Crops and Cropping Systems

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Crops and cropping systems landscape

Food production systems need to respond to a wide range of challenges. They include a fast-growing global population, changing diets, greater urbanization, rising obesity and malnutrition. At the same time, climate change is adding to the already heavy burden on natural resources.

Future land-use changes depend greatly on agricultural yields, composition of crops, dietary choices and changes in technologies and crop management. The FAO baseline scenario predicts that by 2050 there will be approximately 0.18 hectares of arable land available for food production for each person on the planet, down from the current 0.242 hectares. Without the ability to use more land, farmers will need yield increases. These will have to come from genetic improvement and/or increased use of agricultural inputs (fertilizer, water, and pest/weed management). [1, 2, 3]

CROPS

Grains are the largest source of energy in almost all diets worldwide. High intake of whole grains and fibre from grain sources has been associated with reduced risk of coronary heart disease, type 2 diabetes, and overall mortality. The global demand for wheat, maize, rice and soybean will exceed supply if trends continue towards diets that are high in animal-source foods.

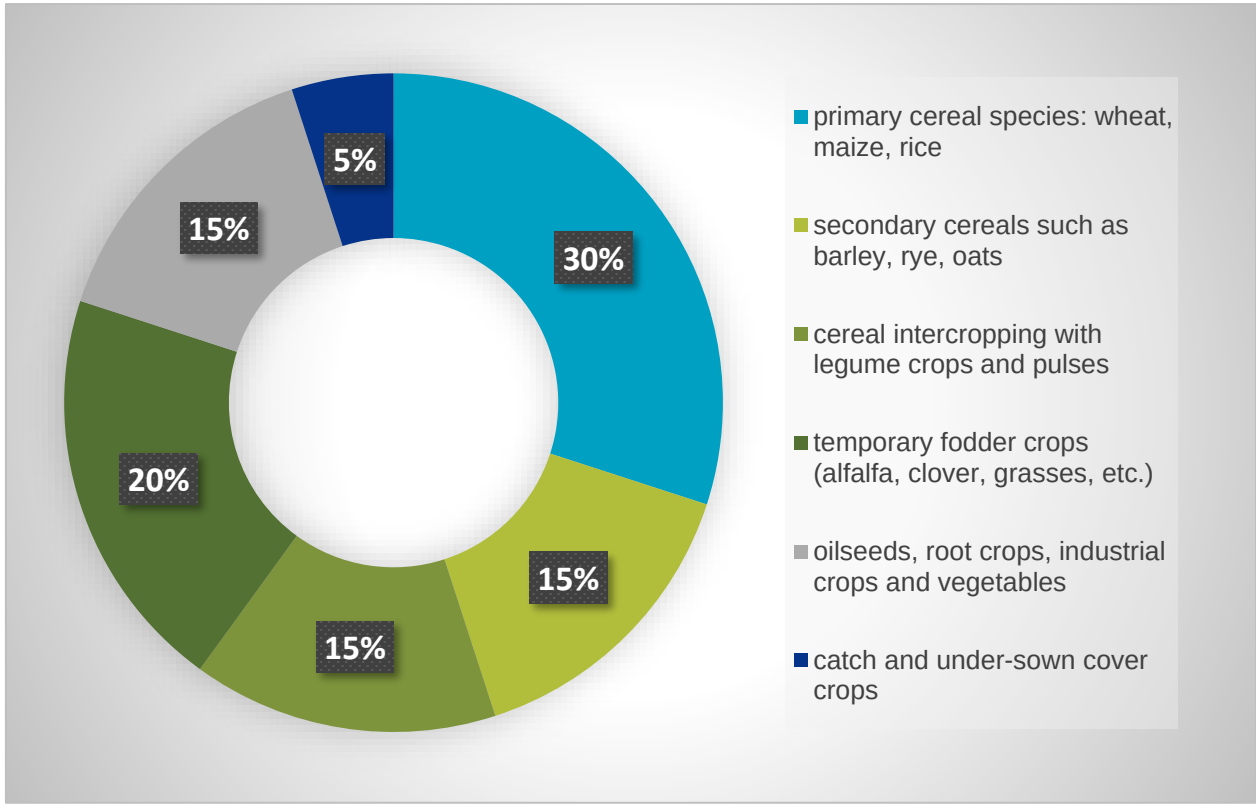
Potatoes provide large concentrations of potassium and other essential vitamins, as well as a rapidly absorbed source of calories. Cassava is grown for its resilience in semi-arid conditions and is processed into storable flour in many countries.

Fruits and vegetables are an essential source of many micronutrients, including provitamin A for prevention of night blindness. Substantial evidence indicates that fruit and vegetable consumption is also important for prevention of cardiovascular disease.

Palm and soybean oil are the most widely consumed oils globally. Compared with soybean oil, palm oil is low in polyunsaturated fat and high in saturated fat; it is widely consumed in many low-income and middle-income countries.

ROTATIONS

Cropland-use activities are largely driven by crop rotations in addition to market forces, availability of inputs, food security needs and extension advice. The choice of rotations depends on many factors, such as how well the crops fit into the agroecosystem and the environmental and economic consequences of the choices made. Crop rotations have been dramatically simplified over the past 50 years due to the advent of synthetic fertilizers and pesticides, and to the increased disconnection between crop and livestock production. When considering crop improvement, it is important to consider the most appropriate rotation crop combinations and the percentage of rotation length[5]:



CLIMATIC REGIONS

South Asia (SA)

Rising temperatures, erratic monsoon rainfall, flooding and sea-level rise are the top climate risks across this densely populated region. The major breadbasket of the Indo-Gangetic Plains faces huge challenges of water management and land degradation.

South-East Asia & the Pacific (SEA)

Key climate risks in Southeast Asia are flooding, sea level rise and salinization. Coastal areas and major deltas – such as the Mekong and the Irrawaddy – are particularly at risk, as they house large populations alongside vast areas of rich floodplain crop production, plus the mangroves that protect coastlines and provide breeding grounds for fisheries.

Central & West Asia & North Africa (CWANA)

This is the world's most water-stressed region, with annual average rainfall between 100 - 400 mm. Climatic risks to water are the main constraint to agriculture-led development, in both the highlands and in major deltas such as the Nile.

West & Central Africa (WCA)

Rainfall variability is the single biggest climate change threat in West and Central Africa. More frequent and severe droughts across the Sahel, including deadly dry spells within growing seasons, are driving changes in livelihoods, for example into livestock, or migration to urban areas.

East & Southern Africa (ESA)

Agriculture has great potential as a driver of economic growth but is held back by sensitivity to uncertain climates. The region faces a geographical patchwork of climate challenges, most commonly shorter and more unreliable growing seasons, particularly in the more arid south.

NUTRITION, HEALTH, FOOD SECURITY

Out of more than 14,000 edible plant species, humans use only 150-200. Just three (rice, maize and wheat) contribute 60% of the calories consumed by humans. Many underused plant species have excellent nutritional profiles, as well as traits of interest for adapting food production to climate change (for example the grains quinoa, millet, sorghum and tef).

To achieve healthy eating for nearly ten billion people by 2050 will require a diet rich in plant-based foods and with fewer animal-source foods. There is evidence that such a diet confers both health and environmental benefits. A shift to this diet results in small reductions in cropland use of 0-2%. Reductions in use for feed crops are compensated by large increases for legumes and nuts, which are relatively low-yielding. The table below shows the global shifts in production required to achieve a sustainable diet in 2050[1], which will vary according to geography and cropping/livestock systems.

This challenge can only be met by production system analysis and engagement at all levels, including policy choices, emerging risks, demographic change, climate change and other factors. Two aspects will be vital. One is the custodianship, breeding and distribution of a wide variety of crops and their wild relatives; the other is breeding for nutrition-rich cereal staples, legumes, roots, tubers and bananas, alongside crop biofortification.

2050 SUSTAINABLE DIET		CURRENT CONSUMPTION AS A % OF TARGET		SUSTAINABLE DEVELOPMENT GOALS
Whole grains	232g	Grains	120%	➔ 50-100% improvement in grains and roots and soybeans
Potatoes and cassava	50g	Starchy Vegetables	100%	➔ 100-200% increase in fruits and vegetables, legumes, and oil crops
Fruits	200g	Legumes	40%	➔ Halving of meat and animal product consumption
Vegetables	300g	Fruit	50%	➔ Doubling of fish and seafood consumption to replace the land animal products
		Vegetables	50%	
		Meat and dairy	200%	

MARKET DEVELOPMENT AND POVERTY REDUCTION

The adoption of new crop varieties has contributed to lifting hundreds of millions of rural people from poverty. It has improved livelihoods and jobs; through improved farmgate prices and access to new markets, the varieties have brought higher and more stable farmer incomes. Research into policy that facilitates access to improved crop resources, knowledge, finance, markets and crop insurance can help lift more people out of poverty.

For market systems to work more inclusively requires improved infrastructure, farmer skills and capability-building in organizations working with farmers. Seed companies need access to distribution models to reach the most remote farmers, along with support to those farmers to change their behaviour in terms of crop choices and agricultural practices.

Women, on average, comprise 43% of the agricultural labour force in low-income and middle-income countries. More than 85% of the world's 1.2 billion youth live in such countries; many of them face limited opportunities for employment or entrepreneurship. Research is required into supplying improved crop varieties that are affordable, accessible and address 'gender' needs (e.g. storage or cooking time, taste and labour intensity). Crops that are of interest to youth and that fit well with youth entrepreneurship should be developed and promoted. These include crops with specific market preferences, high-value crops with short production cycles, and improved input and output traits for good return on investment. Socio-political barriers to adoption of and benefits from crop innovations among women and youth should be explored.

CLIMATE-SMART RESILIENT AGRICULTURE

More information is available in the accompanying Syngenta Foundation paper on Climate-Smart Resilient Agriculture (CSRA).

Climate change poses major risks for agriculture and food production through high temperatures, erratic rainfall, drought, flooding and rising sea levels. Agriculture and food systems produce almost a third of global greenhouse gas emissions, yet agriculture could be a global carbon sink. Of the agricultural greenhouse gases, methane is produced during digestion by ruminant livestock, such as cows and sheep, or during anaerobic decomposition of organic material in flooded rice paddies. Nitrous oxide mainly arises from soil microbes in croplands and pastures and is affected by soil fertility management, such as fertiliser application. Carbon dioxide is released by agricultural land from tillage of soils and during burning to clear land of plants, soil, organic matter and agricultural residues, and from burning fossil fuels in farm machinery, production of fertilisers and transport of agricultural products. Carbon dioxide is also released when converting natural ecosystems, especially forests, to agriculture. Biological processes that produce emissions are intrinsic to crop and livestock production; some greenhouse gases will always be generated by biological processes associated with agriculture.

About 51% of the global land surface can be classified as intact ecosystems with a biodiversity intactness index greater than 9010. Of the other 49% land surface, half is crop and half is grazing land. Habitat loss and fragmentation, particularly through human appropriation of land for food production, is the greatest driver of biodiversity loss. The most threatened biomes are those with greatest agricultural value, including grassland, dry tropical forest and temperate forest biomes.

Crop science can make a substantial contribution to improving food production, climate adaptation and greenhouse gas reduction and thus to keeping the carbon footprint of cropland use and agricultural biodiversity within the boundaries of a sustainable food system. Innovations in plant breeding and production practices should include[6, 7, 8]:

- ➔ **Closing** of yield gaps to about 75% of potential
- ➔ **Developi**ng crops adapted to crop rotations, for example cereals/legumes or rice/potato to improve productivity and preserve soil health
- ➔ **Developing crops that are adapted to a changing climate**, e.g. drought-tolerant maize and heat-tolerant beans, breeding to reduce environmental footprint
- ➔ **Improving water and fertilizer use efficiency** through breeding and crop management
- ➔ **Introducing crop traits** that lessen the need for applied crop protection, e.g. fungal resistance and insect tolerance
- ➔ **Trees that are suitable** for local reforestation and plants that can support the regeneration of degraded pastures and rangelands
- ➔ **Maintenance of existing cropland** and restoration of remaining rangelands, wetlands and pasturelands to preserve biodiversity and avoid further carbon losses.

SYSTEMS TRANSFORMATION

It is possible to feed a global population of nearly ten billion people a healthy diet within food production boundaries by 2050. However, meeting this systemic challenge will only be possible through widespread, multisector, multilevel action. This must include a substantial global shift towards healthy dietary patterns, large reductions in food loss and waste, and major improvements in food production practices.

Systems change will require partnerships between governments, the private sector and civil society. Inclusive partnerships are needed at all levels, from local to global. They should include interdisciplinary research, market strengthening and conducive policy development9.

Agricultural biotechnology policies for smallholder farmers in developing countries vary widely. They do so despite the millions of hectares of GM crops grown and registered as a result of internationally recognised risk assessments. Unconducive policies result in high development and regulatory costs, as well as trade risks resulting from adventitious presence. Policies and stewardship mechanisms need to be developed both nationally and internationally to address where biotechnology (both GM and gene editing) can contribute most to nutritional and environmental goals. Biotechnology and the development of Genetically Modified Organisms along with conventional breeding, molecular and genomic assisted crop/livestock improvement may be vital tools that will assist in meeting the critical goal of sustainable global food security.

Orienting local agricultural policies around imports and exports can displace national production. This compromises the ability of smallholders and farm labourers in low-income and middle-income countries to produce for local and national markets. The result is hardship for food-insecure populations. Trade policy must consider factors affecting food security and support it in the best possible way.

International and national scientific research is essential to change the global food system. The demand for new crop varieties is continuous and expanding. The scientific challenge, for both public and private sector research, is to improve breeding product lines and varietal replacement rates. These must respond rapidly to emerging needs, which are often specific to particular 3geographies and markets. The scaling-out of new varieties through innovative public-private partnerships should be accelerated. Intellectual property policies that support targeted private sector investment should be widened to help scale up innovations and provide better choice to more farmers.

Selecting investments in crops and cropping systems

PARTNERSHIPS & COLLABORATION

SFSA is primarily an implementing and investing foundation. It seeks to catalyse system-level change that benefits pre-commercial smallholders. To do this, we believe it best to operate through multi-stakeholder partnerships. SFSA's grant-making activities are limited; they focus on activities closely aligned with our strategic goals. We seek co-investments and contributions from a wide range of organisations. These include the CGIAR, private foundations, governments, development banks, financial institutions, impact Investors and other strategic partners from both the public and private sectors. Together, we aim for smallholder-appropriate innovation, business and service delivery models and commercial viability to achieve scale.

Public-private partnerships (PPPs) have the potential to accelerate the delivery of outputs from agricultural research and development. SFSA also wishes to encourage new PPPs that can create unique outcomes unachievable by individual parties alone. As we select investments in crops and cropping systems in our countries of focus, we must identify and nurture relationships with key strategic partners across the entire agricultural value chain. These include private companies, research organisations such as NARS, the CGIAR and academia, NGOs focused on seed systems development such as AGRA, as well as funders such as USAID, SDC and the Bill & Melinda Gates Foundation.

The focus must be on bringing the public and private sectors into partnerships that benefit not only smallholders, but also consumers and the environment. Public and private sector interests vary across regions. They depend, for example, on the degree of local seed market development. SFSA investments allow us to work in areas of market or institutional failure. We can respond to requests for assistance from the public sector and encourage the private sector to invest in new markets and more marginalized crops.

The figure below shows selected 'pre-commercial' seed markets that still have low or only moderate interest from the private sector. Novel partnerships and technologies can be used here to develop successful seed system models and address distribution questions. This area represents the bulk of our Seeds sub-portfolio investments in product life cycle stages (PLCs) 1-6. (See figure in the section below on SFSA's unique selling proposition). SFSA also wants to bring crops that we consider have potential into the pre-commercial market area. Through facilitating commercialization, these and the more commercial crops can then move into the top portion of the diagram, where private sector investments eventually take over (PLCs 7-10).

SFSA's role is both to innovate and facilitate the deployment of improved crop varieties to smallholder farmers. Where opportunities exist to create improved varieties by combining the strengths of the public and private sectors, SFSA plays a catalytic role in bringing the partners together and kicking off the collaboration. For example, drought-tolerant genetics from the CIMMYT maize breeding programme in Africa and elite, locally adapted maize genetics from the private sector (Syngenta) in Asia were combined to produce tropical 'AAA' maize. Local companies produce and sell the resilient, productive and affordable three-way hybrid. AAA maize has been well-received by smallholders (mainly women) in four dry states in India; it is now being deployed to other Asian countries. The collaboration has increased investments by both partners in a pipeline of products that neither could have produced alone. It has also increased their capacity to benefit from future partnerships. AAA maize royalty models and agreement templates are already being used in other PPPs.

Another PPP example is the tropically adapted potato breeding programme TAP-5. This is pioneering the combination of resilience and productivity traits from public and private sector leaders in potato breeding. The aim is to develop improved processing and table varieties for tropical regions. Combining the partners' skills and know-how, including ours, has drastically reduced the cost of development and time to market. SFSA's initial investment has catalysed increasing contributions from each sector; the longer-term partnership will ultimately be self-sustaining.

The world's largest public-private breeding initiative, the International Wheat Yield Partnership, is built on R&D investments of more than $70m. It also benefits from SFSA investment in its management and organisation, helping define the ownership and deployment of the products that will emerge. The partnership models and engagement approaches are a result of our experience in earlier PPPs. Ultimately this partnership, and the assets it produces, will be self-funded through increasing investment by both the public and private sectors.

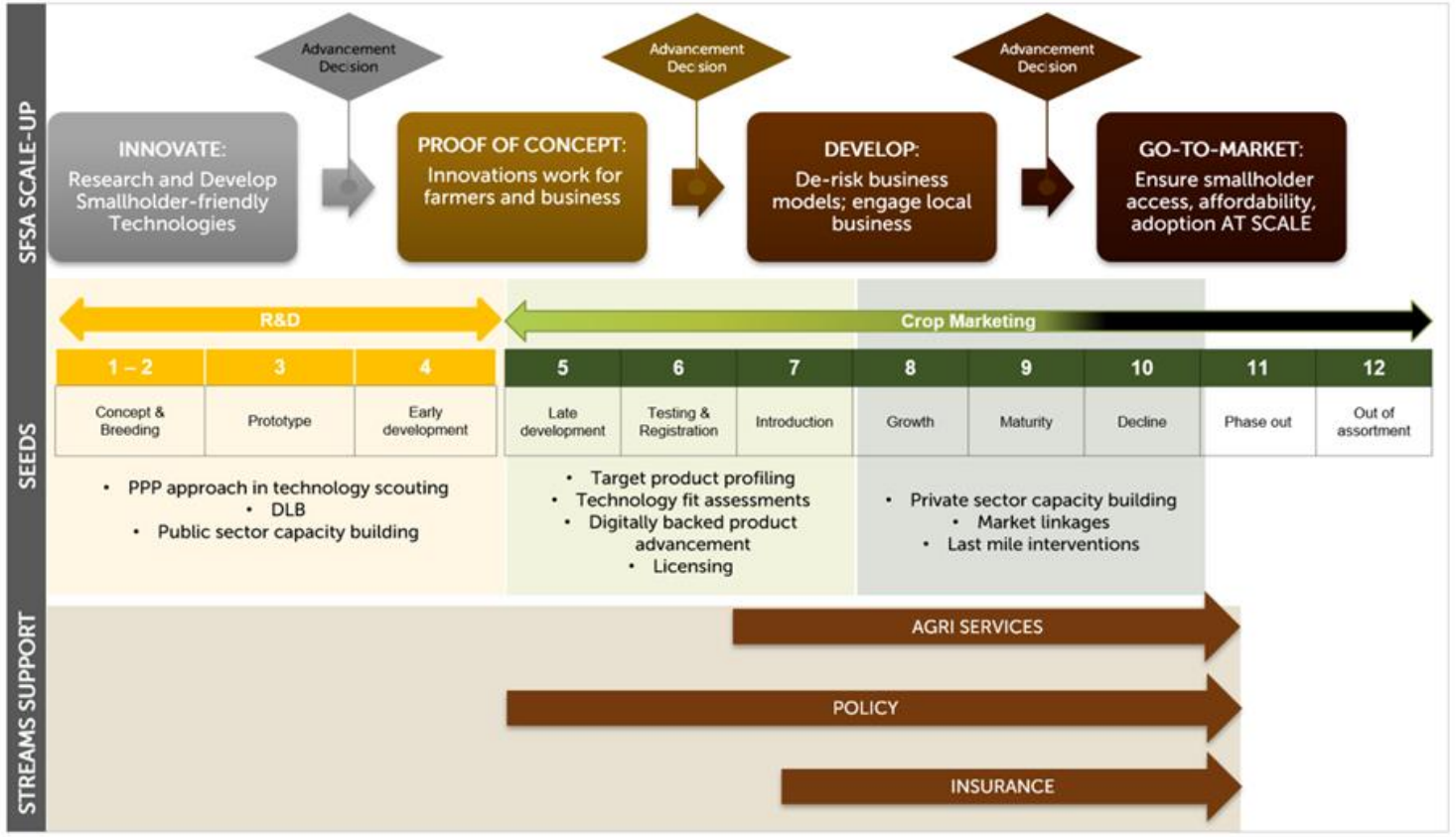
When good germplasm already exists but is not available to smallholders, SFSA uses knowhow and assets developed over the last ten years to catalyse product deployment. Our Seeds2B technology transfer approach has enabled partnerships in over 20 countries. Public-to-private and private-to-private partnerships link demand to supply for key crops where farmers have limited or no choice. For example, Seeds2B has delivered improved soybean varieties from breeding programmes around the world into smallholder markets. It has linked the USAID Innovation Labs and others to local partners and helped manage the process of registration and local seed production to kickstart new markets. Seeds2B Africa is managing the deployment of improved varieties of more than 15 crops in ten countries. It does so through trialling, registration and partnership-building between international research organisations like the CGIAR, national partners such as the NARS, and the private sector. We regard the Seeds2B Handbook as a gold standard for managing the process of technology transfer in development agriculture. International and national partners are increasingly using it to deploy improved seed to smallholders.

There is still progress to be made in breeding crop varieties that have little investment from the private sector. SFSA builds capacity in the public sector to improve the success rate of its variety development and deployment. The assets and approaches developed internally are core to programmes such as Demand-Led Breeding. This initiative helps African NARS identify future market needs, in order to guide their breeding activities and increase the likelihood of successful scale-up.

SFSA'S UNIQUE 'SELLING' PROPOSITION

What are the underlying core principles? SFSA's role is to act as a bridge between the public and private sectors, to build capacity in each sector so that it can function better for smallholder farming. SFSA is a trusted intermediary and a catalyst for investment. The principles of demand-led and market-based solutions are combined with environmental and societal development goals to produce sustainable change.

Which models and tools do we use? SFSA's scaling-up model helps guide our approach to crops' innovation and deployment into cropping systems. The figure below shows where our seeds work sits in relation to SFSA's innovation-to-scale approach. It outlines the uniqueness we bring across the entire development pipeline and how the other SFSA streams of activity help support this.



What is our role in each step? Research partnerships in public (National Breeding Programs and CGIAR) and private sector breeding align resources and capabilities behind bringing new products to market. The Seeds2B sub-portfolio rigorously tests and selects the best technologies to develop and bring to market at scale by using a product life cycle (PLC) approach. This enables seamless transfer of varieties from research to commercialization. Our role at each stage depends very much on the need and opportunity. The 'stage-gate' approach determines whether we should play a role at the next stage. We believe this will help us better tackle the specific challenges faced by seed systems in providing smallholders with the choice, access and affordability of new and improved technologies for the crops they need.

What is the scaling/Go-to-market methodology? Achieving impact at scale depends on the successful integration of new technologies into the value chain that are self-sustaining and profitable to the technology provider and to the user. While selecting investments in crops, it is important that we use our strengths across all our sub-portfolios within each country and cropping system we select. The Seeds sub-portfolio uses its links to local seed producers to build profitable markets for the seed of new varieties. Agriservices colleagues deliver farming knowledge and services, including access to inputs, mechanization, markets and finance. They also gather market demand information to guide future crop investments. The Insurance team helps farmers mitigate risk and increase investment in new technologies. Improved varieties that reduce biotic and abiotic risks (e.g. through resistance to drought and disease) can help reduce the cost of insurance, thereby making it more affordable for smallholders.

HOW TO IDENTIFY KEY INTERVENTIONS IN CROPS AND CROPPING SYSTEMS

What is the process? SFSA proposes to follow a criteria-based approach in 2021/22 to help guide its decisions on what crops and cropping systems to invest in and clarify the SFSA position on crops and cropping systems. This will entail an assessment of the crops, value chain and each country's macro-economic environment, as outlined below. To guide the decision-making process, each criterion is scored based on priority. Each of the three pillars is critical in the decision framework. Crop assessment will guide our approach for the varieties we need to advance to commercialization. The value chain analysis will help us better understand the key linkages necessary to bring varieties from research to smallholders. The macro-economic view will provide a broader picture of factors in each country that could affect the agricultural sector.

This approach allows SFSA to position itself as a major player in strengthening farming and food systems in smallholder-driven markets. It also allows us to partner with key stakeholders along the value chain to bring tangible solutions to the challenges faced by smallholders in Africa and Asia.

Crops

- that are in limited supply and of high value that can change smallholders' lives and livelihoods
- with high local and regional market demand that are under-resourced to catalyze emerging markets
- with potential for supporting climate change mitigation initiatives, including use-efficiency and adaption improvements
- with inherent remuneration systems that can stimulate greater investment and interest by entrepreneurs and the private sector
- that can address wider gender and market needs in farming, for example in storage, cooking time, taste and labour intensity
- able to meet the yield improvements needed for a sustainable healthy diet
- that support national nutritional goals
- of interest to youth and boost youth entrepreneurship
- that fit into sustainable rotations to support soil health initiatives
- that provide under-supplied alternatives to meat protein, with associated reductions in greenhouse gases

Value Chain

- Local National Breeding Program (NBP) degree of development and capability to bring the best varieties into smallholders' hands
- Potential to accelerate scaling out of new varieties through local private sector partners. Development of a viable business model
- Conducive intellectual property rights that can support targeted private sector investments to scale innovations
- Degree of crop diversification and viable crop rotation potential
- Availability and breadth of relevant farmer advisory services
- Market linkages and post-harvest management practices
- Degree to which crop management practices can be improved
- Availability and breadth of farmer financial support, including credit and insurance facilities

Macro-Economics

- Percentage of the population and households involved in smallholder agriculture
- GDP per capita and agriculture‘s contribution to GDP
- Country poverty index
- Food-feed-fuel consumption balance per capita
- Commodity prices and trends for local production vs importation
- Climate change vulnerability index
- Current status of food security, government advocacy and policy support

Decision Framework in order of priority (top being highest)

What is our plan? Over 2021 and 2022, we plan an ambitious review of our interventions in facilitating smallholders' access to seeds of improved varieties. The plan is as follows:

AFRICA ASIA	AFRICA	ASIA AFRICA	AFRICA	AFRICA ASIA
2021	2021 + 2022	2021	2021	2021
Country deep-dive assessments of crops, value chain and the macro-economic environment, and of investments and markets for specific crops. The assessment will be for both existing and new crops in current SFSA countries of focus.	Transitioning the PASTTA program to Seeds2B Africa. Laying the foundation for Seeds2B Africa to become a catalytic intermediary, as a mid-term mechanism for variety commercialization and delivery of new varieties to smallholders at scale through seed companies and markets.	Rollout of variety commercialization guideline/handbook.	Resource mobilization for an Eastern Africa GDA co-developed with CIP for support from USAID on potato value chain interventions. This will help scale up the work being done under the PASTTA program on the potato value chain.	Seeds2B engagement in the One CGIAR efforts to modernize seeds delivery across all crops globally

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