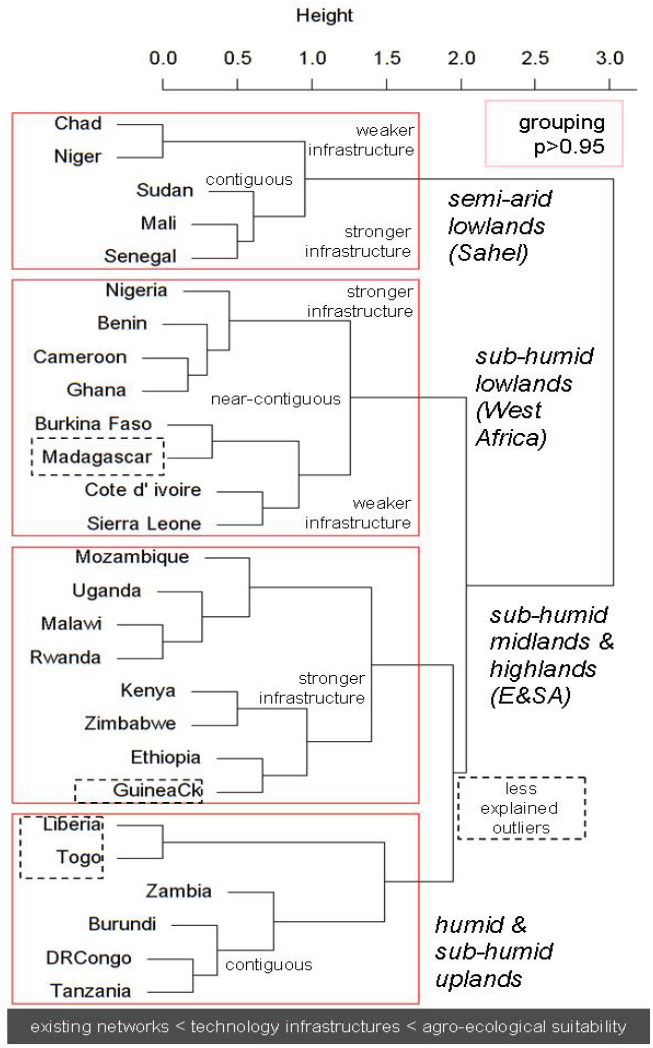

Figure 3. Interpretive clustering of participating countries based upon Value Chain Compact strategies suggests a three-tier application of toolkits.

because of the need for achieving self-sufficiency in staple foods, and the latter because of the need for export crop development (cassava) and greater nutritional security through promotion of biofortified cassava, sweet potato and bean. Strengths and weaknesses in toolkit proportionality also appear but some of these are related to the agro-ecological suitability of the individual priority crops.

Finally the value chain x country binomial matrix was subjected to Cluster Analysis (Figure 3). While the quantitative nature of the data matrix is simple (0 for no participation, 1 for inclusion) the process for inclusion itself is quite complex as it is based upon agro-ecological suitability, levels of technical capacities, toolkit availability, and country positioning within regional and commodity networks. Cluster Analysis reveals four major groups corresponding to different agro-ecological zones ($p>0.95$) and relatively few outliers. Distancing within these groups appears related to technology infrastructure and geographic contiguity. Clearly there is scope to address technology promotion within geographic areas and clusters of countries but at the same time there remains some poorly explained positioning within this interpretation (15%). Binomial Cluster Analysis was also expanded to include backstopping actions of TAAT Enablers, increasing the matrix to 405 cells containing 153 interventions (data not presented). This approach led to fewer major groups (3) and less outliers (7%) but some of the within group positioning appears less rational; suggesting that Enabler backstopping efforts may be more aligned to existing relationships than response to a call for services by individual countries and Value Chain Compacts for their specific expertise. There appears to be much scope for further evaluating the efficacy of TAAT participation, its regional characteristics and the backstopping efforts of its Enablers to better understand its fullest developmental context.

Photo Gallery 12. The Maize-Bean Modernization toolkit (above) developed for west Kenya and the team responsible for its success (below).

The Importance of Cross-cutting Toolkits

Toolkits cutting across several Compacts and the teams to disseminate them are being organized as Quick Wins supported through Clearinghouse Technical Missions. An example is the maize-bean modernization effort mobilized in west Kenya. First an inputs toolkit of proven, commercially-available materials was assembled for dissemination to 2000 farmers through the OSSOM Agrodealer Network. Two important maize breakthroughs promoted by the African Agricultural Technology Foundation; TEGO drought resistance and

Strigaway management of the striga plant parasite, and their accompanying technologies are promoted through this toolkit. In total, it results from combining 17 proven technologies from eight different input and machinery suppliers. Agrodealers are currently test marketing these toolkit components to customers, and conducting product demonstrations and customer open houses around them. The promotion of this toolkit resulted in the formation of a wider team of stakeholders deeply committed to this Quick Win. The primary motivating factor around this team appeals to their commercial interests as TAAT stakeholders. In addition, IITA Youth Agripreneurs are present to ensure that the Quick Win is linked to their parallel ENABLE TAAT Food Basket Outreach activity. Further, under development is multiplication beds of the Orange Fleshed Sweet Potato (OFSP) intended to produce vines for relay cropping with the maize-bean intercrop later in the season. This practice was first identified as a promising local farmer innovation and will be incorporated as a next step in toolkit development. This example demonstrates the importance of cross-cutting approaches as orchestrated through the TAAT Clearinghouse that involves several Compacts and relies heavily upon commercial interests, and many similar efforts are expected to be designed in the future. This approach is the topic of Clearinghouse Technical Report 002.

Documenting the Formation and Success of Technology Toolkits

The monitoring and evaluation of toolkits presents both an opportunity and challenge. It is an opportunity in that the toolkits themselves embody the very rationale for TAAT and their organization and application is the substance of modernizing agriculture. But documenting these toolkits presents a challenge in that they must be fluidly adapted to site-specific conditions and buy-ins by both the private sector and national programs, and require investment by their intended beneficiaries. In one sense the toolkits do not exist as a single entity, but rather as the range of input products on offer from last mile agrodealers. The capacities and willingness of local extension campaigns to promote these products, customer demand, and fair pricing by stockists are all important but complicated factors. These toolkits must be further adjusted for use within mixed farming systems that combine crop enterprises spanning several Compacts. Ultimately the toolkits must be combined into a widely distributed portfolio, adopted within national programs and incorporated into AfDB Feed Africa loans. This process is presented in Figure 4.

While the process of monitoring individual toolkit performance remains the responsibility of TAAT's Value Chain Compact teams that formulate and adapt them, the task of evaluating them as a holistic process falls upon the TAAT Clearinghouse. Toolkits evolve from their basic formulations at the Compact level, differentiate across site-specific conditions, consolidate as the are combined to suit the needs

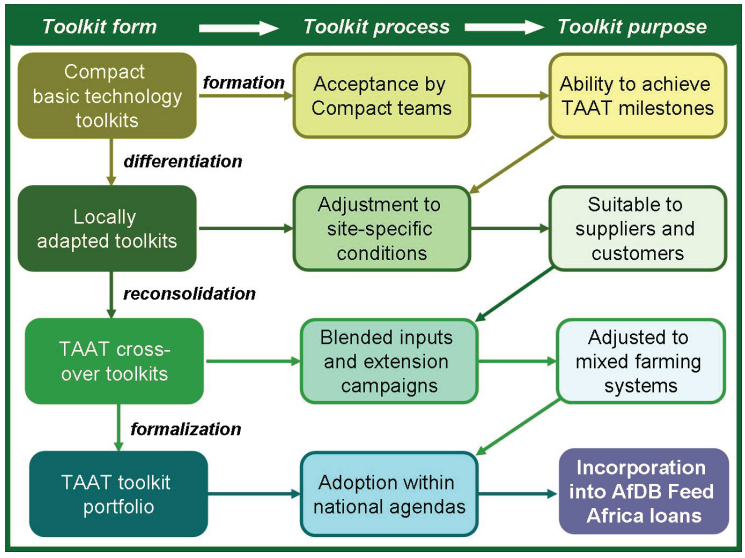

Figure 4. Toolkit formulation, adaptation and purposing.

of farming communities, and become formalized as they are promoted and advanced within country programs and development agendas (Figure 4). This report describes the "basic Technology Toolkits" appearing in the upper left of Figure 4 and later reports will document their further evolution. The Clearinghouse evaluation process tracks toolkits as they are adapted and deployed across countries in a way that allows for lessons to be learned and distributed across agro-ecological zones, levels of agricultural intensification and socio-economic setting. It provides guidelines to the individual Compacts to ensure commonality of monitoring tools through the development of a Performance Monitoring Plan, with the four evolutionary toolkit steps (Figure 4) serving as important milestones. This plan includes clear indicators of process and purpose, participatory methods, and standardized data collection. Similarly, TAAT Enablers receive performance monitoring tools that clearly identify which toolkits they reinforce, and in what ways, so that the strengths and gaps in their backstopping expertise may be identified. The toolkit approach itself greatly facilitates documenting TAAT's progress as a whole because it captures the availability of proven technologies and their successful deployment in terms of their relationship to TAAT's Regional Technology Development Infrastructure.

Conclusion: Technology Toolkits as Unifying and Ongoing Processes

Toolkits and their widespread adoption provide the basis for transforming African agriculture through TAAT. The central feature of these toolkits is the assemblage of input products and equipment needed to modernize African agriculture and the commercial linkages that ensure their availability and cost effectiveness to farmers. Toolkits also must consider the farm management innovations that allow for adoption of these products. Toolkits cannot be mobilized without the formation of multi-stakeholder teams that deploy, promote and adapt them to site-specific farming and input delivery conditions. Clearly, distinction must be made between the "generic" toolkits developed by Compact leaders, and the further refined toolkits intended for site-specific intervention through multi-stakeholder partnership. This report focuses upon the former, but with mention of an adaptive response to modernized maize-bean production in west Kenya. Finally, wider advocacy campaigns are needed that raise awareness of these transformational technologies and build larger commitments toward them, TAAT's so-called Enabling Environment, but this has not been considered within this report.

To a large extent, these toolkits form the bridging mechanism between TAAT Program operations and the agricultural development agendas of other organization, particularly the recently-established African Development Bank Feed Africa loan program. They also shape the collaboration with the private sector as input manufacturers, distributors, and agro-industrial food processors. They provide the substance for partnering agricultural extension activities at national levels, and their promotion offers direct incentives to farmer organizations and commodity producers to work with the individual Value Chain Compacts at local levels. In this way, these toolkits span all aspects of the TAAT Program as their composition and advocacy require an Enabling Environment, their widespread mobilization relates to Regional Technology Delivery Infrastructure, and their refinement and local adoption are the main goal of Commodity Technology Delivery.

But this approach is not without challenges and shortcomings. The toolkit concept was included late in TAAT conceptualization process and has not been fully understood and embraced by some Value Chain Compact teams. Two tendencies run contrary to the fullest development of TAATs toolkits; "ivory tower perspective" and "silver bullet approaches". The former is exhibited by partnership cliques that fail to recognize the important contributions of alternative technologies that were developed by "outsiders" and are beyond their immediate control. This shortcoming results in less potent toolkits advanced within more confined networks formed prior to the establishment of TAAT itself. The latter "silver bullet approaches" result when Compact activities

focus primarily upon a single emergent technology rather than including the accompanying technologies necessary to realize their larger objectives. This case appears for example when campaigns advancing improved crop varieties are conducted that do not include the fertilizer, weed control and pest management technologies ensuring their success. It also results in skewed alliance to NARES and the private sector where national seed programs and seed companies are viewed as more important than the agrodealer networks that serve as "last mile" suppliers of balanced input products composing the toolkits themselves. In fairness, TAAT is a new approach, its Compact leaders were encouraged to quickly assemble their technical and institutional resources, and standard guidelines were not issued on how they could best proceed with toolkit design. The consequences of this pragmatic strategy require immediate attention of TAAT's Monitoring and Evaluation team and corrective interpretation by TAAT's leaders and sponsors.

The Clearinghouse is held responsible for assembling these toolkits into portfolios for wider incorporation into agricultural development agendas. These portfolios are intended for all TAAT partners so that our technologies may be more readily understood and accessed, and to become incorporated into Africa's wider rural development agenda. Not included in detail within this report are TAAT Enablers and their Compacts that provide backstopping specialist services to the Commodity Value Chain Compacts. These Enablers include Capacity Development, Youth Empowerment, Policy Support, Water Management and Input Mobilization. Enablers are not intended to produce their own toolkits, but rather to contribute to the formation, implementation and promotion of those of their commodity counterparts. An exception to this directive is the Fall Army Worm Emergency Response that is closely related to the Maize Compact, and has developed its own Rapid Response toolkit presented earlier in this report. Technology Toolkits represent the unifying embodiment of TAAT as their strategic formulation and widespread adoption at site-specific levels propels agricultural transformation. Ultimately these tested country-level toolkits are intended for incorporation into much larger Feed Africa loan projects to Regional Member Countries under development by the African Development Bank, so it is important that they be advanced in an understandable, business-like, timely and adoptable manner!

Acknowledgement

Concepts presented within this review were developed by Welissa Mulei, Dr. Paul L. Woomer and Rachael Zozo. Toolkit compositions were devised based upon submitted TAAT Compact applications reviewed by the TAAT Clearinghouse and its contracted external reviewers, and approved by the TAAT Program Steering Committee. Photo galleries were developed from numerous sources including internet sites, presentations and publications of TAAT Compact leaders and their partners. This report also appears as Investment Output 2.1.1 submitted by the TAAT Clearinghouse to the Bill and Melinda Gates Foundation in partial fulfillment toward the project "Support to TAAT Clearinghouse Governance" (Opportunity ID: OPP1179223). We gratefully acknowledge the support of the Bill and Melinda Gates Foundation, African Development Bank and the TAAT Program Management Unit toward the preparation of this review.

Technologies for African Agricultural Transformation (TAAT) and its Clearinghouse Office

The developmental objective of TAAT is to rapidly expand access of smallholder farmers to high yielding agricultural technologies that improve their food production, assure food security and raise rural incomes. This goal is achieved by delivering regional public goods for rapidly scaling up agricultural technologies across similar agro-ecological zones. This result is achieved through three principal mechanisms; 1) creating an enabling environment for technology adoption by farmers, 2) facilitating effective delivery of these technologies to farmers through a structured Regional Technology Delivery Infrastructure and 3) raising agricultural production and productivity through strategic interventions that include improved crop varieties and animal breeds, accompanying good management practices and vigorous farmer outreach campaigns at the Regional Member Country (RMC) level. The important roles of sound policies, empowering women and youth, strengthening extension systems and engaging with the private sector is implicit within this strategy. The Clearinghouse is the body within TAAT that decides which technologies should be disseminated. Moreover, it is tasked with the responsibility to guide the deployment of proven agricultural technologies to scale in a commercially sustainable fashion through the establishment of partnerships that provide access to expertise required to design, implement, and monitor the progress of technology dissemination campaigns. In this way, the Clearinghouse is essentially an agricultural transformation incubation platform, aimed at facilitating partnerships and strengthening national agricultural development programs to reach millions of farmers with appropriate agricultural technologies.

Dr. Mpoko Bokanga, Head of the TAAT Clearinghouse

Back cover photographic credit: TAAT's bean toolkit contains several new biofortified crop varieties (upper left) including climbers (top center); application of legume inoculants (upper right) and seed dressing; specially blended fertilizers (lower left); and hermetic grain storage (lower right). Special attention is paid to modernizing traditional bean intercropping systems (bottom center).

TAAT Technology Toolkits and their Strategic Deployment

In collaboration with

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