The Future of Farming

Farmers Out of Poverty

A Preliminary Study

February 2018

Contents

How to Use the Report

This paper is organized according to XPRIZE's ImpactMap development process: Insight, Foresight, Action:

- Insight: hi-fidelity research is conducted, aimed at establishing a baseline, that is, a description of the current state of affairs in a given field (or fields). Establishing this baseline is crucial to identifying gaps, which potential XPRIZEs could solve.
- Foresight: forecasting techniques are employed to determine the baseline scenario (extrapolating the current state into the future), and a preferred future, which will require a series of XPRIZEs in order to be achieved.
- Action: ideation techniques are used in order to identify potential breakthroughs, which could later become XPRIZEs.

Background

Increasing agricultural productivity is a critical first step to reduce poverty and hunger across much of the developing world, and feeding the planet's rapidly expanding population, and yet untapped agricultural potential continues to contribute to persistent poverty and hunger across much of the developing world.

The overwhelming majority of poor people surviving on less than $2 a day in Sub-Saharan Africa and South Asia are smallholder farmers working small plots of land about the size of a football field. These farmers, many of whom are women, often lack basic tools, technologies, infrastructure, financing and know-how, and are powerless against extreme conditions including drought, pests and disease. Reliable,

tailored agriculture advice and localized market and pricing data are hard to come by, and government policies often fall short of meeting smallholder farmers' needs.

The end result is poor farmers getting a fraction of the yields that their counterparts in more developed countries get, and potentially productive, fertile communities relying on costly food imports and food assistance to feed their citizens. This ongoing struggle for smallholder farmers and their families to grow enough food keeps them poor and hungry, at risk of malnutrition and other hunger-related diseases, and impedes the economic growth of developing countries at large.

Smallholder farmer production is uniquely susceptible to a changing climate as farmers often lack access to climate smart technology and innovations, and rising temperatures and unpredictable rainfall will only exacerbate their challenge of low and unreliable yields. It is estimated that climate change could reduce crop production by as much as 10% by 2030 and by 30% by 2080.

When farmers grow more food and earn more income, they are better able to feed their families, send their children to school, provide for their family's health, and invest in their farms. This makes their communities economically stronger and more stable, providing jobs not only in agriculture, but also boosting non-agricultural sector opportunities such as food processing, trade, manufacturing and services. Growth in agriculture drives inclusive growth, generating up to four times greater poverty reduction than growth in other sectors.

Helping farmers improve their yields requires a comprehensive approach that includes: 1) the use of seeds that are more resistant to disease, drought, and flooding; 2) information from trusted local sources about more productive farming techniques and technologies; 3) greater access to markets; and 4) government policies that serve the interests of farming families.

Agricultural development must also address gender disparities and help make food systems more nutritious. In Sub-Saharan Africa and South Asia, women are vital contributors to farm work, but because they have less access to improved seeds, better techniques and technologies, and markets, yields on their plots are up to 30% lower than on plots farmed by men. Addressing this gap can help households become more productive and, according to the United Nations Food and Agriculture Organization (FAO), increase total agricultural output in developing countries by 2.5 to 4%. Improving the quality, accessibility, and affordability of nutritious food produced in developing countries is fundamental to reducing poverty, undernutrition, and creating a healthier, more productive society.

Insight

Trend analysis

Methodological Note

Trend analysis is a method of analysis that allows us to identify the key drivers that will shape the future, how this future will look, and the key areas one needs to change or impact in order to shape a different, more desired future (from a subjective point of view). Another way to describe trend analysis in the context of XPRIZE's studies is environmental scanning - the possession and utilization of information about occasions, patterns, trends, and relationships within an organization's external environment.

Description

The issues that impact the poor are all closely interlinked and call for a comprehensive approach in order to deliver a healthier and more prosperous future. As most of the world's poor live in rural areas, most of the income gains needed to end poverty in the future will need to come from activities in rural areas. In many less developed countries the food system remains, and is likely to remain for some time, a significant source of employment.

Social/Demographic Trends

The demand for food is expected to grow substantially by 2050. A major factor for this increase is world population growth. By 2050, world population will reach almost 10 billion people, which will require farmers to produce 50% to 100% more food than is produced today.

Most of the world's poor live in rural areas. In the next generation, some will migrate to urban areas, but most will not, and the rural population in less developed regions may even increase slightly. Most of the income gains needed to end poverty will therefore need to come from activities in rural areas. In 2010, over 900 million poor people (78% of the poor) lived in rural areas.

Closing the gender gap can improve yield and nutritional outcomes. Women are key players in the agriculture sector, accounting for 43% of the labor force globally and over 50% in some countries in East Asia and Sub-Saharan Africa.

Despite significant progress**, 795 million people still are not getting the minimum dietary energy needs**. The majority of these people are in Sub-Saharan Africa, in which 1 in 4 people are hungry; and in South Asia, in which 1 in 6 people are hungry. More than 2 billion people are deficient in key vitamins and minerals that are necessary for growth, development, and disease prevention. Malnutrition imposes large human, economic, fiscal, and social costs. Malnutrition also leads to maternal and child mortality, child stunting, poor learning capacity, lost productivity and incomes for adults, high health costs, and slower economic growth. It also can perpetuate poverty in affected populations. For the poorest countries, income growth helps reduce the prevalence of calorie deficiency, and in most countries, agricultural growth plays a key role in this income growth.

Technological

Innovative technology is creating new opportunities for income gains, entrepreneurship, and higher skilled jobs in the food system. Technologies that will have the largest impact on agricultural productivity in the next 10 years include innovations in the areas of genetically modified crops, soil and water management, pest control, and post-harvest processing. Ensuring existing and new technologies are

available to poor countries, and poor farmers, can help reduce yield gaps and improve resilience and income generation.

Reduce food loss and waste – Reducing food losses can help reduce income losses for smallholder farmers, and together with lower food waste can increase overall food supply and help preserve food micronutrients. To achieve this, improved technology to provide market information that better targets poorly supplied markets, and which facilitates product differentiation in markets for sale of less-standardized, lower-quality products would be helpful.

Precision Agriculture - Precision agriculture–the use of soil sensors and geolocation technologies for planting, watering, feeding, and harvesting–is associated with large-scale industrial agriculture practices. These practices predominate in wealthier more affluent regions in the Midwestern United States, southern Brazil, and parts of Canada, Germany, and Australia. Less expensive versions of these technologies could greatly improve productivity and output in less developed countries–especially for smallholder farmers.

Aquaculture – Aquaculture can provide an important source of income for poor people. Most of the recent growth in aquaculture has been in developing countries accounting for over 40% of global fish production. Demand for aquaculture–the breeding, rearing, and harvesting of plants and animals in all types of water environments–will continue to grow in order to meet the world's demand for protein. According to a 2006 World Bank report, aquaculture producers will likely see growth rates ranging from 1.4% to 5.3% per year in the next 20 to 30 years. The key technologies required to produce this growth are all widely available today.

Molecular Biology – Advances in this sector could provide a means of making specific changes relatively quickly through over-expression or deletion of genes or the

introduction of foreign genes. With the molecular biology tools now available, plant breeders could potentially achieve grain yields sufficient to meet the world's food needs through 2040. This would greatly benefit smallholder farmers around the world.

Livestock – In addition to raising crop yields, in many areas improved livestock productivity and animal health will be essential to end poverty and raise incomes. Animal agriculture is the only means of livelihood for poor people in many agroecological areas. In mixed crop and livestock systems, livestock help to diversify income sources; they provide draft power, fertilizer fuel, and transportation, as well as act as a store of wealth and savings for poor households.

Economic/Financial

The economies of **less developed countries (LDCs)** have been growing significantly faster than the economies of developed ones, and this trend is likely to continue in the future. However, absolute gaps will likely remain pronounced and could even increase further given the current gaps in absolute per-capita incomes. Moreover, inequalities within countries and regions in LDCs will tend to become more pronounced. This trend means that market demand for food will continue to grow, and feeding the future world population will require raising overall food production. However, production in the developing countries would need to almost double, compared to the developed world.

The demand for meat will likely double between 2000 and 2050. Demand for cereals, for both food and animal feed is projected to reach some 3 billion tons by 2050, up from 2.1 billion tons today. The demand for other food products that are more responsive to higher incomes in less developed countries (e.g., livestock, dairy products, vegetable oils) will grow much faster than that of cereals.

The rural poor derive significant parts of their livelihoods from agriculture and ag-related activities. Rapid increases in productivity will make rural land more valuable. The food sector (in its broader definition) employs the majority of people in less developed countries in both self- and wage-employment, and will continue to do so for the foreseeable future. Self- and wage-employment in farming still generates a large share of rural incomes and can have large poverty-reducing effects. In many countries, the off-farm aspect of the food system accounts for a large share of the economy's manufacturing and services sectors. While the employment share in farming tends to decline as per capita incomes rise, the share of employment in food manufacturing and services tends to increase.

As per capita incomes increase, and eating patterns shift, **the demand for jobs** in these off-farm segments of the food system–including processing, distribution, transportation, storage, retailing, preparation, and restaurants–will increase.

Environmental

While a rapid rise in agricultural production is required to meet growing demand, other important factors - chiefly environmental issues - also come into play. **Climate change** has already begun to affect crop yields and threatens to cause greater damage as the century progresses. Increased incidences of **extreme weather** associated with climate change—such as **drought**, consecutive days of **extreme heat, and flooding**—are issues that might be even harder to solve. And the effects on less developed countries will be even more severe. Climate change is also restricting the means by which production can be ramped up.

Natural resource degradation and depletion needs to be slowed or reversed. Competition for scarce land and water resources in some regions, due to high population densities and growing demand, is increasingly stressing these

resources. Land and water systems, particularly in major Asian food-producing areas are now at risk from intensive agricultural practices that are degrading prime agricultural lands, depleting non-renewable groundwater resources, and degrading aquifers upon which many of the poor depend. The impacts of climate change and the acceleration of the global hydrological cycle—an increase in evapotranspiration and a change in the frequency, intensity, and seasonal patterns of rainfall as global warming continues—place additional pressures on these scarce resources. More efficient and sustainable use of water, particularly groundwater in highly water-stressed regions, is critical.

There are still ample land resources with potential for crop production available. Much of the best land not yet in use is concentrated in a few countries in Latin America and sub-Saharan Africa, but many countries with growing rural populations in these regions are extremely land-scarce. Much of the remaining land is suitable for growing only a few crops, which don't have high market demand. Also, much of the land not yet in use suffers from constraints (chemical, physical, endemic diseases, lack of infrastructure, etc.) which cannot easily be overcome without significant time, funding, or external interventions. Poor rural farmers are not well positioned to transition this land to usable land. Although there are a number of countries (in particular in the Near East/North Africa and South Asia) that have reached or are about to reach the limit of available land for farming, on a global scale, there are still **sufficient land resources available to feed the world's population for the foreseeable future**, provided that the investment required to develop these resources are carried out and the level of agriculture research and development is increased.

Finally, the availability of **fresh water resources** bears resemblance to that of land availability (i.e., globally more than sufficient but very unevenly distributed) **with an**

increasing number of countries or regions reaching alarming levels of water scarcity. Countries facing this issue mirror the countries with few remaining land resources (in the Near East/North Africa and South Asia). In order to circumvent this challenge, approaches that incentivize more efficient water use will need to be deployed.

Political

Effective local and national policies tailored to supporting smallholder farmers can go a long way to improving economic and social outcomes in less developed countries. Reducing transaction costs, improving the structure of markets, and access to information can increase prices farmers receive for their produce (crops, livestock, and fish). It's important to address structural barriers such as movement restrictions and building roads to link smallholder farmers to major road networks; increasing competition in wholesale markets; streamlining or reducing multiple taxes and fees; encouraging private storage and handling; and developing sustainable models of linking market data collection with ICT technology providers to help improve access by poor farmers to market information can go a long way to improving outcomes for smallholder farmers in less developed countries.

Key Factors Impacting Farmers and the Demand for Food					
	Social	**Technological**	**Economic**	**Environmental**	**Political**
Factors impacting the circumstances of smallholder farmers	Most of the world's poor live in rural areas; 75% of the poor in less developed countries live in rural areas	Reduce food loss and waste	economies of less developed countries have been growing significantly faster than the economies of	Climate change, extreme weather, drought, extreme heat, and flooding	Lack of infrastructure, access to markets and information, high transaction costs, high taxes and fees

			developed ones		
	Women are key players in the agriculture sector	Precision Agriculture	the demand for jobs in off-farm segments of the food system will increase	Natural resource degradation and depletion needs to be slowed or reversed	
		Aquaculture			
		improved livestock productivity and animal health			
				There are still ample land resources with potential for crop production available	
Factors impacting the demand for food	The demand for food is expected to grow substantially by 2050	Reduce food loss and waste	economies of less developed countries have been growing significantly faster than the economies of developed ones	Climate change, extreme weather, drought, extreme heat, and flooding	
	795 million people still are not getting the minimum dietary energy needs	Molecular Biology		Natural resource degradation and depletion needs to be slowed or reversed	
				There are still ample land resources with potential for crop production available	
				there are still sufficient land resources available to feed the world's population for the foreseeable future	
				An increasing number of countries or regions reaching	

				alarming levels of water scarcity	

Table 1: Factors impacting farmers and the demand for food

What's In, What's Out

Methodological Note

Determining what the Future of Farmers study entails also means determining what it is not. Therefore, it is important to set boundaries and determine the scope, as they help focus activities and allow for significant creativity within the defined zone of focus.

Areas of Focus

Core:

- Women's empowerment
- Food production – full value chain
- Access to markets
- Access to inputs
- Post-production processing and storage
- Financial services
- Diffusion of technology
- Farming techniques
- Land use
- Climate change
- Natural resources (water, land etc.)

Periphery:

- International trade
- Nutrition
- Food demand
- Energy

- Food-industry-related workforce
- Education
- Health

Who's Doing What? (Benchmark Analysis)

Methodological Note

Benchmarking is a way of discovering the highest level of performance being achieved – whether in a particular company, by a competitor, or by an entirely different industry. This information can then be used to identify gaps in an organization's processes in order to achieve a competitive advantage. However, unlike business-driven benchmark analysis, in the context of XPRIZE prize development, benchmark analysis is aimed at answering the following question: Who (innovators, academics, corporates) is developing solutions to a similar problem? What solutions are they developing? And who is providing funding in this area?

Analysis

Governments, international institutions, non-governmental organizations (NGOs), private companies and universities are all investing significant sums of money to develop innovative solutions focused on reducing poverty in the agriculture sector. Government support, in the form of basic research funding and grants, frequently acts as an important catalyst for innovation in the public and private sector. But impact lenders, foundations, and NGOs are also playing an ever-larger role, especially in efforts to help small farmers increase their productivity. Where these models have been successful, governments and transnational organizations have often stepped in to scale the projects. Several companies and institutions are also forging connections between sustainable agricultural technology providers and policymakers.

Type	Example Organizations	Programs/ Products/ Innovation
Global Organizations/ NGOs/ Academia	**International Research Organizations:** Africa Rice Center (Cotonou, Benin); Bioversity International (Rome, Italy); CIAT–Centro Internacional de Agricultura Tropical (Cali, Colombia); CIFOR–Center for International Forestry Research (Bogor, Indonesia); CIMMYT–Centro Internacional de Mejoramiento de Maiz y Trigo (Mexico City, Mexico); CIP–Centro Internacional de la Papa (Lima, Peru); ICARDA–International Center for Agricultural Research in the Dry Areas (Aleppo, Syrian Arab Republic); ICRIAST–International Crops Research Institute for the Semi-Arid Tropics (Patancheru, India);IFPRI–International Food Policy Research Institute (Washington, DC); IITA–International Institute of Tropical Agriculture (Ibadan, Nigeria);ILRI–International Livestock Research Institute (Nairobi, Kenya); IRRI–International Rice Research Institute (Los Banos, Philippines); IWMI–International Water Management Institute (Colombo, Sri Lanka); World Agroforestry Centre (Nairobi, Kenya); World Fish Center (Penang, Malaysia)	International research organizations are a source of innovative agricultural technology. The most widely known are the 15 international agricultural research centers, supported by the Consultative Group on International Agricultural Research (CGIAR), which carry out research on various agricultural commodities, livestock, fish, water, forests, and policy and management:
	Smart Agriculture Analytics (SAA) - China	SAA has positioned itself as the link between China's agricultural sector and small to mid-sized companies that own best-in-class technologies. Launched in 2012, SAA offers online subscriptions to tailored data feeds that provide subscribers with information. This

		information is collected from Chinese data sources, that SAA translates to English, on potential opportunities for their products as well as policy shifts that often create such opportunities.
	UN - the Food and Agricultural Organization (FAO)	FAO has teamed up with municipalities in several Latin American and African countries on "micro-gardening" projects where low-income residents employ intensive vegetable production techniques on small urban plots.
Governments/ Academia	United States Department of Agriculture (USDA)/Agriculture Research Service (ARS)	The Agricultural Research Service (ARS) of the United States Department of Agriculture (USDA) has a broad research agenda that addresses most technological issues facing agricultural development; over its many decades of existence, it has been the source of innovative technologies. Its research includes over 1000 research projects organized into four research programs: • Nutrition, Food Safety, and Quality • Animal Production and Protection • Natural Resources and Sustainable Agricultural Systems • Crop Production and Protection
	Feed the Future: US Government Global Hunger and Food Security Initiative	The initiative works to give families and communities in some of the world's poorest countries the freedom and opportunity to lift themselves out of destitution. By equipping people with the knowledge and tools to feed themselves, we are addressing the root causes of poverty and hunger, helping people end their reliance on aid, and creating important opportunities for a

		new generation of young people, while building a more stable world. These efforts are: • Generating economic growth and rising incomes • Creating new opportunities for trade in emerging markets • Building opportunities for meaningful work for at-risk communities near their homes • Boosting agricultural productivity • Improving family nutrition, which is essential to mental and physical development and healthy populations • Strengthening agricultural research • Scaling existing, proven technologies to benefit more people • Increasing resilience to prevent recurrent crises and help communities better withstand and bounce back from crises when they do happen
	Chinese Government: Smart agriculture	Under its Soil Pollution Action Plan, the Chinese central government is funding six protection and remediation pilot projects, each receiving ¥ 1-1.5bn RMB (US$160-240mn). It is expected that the government will eventually invest a much larger sum to roll out the most successful **soil remediation policies and technologies.**
	United Kingdom Agency for International Development (UKAID), United States Agency for International Development (USAID), National Aeronautics and Space	**Connecting global knowledge networks to improve policymaking.** The Agricultural Model Intercomparison and Improvement Project (AgMIP) also

	Administration (NASA), Columbia University and others	coordinates global actors in the agricultural value chain, connecting policymakers with the best scientific work on how climate change and policy decisions could affect their agricultural systems.
	USDA and the National Science Foundation (NSF)	Dr. Stephen Moose, a professor of plant genomics at the University of Illinois, has been leading research into **how corn uses nitrogen,** focusing on the genes that control when the plant uses, versus storing, the element.
Private Sector	Metzer Group, Netafim	**Advanced drip-irrigations systems,** vapor transfer irrigation, and hydroponic greenhouse technologies are being developed and employed to enhance the efficiency of water utilization in agriculture.
	International Rice Research Institute (IRRI)	**Drought-tolerant and salt-tolerant plants,** which are being developed by using molecular biology techniques, employ emerging technologies that can reduce the consumption of freshwater sources.
	Yara N-Senso	**Use of Sensors to Adjust Fertilizer Application** - This high-clearance sprayer makes variable-rate nitrogen applications to corn based on sensor readings. The sensors –the white camera-like modules on the outriggers– monitor plant stresses that are frequently related to nitrogen status.
	Trimble	**Use of Global Positioning System (GPS)** - In Missouri, an agricultural engineer examines corn from this combine's grain flow sensor. The combine is linked to the satellite-based GPS, allowing precise yield and location data to be correlated with soil samples taken earlier throughout the field. This information will help growers

		plan best fertilizer rates for the next crop
	Skygreen Singapore, Farmedhere Chicago, Mirai Corp Japan, Aerofarms Newark	**Urban Agriculture + Automated vertical farms** - stacking farms on top of another and using automation, vertical farms can produce 100x more effectively per acre than conventional agricultural techniques.
	Pentair	**Aquaponics** - a unique combination of fish farming (aquaculture) with hydroponics. Fish convert their food into nutrients that plants can absorb, while the plants clean the water for the fish. Compared to conventional farming, this technology uses about half of the water, while increasing the yield of the crops grown. As a bonus, it also can raise a significant amount of fish.
	Trringo	**Smartphone app –** called the Uber for tractors because of how it disrupted India's farm equipment renting process.
	Southern African Confederation of Agricultural Unions (SACAU)	**Piloted a digital aggregation platform** akin to a "virtual cooperative." Farmers use the platform for aggregation, and then leverage the volume to negotiate better prices with suppliers.

Gap Analysis

Methodological Note

Gap analysis involves the comparison of actual performance with potential or desired performance. Simply put, gap analysis addresses three questions:

- "where we are" (the present state); and

- "where we want to be" (the target state)
- what must be addressed to get from today to the target?

The first question is answered through the previous research components, that is, the trend and benchmark analysis. These two components are basically a description of the present state and the elements that will shape the future. The second question is answered through the description of the desired end-state (as was described in the hypothesis section). So, if we know where we are (current state), what the desired state is, and who is working on solving related-challenges, we can also identify what areas are being neglected (and for what reason). These areas (and reasons) are the gaps.

Gap Description

The ability of smallholder farmers to participate in global food systems depends on, in large part, to their access to electricity. **Improved access to electricity** increases efficiency and reduces food loss. Electricity is hardly a new innovation, but there are still many people—almost two-thirds of sub-Saharan Africa, for example—who lack access. Even where energy infrastructure exists, cost can often be a barrier. Access to affordable, reliable and sustainable energy enables smallholders to improve efficiencies in land preparation, planting, irrigation and harvesting. It also allows them to use certain methods for storing, cooling and preserving goods.

Increased internet connectivity to access information and knowledge is essential to improve productivity on smallholder farms. For many of us, the internet is a fundamental part of everyday life. But over 4 billion people—more than 55% of the world's population—remain unconnected to the web. The vast majority of smallholder farmers live in remote areas, where good, fast internet connectivity reaches less than 30% of the population. Women constitute almost half of the agricultural labor force in

developing countries, yet they are less likely to access the internet than men in the same communities. If this "digital divide" were closed, smallholder farmers could access information and knowledge-related to weather, rainfall or market demand, allowing them to grow and harvest food more efficiently. Timing has increasingly become source of competitiveness, and access to real-time information is crucial. To be truly transformational, internet access must be reliable, affordable and secure.

Mobile devices and platforms will need to connect more smallholder farmers to markets. Connectivity is not only about access to information—it is also about access to services. For example, mobile banking can give smallholder farmers access to formal financial services such as banking and loans, which they all too often lack. Look at the example of Trringo: this smartphone app is referred to as the Uber for tractors because of how it has disrupted India's farm equipment renting process. Another example comes from SACAU, who piloted a digital aggregation platform akin to a "virtual cooperative." Farmers can use the mobile platform for aggregation, and then leverage the volume to negotiate better prices with suppliers. This platform, designed by farmers for farmers, also includes a host of other features. This technology is essential. For many smallholder farmers, investing in a mobile phone as an agricultural tool has perhaps become the single most strategic decision.

Limited access of foundational technologies like electricity, the internet, and mobile phones prevent a vast amount of smallholder farmers from **utilizing geospatial analysis**. Geospatial technologies could help individual farmers assess, monitor, and plan the use of their natural resources. In this realm, FAO and Google are partnering to make geospatial tracking and mapping products more accessible. If geospatial technology was easy to download and use, a smallholder in Colombia could discover the distance to the nearest river, or a farmer in Malawi could use sensors to more efficiently manage their farm.

Agricultural productivity improvements will require advances in other fields beyond molecular biology, including chemistry, electrical engineering, remote sensing, and computer science. The tools from these fields are not necessarily developed specifically for agriculture, but their application can make improvements in controlling the management of soil, water, crop, and energy inputs to agriculture. If smallholder farmers could access new technology and tools from these fields that are tailored to their needs they could see profound improvements in the quality and quantity of their production.

Closing the gender gap can improve yield and nutritional outcomes. Women are key players in the agriculture sector, accounting for 43% of the labor force globally and over 50% in some countries in East Asia and Sub-Saharan Africa. But across all regions they own fewer assets (land, livestock, and human capital) and have less access to inputs (seeds, fertilizer, labor, and finance) and services (extension and insurance) than men do. Ensuring that women have the same access to assets, inputs, and services in agriculture as men could increase women's yields on farms by 20-30% and potentially reduce the number of hungry people by 12-17%.

In addition, in many less developed countries, women lack discretionary income earning opportunities and labor-saving technologies. Making education, labor markets, and civil engagement as accessible to women as men is particularly important to improve nutrition of the women themselves and their children. The most relevant aspects of women's empowerment for nutrition are: increasing women's access to and control over resources—primarily incomes; increasing women's decision-making power related to food purchase and preparation; and reducing time and labor constraints.

Women also constitute almost half of the agricultural labor force in developing countries, yet they are less likely to access the internet than men in the same communities. Access to the internet can provide key information on topics related to soil, fertilizer, weather, rainfall, availability of inputs, and market demand. This would allow women to make more informed decisions regarding their farms and enable them to work smarter and more efficiently.

Precision Agriculture - For precision agriculture technologies to diffuse on a wide scale, they will need to be scaled down to work for small plots in the developing world. This will enable the greatest potential productivity gains to be made.

Production Costs - The cost of genetically transformed seeds can be five to seven times higher than conventional seeds. If more smallholder farmers could afford these transformed seeds, they could greatly improve crop yields, which would allow them to adequately feed their families and sell excess production in local markets, thus increasing their income.

Nutrient-rich Crops – Increasing nutrient content has not been a commonly used criterion for plant breeding except in very special cases such as biofortification. The traditional focus of plant breeding research has been on increasing the yield of staple crops—mainly rice, wheat, and maize—and their resistance to pests and diseases, and tolerance to droughts and floods. Breeding needs to be expanded to include a focus on nutrient content to improve access to nutrient-rich foods and to a broader set of crops.

Biofortified Crops – Biofortification is a purposeful effort to breed plants to improve the nutrient content while not compromising on traditionally valued traits such as yields, resilience, and taste. Efforts need to increase to add nutrient-dense traits to traditional staple crops including maize, rice, millet, beans, and cassava. Nutrient

content should be the main criterion for plant breeding. Biofortification offers a promising approach to help address micro-nutrient deficiencies, especially for people currently consuming and undiversified cereal-based diet.

Diversified Production – Many small-scale farmers engage in monocropping agriculture (the practice of growing a single crop year after year on the same land), primarily of staple grains. The resulting household diet often lacks sufficient nutrient diversity and contributes to poor nutritional outcomes. When small farm households produce a more diverse set of foods (for example, fruits and vegetables, legumes, milk, eggs and fish) and receive nutrition awareness training, the result often is greater dietary diversity, higher micronutrient intake, and positive impacts on the nutritional status of children in the household.

Grand Challenges

Methodological Note

Grand Challenges (GCs) are lists of difficult but important problems articulated by the research team to encourage the discovery of (mainly) technological innovation (i.e., breakthroughs) that could potentially solve the main issues. In other words, a GC is one or more critical barrier(s) that, if removed, would help solve an important problem with a high likelihood of global impact through widespread implementation.

Articulating important challenges that have the potential to deliver real impact, and allocating significant resources to address these GCs later in the process, allows XPRIZE to bring the best minds to the table by engaging crowds who might not otherwise be engaged in global research.

Key Challenges

- Addressing the gender gap
- Ensuring a sustainable natural resource base
- Addressing the advderse effects of climate change and intensification of natural disasters
- Eradicating extreme poverty among smallholder farmers
- Ending hunger and all forms of malnutrition
- Making food systems more efficient, inclusive and resilient
- Improving income earning opportunities in rural areas
- Building resilience to protracted crises, disasters and conflicts
- Preventing transboundary and emerging agriculture and food system threats
- Addressing the need for coherent and effective national and international governance

Framing a Grand Challenge

- **Widely applicable problem... -** The United Nations Food and Agriculture Organization (FAO) estimates that globally, 842 million people are currently undernourished. Shockingly, half of these hungry people are small-scale farmers and their families, for whom agriculture is a livelihood, providing food for their own needs and generating income. A failed harvest due to drought, or the loss of land caused by irresponsible large-scale investments, can have devastating effects on the livelihoods of farmers.
- **for which scientifically sound solutions are imaginable... -** geospatial technologies, soil mapping, improved storage, increased access to electricity and internet services, and the re-engineering of certain crops to make them more nutritious and drought-resistant could all be transformative.
- **but not quite at hand... -** Some of these innovations are 20-30 years away.
- **with deep societal importance -** Smallholder farmers produce as much as 80% of the food consumed in some parts of the developing world, yet make up a majority of the world's undernourished population. In Africa, over 80% of farmers are smallholders and they produce 70% of the continent's food. Emerging technologies have the potential to revolutionize the way food is consumed, handled, and produced across the developing world. New technologies will empower smallholder farmers to have more sustainable livelihoods and enable them to permanently climb out of poverty.

Foresight

Methodological Note

Scenarios inform present-day decision-making by exploring different possible futures. In contrast to forecasting, scenarios examine what is most uncertain and surprising as a mechanism to generate insight and provoke action regarding future-focused risks and opportunities. Scenarios can stretch our thinking about divergent plausible futures. Importantly, the value of scenarios analysis is to examine all of the possible futures identified—rather than focusing on the more desirable ones—with the understanding that any scenario may occur. Thus, scenarios are a tool to uncover blind spots and broaden perspectives about alternative future environments in which today's decisions might play out. The implications drawn from scenarios are designed to trigger discussion, rather than serving as prescriptive outcomes.

Baseline Scenarios

The projections show that feeding a world population of 9.1 billion people in 2050 would require raising overall food production by some 50% to 100% between 2005/07 and 2050. Production in the developing countries would need to almost double. This implies significant increases in the production of several key commodities. Annual cereal production, for instance, would have to grow by almost one billion tons, meat production by over 200 million tons to a total of 470 million tons in 2050, 72%of which is in developing countries, up from 58% today. Feeding the world's population adequately would also mean producing the kinds of foods that are necessary to ensure nutrition security. Smallholder farmers produce as much as 80% of the food consumed in some parts of the developing world. Given this, smallholder farmers are integral global stakeholders and must continue to play a key role in the

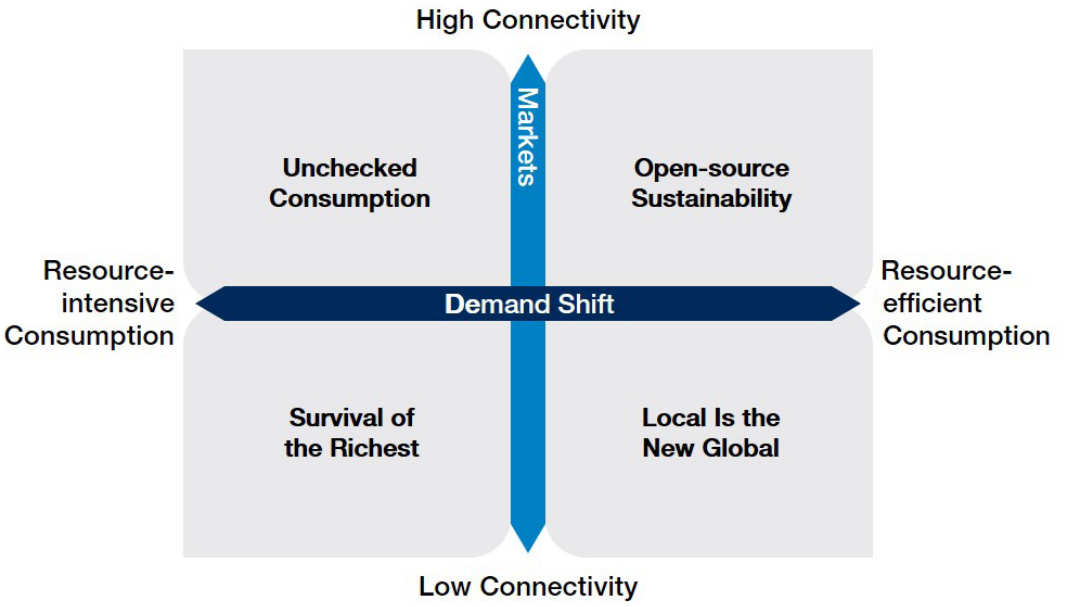
future as their production will need to double in order to contribute sufficient food for 9.1 billion people by 2050. If this fails to occur, much of the world will go hungry and become entrenched in poverty.

World Economic Forum scenarios analysis

The World Economic Forum conducted a scenarios analysis to respond to the following focal question: How will food systems nutritiously and sustainably feed 8.5 billion people in 2030?

A scenarios analysis is built around the forces of change that will most profoundly and unpredictably impact the focal question. After compiling a long list, experts identified "demand shift" and "market connectivity" as the two most critical uncertainties.

1. **Demand shift:** The uncertainty encompasses the nature of future demand for food and agricultural commodities, with particular focus on the environmental impact and health implications of consumers' choices. Demand shift uncertainty is thus focused on whether demand will be relatively more resource-intensive versus resource-efficient.
2. **Market Connectivity:** This uncertainty pertains to the openness of trade, trust in and resilience of commodity markets, and inclusivity of technological innovations. This uncertainty focuses on whether markets will be defined by high connectivity versus low connectivity.



The Scenarios: Four Potential Future Worlds

1. **Survival of the Richest:** In a world of resource-intensive consumption and disconnected markets, there is a sluggish global economy and a stark division between the "haves" and "have-nots." In this scenario, a relatively few isolated, wealthy populations are able to produce and innovate to meet their needs; isolated, poor or import-dependent markets are facing intensifying hunger and poverty. Population growth, rising inequality and food prices have led to increased conflict and migration, and intensifying resource needs have prompted a new wave of investments by foreign entities in land and water resources. Climate change continues unabated. Technology innovation is defined by a broad disparity of access and adoption. Reactionary decision-making and a crisis mindset are perpetuating a fragile system.

   There are many losers in this scenario. For example, life for smallholder farmers has become riskier and more uncertain than ever before: dire economic conditions, limited access to natural resources (especially water) and

more extreme weather conditions have forced tens of millions to seek other sources of income to feed themselves and their families. In the long term, future generations will also suffer from irreversible environmental damages and a weak global economy.

2. **Unchecked Consumption:** In this scenario, there is a combination of resource-intensive consumption and highly connected markets which has enabled rapid growth with serious consequences. Driven by ever-increasing demand, trade is accelerating as markets boom. Technology has spurred efficiencies in food production and distribution, with yield improvements as the top priority. Obesity and health costs rise dramatically as billions of consumers transition to a high-volume, high-calorie, low nutrient-density diet. The "footprint" expands as natural resources—including water, biodiversity and land—are severely depleted and components of key ecosystems such as fisheries and dryland begin to collapse, increasing costs of water purification and intensifying impacts in other regions as consumers seek alternate sources of food.

   This future comes at a heavy cost for others. Regions with limited access to natural resources are facing even scarcer access, while those with abundant natural capital are under pressure from actors searching for more resources: for instance, tropical forest countries are facing alarming rates of deforestation. At the same time, small and medium enterprises are losing market share against efficient and powerful global players, and smallholder farmers disconnected from global markets are likely to be left behind.

3. **Open-source Sustainability:** In this scenario, a combination of resource-efficient consumption and highly connected markets enables a rise of greater transparency in business and in markets. Commodity markets have been stress-tested, and checks and balances instated, to reduce volatility and the risk of a crash. There is a proliferation of food sources, which reduces over-reliance on a few breadbaskets, improving the resilience of food systems. An increasingly interconnected trade system, however, still leaves the world susceptible to the effects of extreme weather events and other economic and political shocks. A stronger global economy enables more consumers to purchase food priced at its "real" cost, as influenced by new business models and policies that support sustainable choices and healthy diets. There is a movement towards personalized nutrition and healthcare, and more people use mobile apps to drive their shopping and eating habits. A rural transformation attracts youth to data-driven agriculture, but older farmers struggle to keep pace.

   This future has a relatively high proportion of winners. For farmers, there is greater availability, affordability and adoption of technologies that increase productivity, decrease costs, and expand access to key information services.

4. **Local is the New Global:** In this scenario, resource-efficient consumption and low connectivity of markets have led to fragmented food systems whereby nations rely heavily on self-sufficiency. There is a rise in local food movements as consumers increase their focus on sustainable local products. Consumers in developed countries rediscover and appreciate local diets and develop a new respect for food, taking additional measures to reduce food waste. Progressive policies have successfully reduced the price point for healthier diets relative to unhealthy diets. Together, these factors enable a shift toward more balanced

diets and a reduction in obesity and related diseases. Shorter supply chains and increased plant-based diets reduce the strain on environmental resources. However, at the macro level, comparative advantages among food-producing regions are lost. Nations without good agricultural land struggle to meet demand and hunger hotspots proliferate.

In this world, import-dependent countries and emerging mega cities, such as Lagos, are struggling to feed a growing population and facing increasing malnutrition. This prompts scarcity, unrest and migration. Other losers in this scenario are industrial farmers who are unable or resistant to rebalancing their crop production as demand shifts toward a greater variety of crops. Local food movements could also negatively impact sales for global food producers and retailers, as clients defer to local producers and brands.

The future is uncertain. And navigating uncertainty requires thoughtful consideration and contingency planning for unforeseen developments. Scenarios can be a powerful tool to explore potential futures, considering how key trends and uncertainties could lead to different outcomes. They can broaden our perspectives on the possibilities for what the future may hold, and the implications of the choices we make today. Scenarios are also important because they can provoke and challenge leaders to think in new ways about what the future may bring and to motivate action on the key issues that will shape the future.

Preferred Future

The preferred future is typically captured as a vision. A vision is an image of the future. It creates an attractive mental picture of an outcome that people can strive for.

Most people think of the future in ideas rather than images. Attractive ideas are progress, security, enjoyment; unattractive ones include overpopulation, pollution, sickness, and death. None of these are visions, however, because they are not images. What does it look like? How does it feel? What does it taste like, sound like? The vision is something tangible and concrete—something that excites people and enables them to take action in support of reaching the preferred future state.

A future of plenty or a future of scarcity is certainly not a given. It's possible to address system failures to leverage, shift, or even reverse trends—even global mega trends—by enabling and incentivizing bold actions. But to truly think boldly, we cannot start with today. It's imperative to start with a preferred future state. The following is an example of a preferred future state:

"All smallholder farmers—especially women—have the knowledge, tools, and resources to sustainably produce a variety of nutritious foods for their families and sell excess production in local markets."

Action

Methodological Note

Solving grand challenges is complex. XPRIZE only launches the most impactful prizes, those that when launched in conjunction with others will achieve a moonshot and radically transform a given domain. XPRIZE begins this process by developing a Futures ImpactMap that maps the full landscape of what is currently happening, what needs to change, and which breakthroughs would not happen unless the crowd was incentivized to develop radical innovations. Once we know which breakthroughs will not be achieved by traditional actors alone, XPRIZE sources brilliant Visioneers in the crowd to vet and evaluate which breakthroughs should become the next XPRIZE. The challenges facing smallholder farmers are complicated and seemingly unsolvable. Only brave, radical new thinking will solve them. Can you identify some breakthroughs that will transform small-scale agriculture and lift tens of millions of smallholder farmers and their families from poverty?

Conclusion

Transformational change is the process of creating a new era. It begins with one or more bold leaders who see that the old era is no longer suitable for the present, much less the future. These bold visionaries articulate a preferred future for the new era and enroll others in the campaign to bring that future about. These leaders and those that follow face enormous obstacles from the doubts and resistance of the majority to the challenge of leaving behind old ways of doing things even before the new ones are ready. Nevertheless, they are compelled to engage in this work because it must be

done sooner or later, and it's best to start today before the terms of change can be dictated.

Definitions

1. **Breakthrough:** To overcome "Grand Challenges" and achieve a "Preferred Future," it's essential to identify potential breakthroughs that can create massive, global impact. Breakthroughs are evaluated based on 4 criteria: impact potential, level of audacity, market readiness level, and desired timeline for impact.
2. **Domain:** XPRIZE operates within 7 domains: shelter and infrastructure; energy and resources; planet and environment; health and wellness; learning and human potential; space and new frontiers; and civil society. Emerging exponential technologies and other innovations in policy and financing have the potential to address grand challenges in these areas, but require new action by key stakeholders and innovators from around the globe.
3. **Futures ImpactMap:** Is an analytical tool for understanding persistent problems and barriers that make up grand challenges in various domains as well as the actions that key stakeholders can take to overcome them and achieve a preferred future state. XPRIZE uses Futures ImpactMaps to help identify potential XPRIZE competitions and other actions that can accelerate a bridge to abundance for all across domains.
4. **Grand Challenge Area:** Is a topic area like "Nourishing the Next Billion," which comprises a combination of complex and overlapping social, technological, economic, environmental, and policy issues. Only the most effective actions will address these issues and accelerate progress toward a more positive future.
5. **Grand Challenge Statement:** A problem statement, which defines the issue to be solved.

6. **Preferred Future:** Is typically captured as a vision—an image of the future. It creates an attractive mental picture of an outcome that people can strive for.
7. **Scenario:** Scenarios inform present-day decision making by exploring different possible futures. In contrast to forecasting, scenarios examine what is most uncertain and surprising as a mechanism to generate insight and provoke action regarding future-focused risks and opportunities.
8. **XPRIZE:** The XPRIZE Foundation is the global leader in designing and implementing innovative competition models to solve the world's grandest challenges. XPRIZE utilizes a unique combination of gamification, crowdsourcing, incentive prize theory, prize philanthropy, and exponential technologies as a formula to make 10x (vs.10%) impact in the grand challenge domains facing our world. The XPRIZE philosophy is that—under the right circumstances—igniting rapid experimentation from a variety of diverse lenses is the most efficient and effective method to driving exponential impact and solutions to grand challenges.
9. **XPRIZE (competition):** An XPRIZE is an incentivized prize competition designed to create 10x impact on the world. The exponential trend of computing power has led us to this period in time, where technology that was just 30 years ago only available to industries like NASA is now on the smartphones in our pockets. XPRIZE competitions leverage this exponential technology with the power of the crowd to spur innovation in areas where there is market failure, empowering individuals across the globe to become the world's next change makers. The competitions are engineered for success: they are required to meet a series of 10 criteria through a rigorous evaluation at our Visioneers Summit in order to be deemed ready for launch. Each XPRIZE competition results in audacious breakthroughs that have scalable impact, leading us closer to the XPRIZE Foundation's vision of a future in which

humanity as a whole benefit by having access to what was once scarce, and is now made abundant.