





World Vegetable Center

World Vegetable Center STRATEGY 2017-2025

Healthier lives, more resilient livelihoods

World Vegetable Center

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NOTE: *The World Vegetable Center (WorldVeg) was established in 1971 as the Asian Vegetable Research and Development Center (AVRDC) in Shanhua, Taiwan. WorldVeg continues to have its headquarters in Taiwan and has established regional centers in Thailand, India, Tanzania, Mali and Benin.*

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CONTENTS

FROM QUANTITY TO QUALITY

The idea of establishing a vegetable research center in Asia dates back to the early 1960s. As the Green Revolution gathered momentum, Dr. Frank Parker, then Assistant Director for Research and Technology of the United States Agency for International Development (USAID), realized that increasing supplies of rice, wheat and other staples could alleviate hunger, but would not address the larger and more complex issue of malnutrition. Health was his priority. To that end, he advocated for greater production and consumption of vegetables to provide the minerals, vitamins and proteins essential for balanced diets. From those initial ideas the Asian Vegetable Research and Development Center

The Center was established with the signing of a Memorandum of Agreement and a Charter on May 22, 1971.

(AVRDC) came into existence with the signing of a Memorandum of Agreement and a Charter on May 22, 1971 and the official opening of a 110-hectare research facility in Shanhua, Taiwan on October 17, 1973. AVRDC has since become the World Vegetable Center (WorldVeg) with staff based in Asia and Africa.

Almost 50 years on, Dr. Parker's arguments could not be more relevant. More than 2 billion people do not get enough essential vitamins and minerals from the foods they eat either because their diets lack these micronutrients or their bodies are unable to absorb or utilize them because of poor health. Many adolescent girls and women of childbearing age suffer from anemia due to iron-deficient diets. About 159 million children are stunted, and these malnourished children will never reach their full potential.

In contrast to the billions of undernourished, there are now 2.1 billion people who are overweight or obese because they consume too much salt, sugar and saturated fats, prompting a steep rise in non-communicable diseases such as diabetes and cardiovascular disease (Ng et al., 2014). Both problems are the result of unbalanced diets that generally lack diversity and are low in fruit and vegetables.

The moral imperative to address this double burden of malnutrition is beyond doubt, but finding the means to do so remains a challenge. The cost of malnutrition to the global economy has been estimated at US$ 3.5 trillion per year, or US$ 500 per individual (FAO, 2013).

Food systems must nourish people, not merely feed them. This requires moving from an emphasis on the quantity of production to a greater focus on the quality of what is produced, from emphasizing a few key staple food crops to a focus on diverse and healthy diets, and from targeting supply-side interventions to a focus on both supply and demand.

Food systems must nourish people, not merely feed them.

The World Vegetable Center's R&D activities, conducted through partnerships worldwide, are guided in particular by nine of the 17 **Sustainable Development Goals** of the 2030 Agenda for Sustainable Development:

Vegetable production, processing and marketing create new jobs and new sources of income for smallholder farmers, laborers, and traders, particularly women and youth, promoting their participation in the economy and society.

Vegetables are humanity's most affordable source of vitamins, minerals and other vital nutrients.

Safely produced vegetables are essential for human health. Good health is a precondition to exploit the nutritional value of vegetables.

It's no simple task. On the supply side, a lack of farm diversification, low productivity, and high postharvest losses limit availability and access to nutritious food. Lack of quality seed thwarts the ability of farmers to produce a good crop. Climate change complicates matters further, leading to erratic drought spells or floods, increasing temperature and salinity and changes in pest and disease pressure. Food safety is a concern throughout the value chain, from excessive use of pesticides in the field to risks from microbial contamination before or after harvest. Perishable vegetables wilt and rot without adequate storage and transport. Vegetable farmers are often poorly informed about market demand and market prices, and thus cannot negotiate fair prices for their produce. Production gluts and inability to aggregate and store harvests send prices even lower.

On the demand side, people who need vegetables most may not be aware of their benefits to nutrition and health and may be unable to afford them. Diets do not necessarily improve with increasing incomes; vegetable consumption may actually decline as incomes rise. Without good agricultural practices and effective, affordable traceability systems, it is difficult to assure consumers of the quality and safety of their food supply. With increasing urbanization, opportunities will expand for affordable, nutritious vegetables.

Vegetable production systems are complex precisely because of the diversity of crops, production methods, and marketing approaches they encompass. Yet opportunities abound to harness this diversity for the benefit of all. The boxes throughout this document illuminate examples of these opportunities, and there are many, many more.

Over the past few years, nutrition and food safety have gained in importance and visibility on international development agendas, in part through the effort of the Global Panel on Agriculture and Food Systems

Vegetable production, processing, and marketing have the potential to advance the position of women if interventions are gender-sensitive.

Incorporating vegetables into food systems helps farmers build resilience to climate and market shocks.

Modernizing vegetable value chains creates employment in rural and urban areas, and attractive opportunities for unemployed youth.

Vegetable biodiversity is conserved and used to sustainably diversify agricultural systems.

Careful postharvest handling of vegetables reduces waste. Vegetables diversify agricultural production systems and offer an alternative to processed food.

Our goals can be achieved through active partnerships with the public and private sector, national and international organizations.

for Nutrition. The year 2016 marked the beginning of the Decade of Action on Nutrition. Sustainable Development Goal 2 (SDG2) of the 2030 Agenda for Sustainable Development recognizes agriculture and food systems as major contributors to food security and nutrition.

Such initiatives are timely because of the magnitude of the current challenge and because of future threats and uncertainties. Food systems must be resilient and ready to nourish a population that is expected to grow from 7.5 billion now to 9.7 billion in 2050. Climate change will require more resilient crops and varieties, and shifts in production systems. Urbanization is changing how food is consumed, processed and marketed; urban markets already cater for the majority of food demand in Asia and Africa, and this is predicted to reach 75% in the next 10-20 years[1]. Rural farmers need to be connected with urban markets through infrastructure that enables year-round vegetable production, processing and marketing. Food quality and safety will be key to build trust between producers and consumers. More diverse and sustainable food systems are needed to support and maintain the nutritional needs of current and future populations while protecting the natural resources that produce food.

Given these new and rapidly evolving challenges and opportunities, the World Vegetable Center has revised its strategy through a series of partner consultations in Africa and Asia and with extensive discussion among WorldVeg staff. The result is this new strategic plan, describing the areas the Center intends to focus on in the next eight years[2]. It is also an invitation to work with us toward a healthier and more resilient world.

[1] Thomas Reardon, Michigan State University, presentation at the USAID Feed the Future Horticulture review and strategy meeting, Putrajaya, Malaysia, 9 September 2016.

[2] These ambitions are turned into action through four-year rolling operational plans.

THE WORLD OF VEGETABLES

Compared to staples, vegetables can be a true WIN (women, income, nutrition) situation in agriculture: women are the custodians of vegetable value chains, and vegetables generate higher margins and income (up to five times) than staples per unit area. High value vegetables with short growth periods offer an excellent business opportunity for farmers to produce multiple crops throughout the year on relatively small areas of land. Take a look at the world of vegetables:

Vegetables vanish from urban diets?

Urbanization leads to more intensive marketing and a distribution infrastructure that supports large supermarkets and imports, which "globalizes" food consumption patterns. People consume more processed foods, fats and oils, and more animal protein from meat and dairy, resulting in diets that are lower in fiber, vitamins and minerals.

Source: Kearney J (2010) Food Consumption Trends and Drivers. Philosophical Transactions of the Royal Society B. 365:1554

Growing stronger with gardens

Women with household vegetable gardens in Bangladesh gained more control over what the household consumed, generated a small but valuable amount of cash, and gained respect and self-confidence with recognition of their agricultural skills.

Source: Patalagsa MA, Schreinemachers P, Begum S, Begum S (2015) Sowing seeds of empowerment: effect of women's home garden training in Bangladesh. Agriculture and Food Security 4:24.

Increases in **women's empowerment** increase **household dietary diversity**

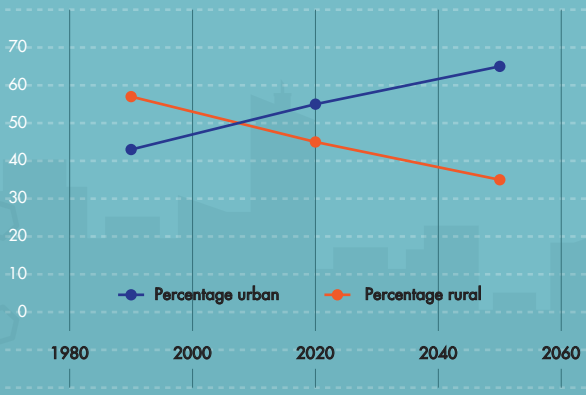
Source: Sraboni E, Malapit HJ, Quisumbing AR, Ahmed AU (2014) Women's Empowerment in Agriculture: What Role for Food Security in Bangladesh? World Development 61:11-52

Vegetables vie for urban consumers!

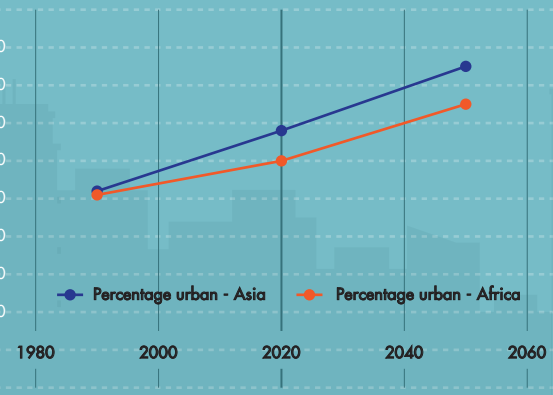
Urban horticulture activities are increasing globally with at least 100 million people involved worldwide. With potential yields of up to 50 kg per m^2 per year and more, vegetable production is the most significant component of urban food production contributing to global food security.

Source: Eigenbrod C, Gruda N (2015) Urban vegetables for food security in cities. A review. Agronomy for Sustainable Development. 35:483.

Percentage global urban vs rural population



Percentage, urban population, Asia vs Africa



Source: UN Department of Economic and Social Affairs (2014) World Urbanization Prospects.

Smallholders* manage…
80% of the farmland in sub-Saharan Africa and Asia

Smallholders provide…
80% of the food supply in sub-Saharan Africa and Asia

Source: NEPAD (2014) Agriculture in Africa: Transformation and Outlook.
*working 10 or less hectares

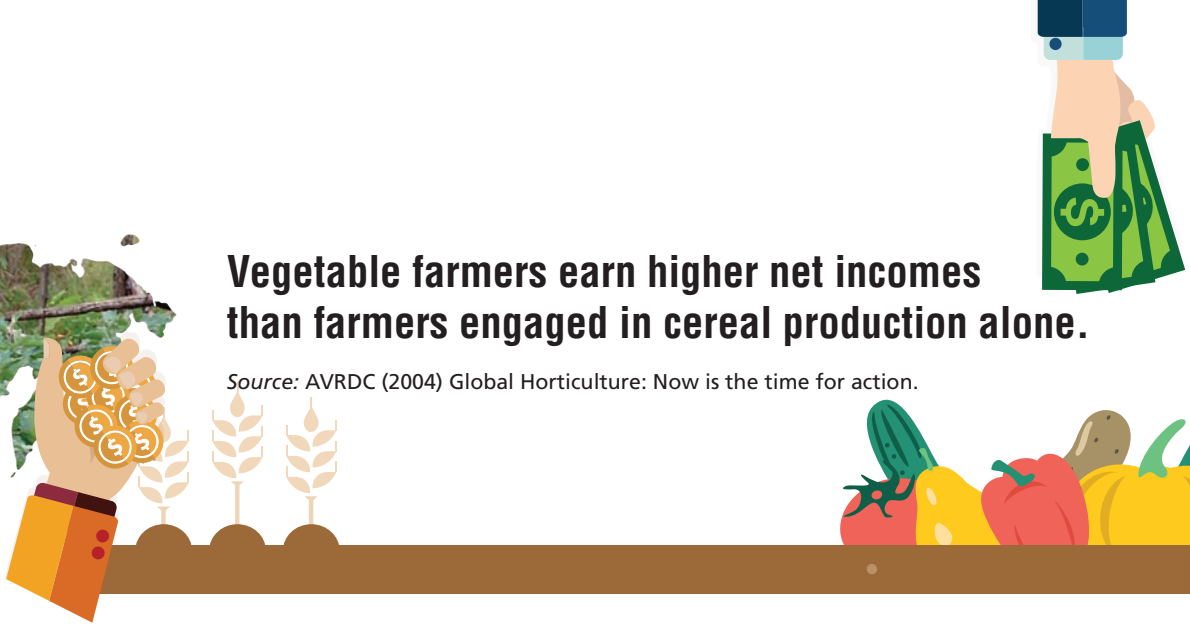
Bangkok
peri-urban farms provide **one-quarter** of the city's vegetable supply

Ho Chi Minh City
peri-urban farms provide **three-quarters** of the city's vegetable supply

Source: Midmore D (2015) Principles of Tropical Horticulture. CABI.

Just 400 grams for health:
Consuming 400 grams of fruit and vegetables daily (the weight of a football) can help prevent chronic diseases such as heart disease, cancer, diabetes and obesity, and alleviate micronutrient deficiencies.

Source: Food and Agriculture Organization (FAO) - World Health Organization (WHO) (2004) Joint FAO/WHO Workshop on Fruit and Vegetables for Health.



Vegetable farmers earn higher net incomes than farmers engaged in cereal production alone.

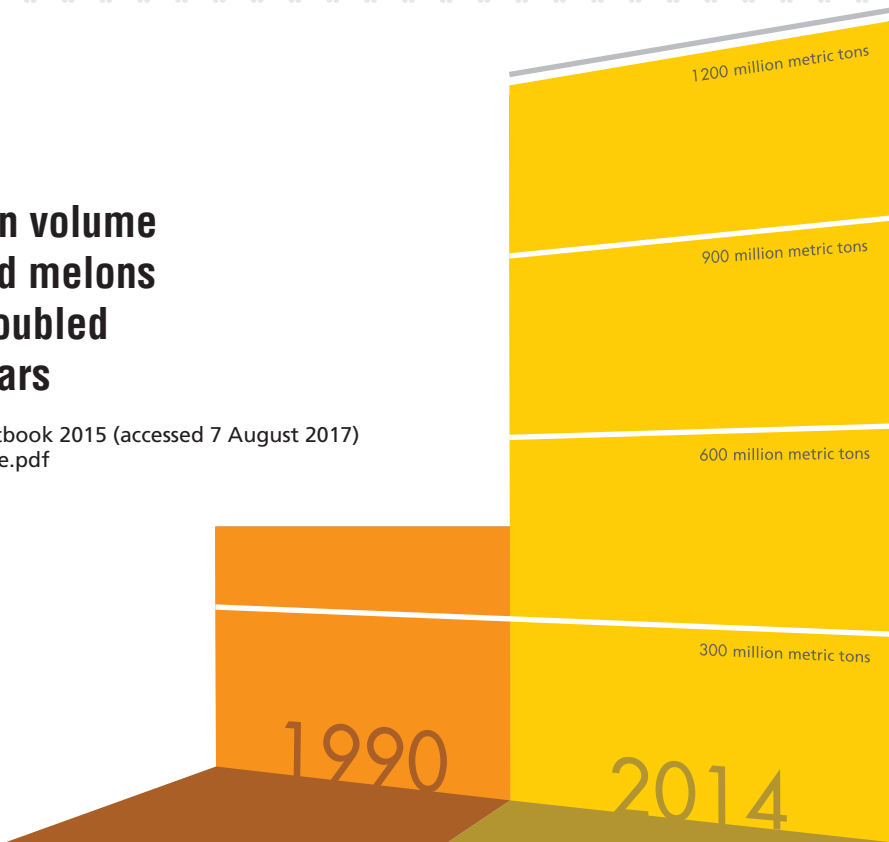
Source: AVRDC (2004) Global Horticulture: Now is the time for action.

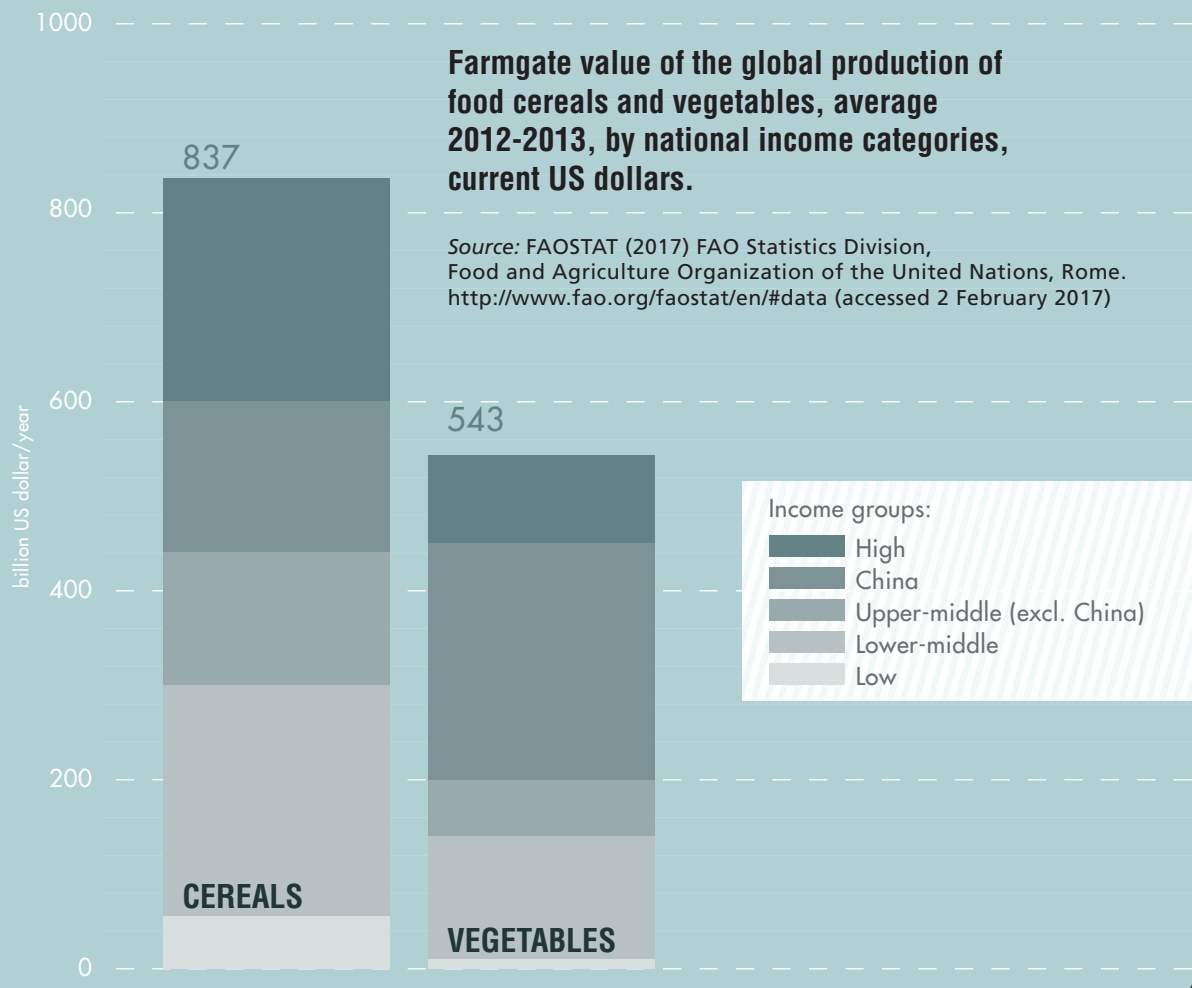
Microbes must be managed in the food supply: Unsafe food containing harmful bacteria, viruses, parasites, worms or chemical substances causes more than 200 diseases and creates a vicious cycle of illness and malnutrition. 1 in 10 people fall ill every year from eating contaminated food, and 420,000 people will die as a result. Children under five are particularly at risk, with 125,000 young children dying from foodborne diseases every year.

Source: World Health Organization (accessed 3 July 2017)
http://www.who.int/mediacentre/news/releases/2015/foodborne-disease-estimates/en/

Global production volume of vegetables and melons has more than doubled in the past 25 years

Source: FAO Statistical Pocketbook 2015 (accessed 7 August 2017)
http://www.fao.org/3/a-i4691e.pdf





Farmgate value of the global production of food cereals and vegetables, average 2012-2013, by national income categories, current US dollars.

Source: FAOSTAT (2017) FAO Statistics Division, Food and Agriculture Organization of the United Nations, Rome. http://www.fao.org/faostat/en/#data (accessed 2 February 2017)

Get women what they need to grow:

About 80% of food producers in the developing world are women, yet they have less access than men to land, improved seed, fertilizer and equipment. Access to quality inputs and resources could increase their yields by 20-30%--and decrease by 100 to 150 million the number of hungry people worldwide.

Source: FAO (2011) The State of Food and Agriculture 2010-2011: Women and Agriculture.

2,000,000,000

Nutrition Needed Now! Without additional efforts to promote pro-poor development, reduce inequalities and protect the vulnerable, more than 2 billion people will continue to be undernourished.

Source: FAO (2017) The future of food and agriculture – Trends and challenges. FAO, Rome.

WorldVeg pays attention to postharvest:

More than 50% of fruit and vegetable losses in developing countries occur in production and processing. WorldVeg promotes simple improvements in packing, such as lining wooden crates with paper, which reduces damage to tomatoes by almost 20%.

Source: FAO (2011) Global food losses and food waste: Extent, causes and prevention. FAO, Rome.

Less waste, more $$$: Every $1 invested in food loss and waste reduction—through training programs, providing equipment like scales to quantify food, and improving storage and packaging—produces a $14 return on investment.

Source: Lipinski B, Hanson C, Lomax J, Kitinoja L, Waite R, Searchinger T (2013) Reducing food loss and waste. World Resources Institute.

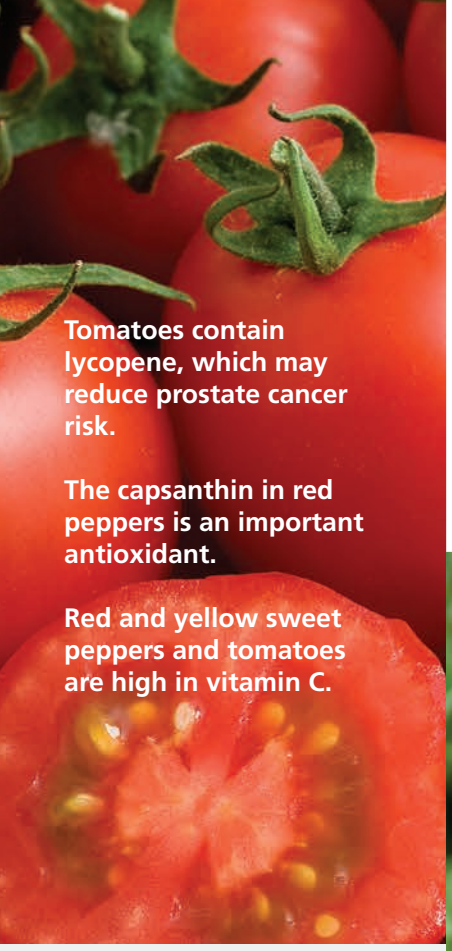
33% of global postharvest losses account for 10% of the world's total energy use.

Source: FAO (2017) The future of food and agriculture – Trends and challenges. FAO, Rome.

Youth are the future of horticulture in Africa:

Rewarding careers await those among Africa's 350 million young people, if given the opportunity to learn and apply modern approaches and technologies to produce vegetables and other crops.

COLORS of LIFE



Tomatoes contain lycopene, which may reduce prostate cancer risk.

The capsanthin in red peppers is an important antioxidant.

Red and yellow sweet peppers and tomatoes are high in vitamin C.

The human body converts carotenoids in butternut squash, carrots, and yellow peppers into vitamin A to help protect eye health, reduce the risk of some cancers, and help prevent heart disease.

Dark leafy green vegetables are good sources of iron. Green vegetables can help protect against some forms of cancer. Amaranth, artichokes, asparagus, broccoli, green beans, cucumbers, peas, lettuce, green pepper, spinach, and zucchini contain chlorophyll, and some contain lutein; when consumed with foods that contain zeaxanthin (grapes, maize, red pepper, egg yolks and oranges), green vegetables may help reduce cataracts. Compounds in bitter gourd help to regulate blood sugar. Cabbage contributes zinc, an essential mineral for a healthy immune system; it helps to build proteins, trigger enzymes, and create DNA. Green sea vegetables such as kelp provide iodine, a trace mineral to regulate the thyroid.

Cauliflower, garlic, ginger, jicama, and onions contain anthoxanthins, which may lower blood pressure and cholesterol.

Eggplant has anthocyanins, important antioxidants that protect cells from damage.

Diets need balance: Staple crops like rice or cassava provide a lot of calories but few other nutrients. For a healthy, balanced diet, eat more vegetables, which provide a diversity of essential vitamins, minerals and proteins.

Percent of recommended nutrition intake (RNI) supplied by 100g of selected commodities for pregnant women

	Protein (g)	Vitamin A (µg RE)	Iron (mg)	Folate (µg)	Zinc (mg)	Calcium (mg)	Vitamin E (mg α·TE)
RNI for pregnant women (1st trimester)	60	800	30	600	11	1000	7.5
				Percentage (%) of RNI			
Rice	0	0	1	2	4	0	0
Cassava (root)	2	0	1	5	3	2	0
Millet	6	0	2	**14**	8	0	0
Meat (chicken)	**37**	0	3	1	**14**	1	3
Mungbean	**40**	2	**22**	**104**	**24**	**13**	7
Vegetable soybean	**18**	2	**13**	**28**	**13**	4	**78**
Cabbage	3	1	1	**10**	2	4	2
Tomato	2	18	1	3	2	1	7
Slippery cabbage	6	**106**	5	**30-177**	**11**	**18**	**58**
Moringa leaves	7	**146**	11	**49**	5	10	**65**
Amaranth leaves	9	**160**	6	**31**	6	**32**	17
Jute mallow	10	**188**	12	**21**	0	**36**	**36**
Nightshade	8	**101**	**13**	**10**	**9**	**21**	**28**
Vegetable cowpea leaves	8	**198**	6	**27**	3	**54**	**101**

Source: RNI -- FAO/WHO 2004; nutrient data - USDA Nutrient Database, WorldVeg; Keatinge JDH et al., 2011
*green numbers indicate high levels of nutrients

Real cash crops: In Tanzania, farmers can realize a net income per hectare of USD 3000-4000 annually or more when they grow traditional vegetables African nightshade, okra, or amaranth. The country's annual per capita gross national income is USD 940 (World Bank, 2015).

VISION

Healthier lives and more resilient livelihoods through greater diversity in what we grow and eat

MISSION

Research and development to realize the potential of vegetables for healthier lives and more resilient livelihoods

VALUES

Dedication to innovation and knowledge sharing
WorldVeg conducts world-class science, respects ethical standards and is committed to sharing results in a transparent manner.

Commitment to impact
WorldVeg aspires to achieve positive, tangible and lasting impact contributing to the Sustainable Development Goals.

Commitment to partnerships
WorldVeg believes in the value of partnerships to advance research for development.

Respect for people
WorldVeg respects diversity of gender, culture, ethnic origin, religion, age, beliefs and views.

Respect for the environment
WorldVeg strives to minimize its environmental impact and to introduce greener technology and practices.

VEGETABLE SCIENCE FOR IMPACT

WorldVeg strives to achieve faster, greater and lasting positive impact on the nutritional status, incomes, and well-being of people—particularly in Africa and Asia—based on quality, long-term complementary partnerships in vegetable science and development.

Thematic priorities

The Center will implement its science for development agenda through three outcome-oriented 'flagship programs': *Safe and Sustainable Value Chains, Healthy Diets,* and *Vegetable Diversity and Improvement,* and one cross-cutting flagship program: *Enabling Impact* (Figure 1). These flagship programs emerged from partner consultations in 2016 and extensive discussions among Center staff and are based on relative strengths, identified trends, and potential for impact. They bring together WorldVeg staff and partners from the public and private sector, from research and development organizations, and from farmer organizations and civil society. They are gateways to achieving outcomes and impact and each is operationalized through two to four 'innovation clusters'.

Innovation clusters are teams of WorldVeg staff and partners working towards a clear and measurable set of outcome targets through discovery, piloting, and scaling activities and continuous improvement of a coherent set of products and services. This is not a linear, predictable process moving from ideas to application to impact, but rather an iterative pathway to impact with numerous feedback and feedforward loops allowing for unexpected outcomes and trajectories. We will be very proactive in seeking partnerships that address organizational, policy and institutional changes needed for further improvement, uptake and scaling of innovations.

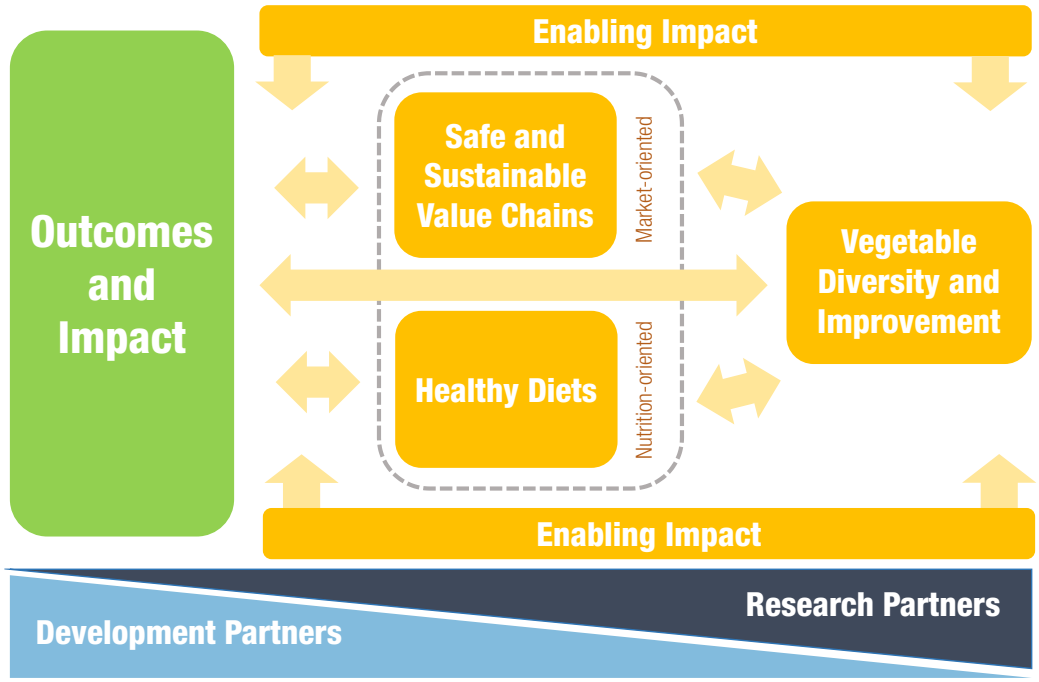


Figure 1 Linkages between strategic research flagships, partners, outcomes and impact.

The **Safe and Sustainable Value Chains** flagship contains four innovation clusters on a gradient from intensive to extensive vegetable production systems: *urban and peri-urban systems, off-season systems, intensifying systems* and *cereal-legume systems*. Activities in this flagship are market-oriented and promote sustainable and diversified agricultural production systems, aiming to create income and employment opportunities in the vegetable sector, particularly for women and youth, and catering to market demand for safe vegetables.

The **Healthy Diets** flagship contains two innovation clusters: *rural and urban gardens, nutrition and health* and *traditional vegetables to enrich diets.* Activities in this flagship are nutrition-oriented and aim to improve the quality of diets of the rural and urban poor with a particular focus on women of reproductive age and children under five as they are the most vulnerable to malnutrition.

The **Vegetable Diversity and Improvement** flagship contains two innovation clusters: *vegetable biodiversity* and *high performance vegetable lines*. Activities in the first innovation cluster will ensure that vegetable germplasm is collected, characterized, conserved and distributed for use in breeding programs worldwide in accordance with phytosanitary and quarantine requirements. The second innovation cluster focuses on the genetic improvement of selected vegetable species.

There are many linkages between flagships. For example, some women who become skilled at producing vegetables for home consumption may start selling vegetables and gradually develop their own business, reaching urban markets with safe vegetables. Products of the *Vegetable Diversity and Improvement* flagship feed into the two systems flagships (Figure 1).

The **Enabling Impact** flagship provides support to the other three flagships in terms of monitoring and evaluation, knowledge management, best practices for scaling, and strengthening of partners' capacity to innovate. The flagship conducts impact evaluations of the Center's development-oriented work and stimulates organizational learning to achieve faster, greater and lasting positive impact.

Geographic priorities

The Center sets geographic priorities in close collaboration with its technical and financial partners and based on situational analyses and ex-ante impact assessments using available data and baseline studies. Criteria for priority setting may include:

- Number of malnourished people, and women and children in particular – expected impact of our work on diet diversity and improved nutrition security.
- Number of poor working in horticulture – expected impact of our work on income generation and job creation, in particular for women and youth.
- Number of poor consumers who would profit from horticultural innovations – expected impact of our work on poverty reduction through more affordable and accessible vegetables.
- Level of productivity in vegetable production – expected impact of our work on productivity gains and reduced postharvest losses.
- Imports of vegetables and processed vegetables – expected impact of our work on import reduction, savings on foreign exchange and creating employment.
- National capacity to undertake vegetable research – expected impact of our work on capacity strengthening.
- Strength of national or regional partners to scale research products.

Phased approach

Activities in the innovation clusters will be conducted in three distinct phases, moving from discovery research, to piloting, to scaling. Ownership of the activities will change moving from one phase to the other, with scaling activities often led by our partners from the public and private sector, with WorldVeg providing backstopping in capacity strengthening and stewardship over products used. WorldVeg will keep oversight over progress made, allowing for changes in emphasis of research, piloting and scaling. WorldVeg will take a proactive approach towards linking with scaling partners from the public and private sector, at times taking on scaling work ourselves, but always building capacity of national partners and with a clear exit strategy.

Open data

WorldVeg regards the results and outputs of its research as international public goods and is committed to their widespread diffusion and use. We have clear and transparent principles that apply to the creation, acquisition, management and dissemination of data collected or generated from experiments and field trials, knowledge and publications, technologies, tools, know-how, and improved germplasm. This open approach is essential to achieve the maximum possible access, scale and scope of impact from our research.

Support services

WorldVeg works as a distributed network from its headquarters in Taiwan and through its regional centers in South Asia (India), East and Southeast Asia and Oceania (Thailand), Eastern and Southern Africa (Tanzania) and West and Central Africa (Mali, Benin). We will maintain or strengthen these research facilities to the highest international standards to be able to conduct world-class science and attract world-class staff, students and partners to work with us.

WorldVeg will adopt a proactive approach to risk management and business continuity and quality control in all research and administrative operations. WorldVeg will continue to implement projects using full cost recovery principles. We will strive to maintain a cordial and conducive working environment enabling recruitment and retention of high-caliber staff and attracting students, visiting scientists from all over the world.

Partnerships and capacity strengthening

We are committed to partnerships that are long-term, based on trust and mutual respect. WorldVeg nurtures these partnerships in a professional and transparent manner and strengthens capacity of partners where needed to advance science and enhance impact.

WorldVeg **links** with advanced research institutions and national and international research associations (Association of International Research and Development Centers for Agriculture [AIRCA], CGIAR) to leverage cutting-edge knowledge and skills to advance the vegetable science agenda.

Strong and diverse partnerships ensure the science of our strategic research flagships has impact

By proactively **reaching out to partners** from the public and private sector, we facilitate scaling of knowledge and products and obtain feedback on their performance, thereby achieving positive and lasting outcomes and impact.

Strategic plans and frameworks developed by regional and continental organizations guide and inform our work. Institutions such as the Association of Southeast Asian Nations (ASEAN), the Asian Development Bank (ADB), the African Development Bank (AfDB), Forum for Agricultural Research in Africa (FARA), Asia-Pacific Association of Agricultural Research Institutions (APAARI), West and Central African Council for Agricultural Research and Development (CORAF), and Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), among others, are important partners for WorldVeg.

We contribute to **partner capacity strengthening** in vegetable science at individual and institutional levels where and when needed. The International Vegetable Training Course (IVTC) hosts trainees from all over the world for periods of up to two months in Thailand. We are actively looking for opportunities to expand IVTC activities to Africa. Offering MSc and PhD scholarships, staff exchange with partner institutions, and visiting scientist schemes remains an essential element of the WorldVeg approach to research and development.

OPERATIONAL PRINCIPLES

Our work is guided by the following five principles ('the 5Cs'):

We connect people and institutions along research to impact pathways aiming for transformational innovation and change;

We concentrate our efforts in innovation clusters and work in regions where we believe we will have the greatest potential for impact;

We gain critical mass in research areas by working as an 'open science center', establishing strategic partnerships and networks with national and international research institutions;

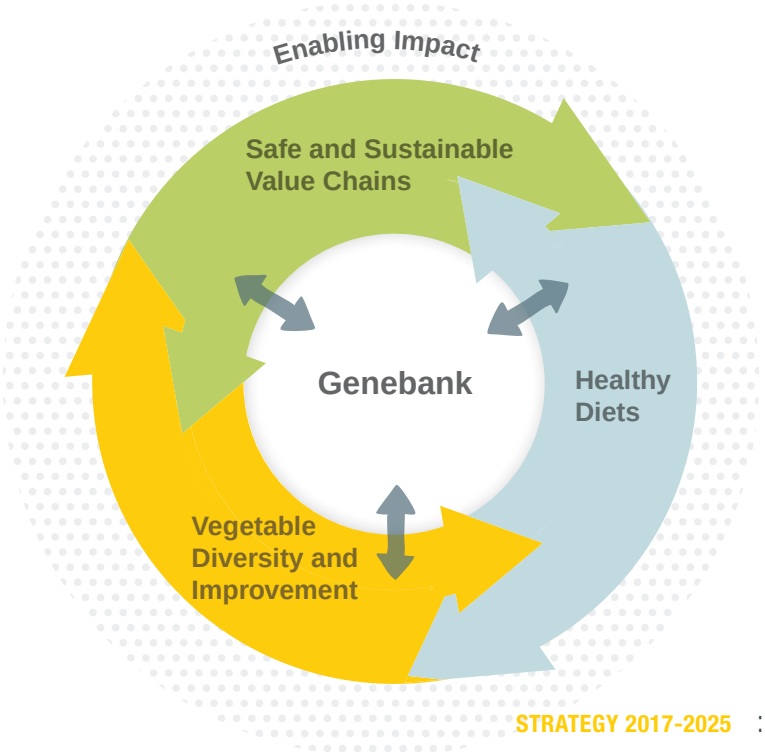
We nurture creativity through scholarship programs, visiting scientist programs and allocating funding for innovative research;

We communicate our activities and achievements on a regular basis and in a transparent and easy-to-access manner that facilitates uptake, feedback and stewardship.

FLAGSHIP PROGRAMS

The Center will implement its science for development agenda through three outcome-oriented flagship programs: *Safe and Sustainable Value Chains, Healthy Diets*, and *Vegetable Diversity and Improvement,* and one cross-cutting flagship program, *Enabling Impact*, contributing to the Sustainable Development Goals (SDGs).

The WorldVeg Genebank (page 42) is at the heart of many of our research and development activities.



COMBINE PUBLIC AND PRIVATE SECTOR R&D

Farmers need high yielding varieties that can withstand abiotic and biotic stress. Improved lines of tomato and African eggplant developed by the World Vegetable Center and introduced to Tanzania in collaboration with national partners and distributed through private companies have had impact in Tanzania, but just how much was never quantified.

A study was conducted to assess the adoption, economic impact and **returns to vegetable improvement** for Tanzania. Teresa Sequeros, an independent consultant hired by WorldVeg, visited all vegetable seed producers in Tanzania to collect data on seed sales of all current varieties of tomato and African eggplant and their origin. She found that 87% of tomato and 98% of African eggplant seed sales by private companies were unmodified open-pollinated WorldVeg lines. By her estimate, WorldVeg research generated US$ 255 million in economic returns to farmers and consumers for tomato between 1987 and 2014, and US$ 5 million for African eggplant, which was introduced more recently. There was an internal rate of return of 26% for investments into tomato research and 12% for African eggplant (though the latter was projected to increase to 26% by 2024). It's solid proof that international vegetable breeding research produces very attractive returns on investment.

Schreinemachers P, Sequeros T, Lukumay PJ. 2017. International research on vegetable improvement in East and Southern Africa: Adoption, impact and returns. Agricultural Economics. doi: 10.1111/agec.12368.

Safe and Sustainable Value Chains

This flagship targets in particular women and youth already involved or entering the vegetable sector and links them to markets, promoting good agricultural practices and quality seed in a value chain approach aimed at making vegetable production profitable, safe and sustainable.

Vegetable farming has great potential to supply healthy food to a malnourished and increasingly populated world, but first and foremost consumers must be able to trust that vegetables are safe to eat. Vegetable crops grown for markets suffer from high pest and disease pressure and smallholder farmers often apply large amounts of pesticides inappropriately, using wrong products, dosage, timing, equipment, etc. During postharvest handling there are also risks of spoilage and microbial contamination. Food safety issues must be addressed to enable farmers to access increasingly well-informed domestic urban markets as well as export markets, and ensure that vegetables can contribute to economic growth and healthier populations.

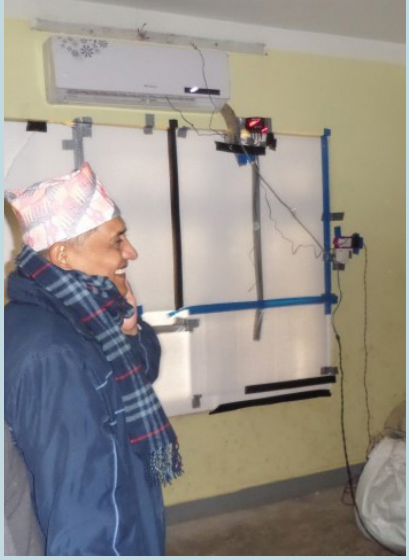
Some countries have developed standards for good agricultural practices (GAPs), however such standards have not been widely promoted and adopted. There are clear incentives for farmers to adopt GAP standards and food safety regulations if they are targeting high-end export markets, but incentives for farmers to adopt such standards for domestic markets have been mostly lacking. However, rising income levels and a growing well-informed urban population in Africa and Asia are now creating demand for quality fresh vegetables and processed vegetable products. Urban consumers are becoming increasingly aware of food safety and are often ready to pay a premium for a reliable, consistent supply of safe vegetables. Concerns for food safety include pesticide use and microbial contamination before and after harvest, aflatoxin contamination and high nitrate as well as heavy metal accumulation in leafy vegetables. There is a huge opportunity to connect vegetable

production systems to urban demand for quality food in cities across Africa and Asia.

With access to markets, vegetable farming can build resilience among farming households, reducing vulnerability to extreme weather events due to climate change and market shocks because of a large choice of crops, availability of heat- and salt-tolerant varieties, and rapid growth and harvest cycles. Opportunities include integration of vegetables into existing cropping systems or moving into more specialized vegetable production systems, using technologies such as improved varieties, grafting, protected cultivation, soil conservation techniques, and drip irrigation.

WorldVeg is well placed to work in this area because of its track record in linking farmers, women and youth to markets, developing baskets of good agricultural practices (in particular integrated pest management options) for different vegetable production systems, and providing seed sources that best match consumer demand and growth conditions.

This flagship combines improved vegetable varieties with good agricultural practices and good postharvest practices in a value chain approach aimed at making vegetable production profitable, safe and sustainable. We will broadly work on a gradient from intensive to extensive vegetable production systems: (a) *urban- and peri-urban systems*, characterized by year-round vegetable production that are typically irrigated, small-scale, and input-intensive, with good market access; (b) *off-season production*, cultivation of crops outside the regular cropping calendar when supply is low and prices are high, which can give farmers better profits and consumers more choice; (c) *intensifying systems*, areas in transition from low value staple crops toward high value vegetables and can be rainfed or irrigated, open-field or protected cultivation, and seasonal or continuous vegetable production; (d) *cereal-legume systems*, systems in which short-duration grain legumes such as mungbean are integrated in between two successive staple crops such as rice and wheat or maize.



PRODUCE, PACK AND PROMOTE

Smallholder vegetable farmers can tap demand for high-quality and safe vegetables for retail stores, hospitals, hotels, and urban consumers, but first they have to get the crop out of the field and ensure it meets customer specifications. Value chain studies conducted by WorldVeg in Bangladesh, Cambodia and Nepal showed that almost a quarter of the harvested tomato, cauliflower, eggplant and leafy mustard never reached consumers due to poor handling and transport practices. At community-operated **packhouses**, producers collectively plan production, consolidate their harvests, and carry out grading and quality assurance for more competitive marketing. Packhouses have facilities for cooling and storing to keep vegetables fresh, such as Coolbots (a device to regulate an air conditioning unit to chill a room for cold storage) and simple evaporative coolers. Through USAID-supported postharvest training, hundreds of farmers in Asia and Africa learned how to manage smallholder packhouses and are now training others to do the same. As demand for fresh, safe vegetables increases, farmers have discovered that joint packhouse operations can raise their produce to a new level of quality, and their income to new heights.

REDUCE OR ELIMINATE THE NEED FOR PESTICIDES

Pesticide misuse is widespread in many regions of the world, posing risks to the health of farm families, consumers and the environment. But there are **alternatives to pesticides**—and the most efficient and effective approach is to develop insect resistance within the plant itself. Consider tomato: it is the 4th most important food crop by farmgate value in low and middle income countries. Unfortunately it is also very popular among insect pests. More than 50 years ago, tomato breeders began to develop insect-resistant tomatoes to reduce pesticide use and increase grower profit. They crossed thousands upon thousands of different tomato lines—including some wild relatives of tomato—in an effort to breed tomato with resistance to pests and diseases as well as good fruit characteristics, high yield, and tolerance to heat and drought. Yet no resistant cultivars are available to date. In search of a faster way to screen, or evaluate, tomato plants for resistance traits, WorldVeg researchers began taking a closer look at trichomes, the very fine hairs without or with glands containing an array of chemical substances on tomato stems and leaves. There are different types of trichomes, and by checking the trichome type on more than 255 accessions of *Solanum galapagense, S. cheesmaniae* and *S. pimpinellifolium* (wild relatives of tomato) and conducting assays with whitefly and spider mites, breeders were able to identify tomato accessions resistant to these pests, bringing the dream of insect resistant cultivated tomato a step closer.

If resistance can't be bred into a crop, finding **natural enemies and pheromones to use in biocontrol programs** is another safe alternative to pesticide use. Amaranth is a popular traditional crop in Eastern Africa, but infestations of the leaf webber (*Spoladea recurvalis*) can lead to 100% yield loss. WorldVeg entomologists carried out a systematic survey to identify the most effective parasitoids of *S. recurvalis*. In other WorldVeg studies in Cambodia, Lao PDR, and Vietnam, the fungi *Bacillus thuringiensis* and *Metarhizium anisopliae* were found to be effective against pod borers and aphid in yard-long bean. They were also effective against other insect pests on leafy brassicas. Pheromone traps also have been evaluated. Recent advances to harmonize regulatory processes for biocontrol agents in this region may lead to commercialization of these IPM component technologies in the near future.

Each of these systems has its own challenges that are addressed through a combination of technological, organizational and institutional/policy innovations to ensure safe vegetables, free from chemical residues and microbial contamination reach markets. WorldVeg will actively seek to become part of innovative partnerships that link vegetable farming to urban demand for quality vegetables. We will contribute to technological and organizational (business model) innovation, while raising awareness about policy and institutional innovation needed to achieve truly transformational change.

In terms of technological innovation, we will work with farmers to diversify their production systems to include vegetables and adhere to pre- and post-harvest GAP standards to produce safe products for urban and export markets. We will facilitate testing and adoption of appropriate and resilient vegetables and/or vegetable legume crops well suited to growing and market conditions and with long shelf-life and resistant to pests and diseases. We will pay particular attention to the introduction of IPM strategies limiting the use of chemical pesticides and use of ICT decision aides guiding integrated pest and crop management decisions. We will study ways to mitigate pest and disease incidences and reduce mineral fertilizer and water use by improving soil health through the development of alternative cropping systems and rotations.

We will stimulate year-round safe and intensive vegetable production through technologies such as affordable protective structures, IPM, and vegetable grafting. We will leverage postharvest technology from advanced research institutions and private sector partners to reduce postharvest losses and satisfy market opportunities for fresh, and where relevant, processed vegetables. We will also leverage knowledge from advanced research partners to assess food safety risks and monitor and trace chemical and microbial contaminations along the value chain using cost-effective and reliable ICT-based methods.

In terms of organizational innovation, we will focus on linking farmer groups and in particular women and youth with urban wholesale and emerging supermarket/high-value retail sector markets in both Asia and Africa, and with vegetable processing and marketing firms for local and export markets. We will facilitate aggregation of production, processing and marketing processes to ensure stable and safe supply,

PERFECT TIMING FOR VEGETABLE PRODUCTION

Off-season and **year-round farming systems** extend the harvest and raise incomes of farmers, processors and retailers, all to the benefit of consumers, who can purchase local rather than imported produce, have greater choice at the market, and a more diverse, nutritious diet at home. In Pakistan, for instance, supplies of tomato, peppers, cucumber, and bitter gourd were once scarce during the winter season. Now those crops are among the many grown in screenhouses, polyhouses and other protected cultivation structures developed by WorldVeg and Punjab Agricultural University (India), and growers are producing fresh vegetables at a time when they are most needed. In summer, Pakistan growers use shade net shelters to produce spinach and coriander, normally cool-weather crops. In Tajikistan, a project to promote small backyard protected cultivation structures to improve local year-round vegetable supplies has shown major yield improvements with the use of better varieties, staking and careful pest and disease management.

A CAREER FOR YOUNG PEOPLE

Malnutrition, poor dietary quality, youth unemployment and the migration of young people to cities are widespread problems in rural areas of eastern and southern Africa. With access to relatively small spaces of land, **urban youth and women** can find meaningful and profitable employment in vegetable production. The Australian Centre for International Agricultural Research-funded VINESA Project in Ethiopia, Malawi, Mozambique and Tanzania used an entrepreneurial, value chain approach to train unemployed youth by immersing them in Best Practice Hubs for several months. Among other skills, hub participants learned how to identify consumer needs; reduce postharvest losses; and build and nurture relationships with key value chain players. The youth form groups for mutual support after they graduate from the hubs, and together, continue to hone their skills in seed and seedling production, crop nutrition, and marketing. Several graduates have now become respected hub leaders and crop producers, bringing the benefits of training full-circle in their communities. VINESA's intensive training benefited nearly 500 young people from 2013 to 2017.

thereby creating new income and employment opportunities. Market opportunities will be identified based on consumer perceptions of, and willingness to pay for quality and safety.

Truly transformational change will require working on an improved legal and business environment, collective action and investment in production, storage and marketing infrastructure and introduction of traceability systems. We will be mindful of the importance of affordable financing throughout the value chain, particularly for youth. We will link with national and regional partners to strengthen policy and regulatory frameworks in particular for seed systems development, commercialization of biopesticides and other biocontrol technologies and crop insurance.

Valuable lessons can be learned from experiences across Asia, and appropriate strategies will be adapted for Africa. WorldVeg will endeavor to establish a research and development network on food quality and safety issues for horticultural products as part of the AVRDC-ASEAN Regional Network on Vegetable Research and Development (AARNET) by setting thematic priorities with ASEAN member states. Similar networks will be established with regional organizations and international agricultural research and development centers in South Asia as well as sub-Saharan Africa.

SAFE AND SUSTAINABLE VALUE CHAINS
Strategic Objectives for 2025

Farmers and value chain actors have increased access to quality seed and safe, sustainable pre- and postharvest practices contributing to more resilient livelihoods.

INNOVATION CLUSTER: URBAN AND PERI-URBAN SYSTEMS

Product package: Improved high-yielding vegetable varieties with resistance to biotic stress, good agricultural practices, and urban-appropriate postharvest and marketing practices.

Vision: A constant supply of safe, nutritious, affordable vegetables is available in peri-urban and urban centers through the adoption of improved high-yielding, insect and disease resistant varieties, the introduction of good agricultural practices (healthy seedling production technology, protective structures, IPM strategies, cultural practices, and water management, especially safe use of wastewater), and improved harvest and postharvest technologies.

INNOVATION CLUSTER: OFF-SEASON SYSTEMS

Product package: Heat tolerant, flood- and disease-resistant vegetable varieties combined with cultivation methods to promote production in the off-season.

Vision: Availability of wholesome vegetables at affordable prices increases in the off-season through methods that minimize production costs and improve market opportunities. Growers adopt high yielding and better adapted varieties for abiotic constraints (heat, flooding or drought) and biotic challenges (insects and diseases); use grafting technology and protective structures including rain shelters (net houses, plastic houses and low tunnels); and follow IPM strategies, water management techniques for dry periods, and improved cultural practices.

INNOVATION CLUSTER: INTENSIFYING SYSTEMS

Product package: High yielding varieties with resistance to pests and diseases combined with good agricultural practices (GAP).

Vision: The indiscriminate use of agrochemicals in intensive vegetable production systems is reduced by working with national research organizations, policy institutions and private sector partners to expedite the adoption of innovations in grafting, protected cultivation, IPM, soil fertility management, irrigation management and cultural practices. Postharvest technologies and small-scale processing technologies are developed and promoted. Market information systems and collective marketing activities strengthen vegetable value chains, particularly for farmers.

INNOVATION CLUSTER: CEREAL-LEGUME SYSTEMS

Product package: High yielding, short duration, salt and drought tolerant, bruchid and yellow mosaic virus resistant legume varieties with synchronized maturity that can be integrated into cereal production systems and be harvested mechanically.

Vision: Vegetable legumes, especially mungbean, vegetable soybean, yard-long bean or cowpea, are in rotation within the cereal systems of Asia and Africa to break pest and disease cycles, improve soil structure and fertility, enhance sustainability, and increase farm profitability. Good agricultural practices for seed treatment, drilling, integrated pest management, and mechanical harvesting are adopted. Grains from vegetable legumes are stored using novel storage technologies and consumed as dry pulses. Legume producers are linked with processing industries, significantly increasing economic returns.

SCHOOL GARDENS TEACH NUTRITION

In school gardens, children learn about the importance of a balanced diet including vegetables for their nutrition and health. Those lessons go home to parents, and to the community. The **Vegetables Go to School** project in Nepal, Bhutan, Burkina Faso and Indonesia tested how school gardens in combination with nutritional education affect children's nutritional outcomes. With funding from the Swiss Agency for Development and Cooperation and in collaboration with the University of Freiburg and the Swiss Tropical and Public Health Institute, WorldVeg researchers worked with national partners to implement school gardens and evaluate outcomes and impact. Results for Bhutan and Nepal clearly show that the school garden intervention led to a significant increase in children's awareness about fruit and vegetables, their knowledge about agriculture, food and nutrition, and their stated preferences for eating fruits and vegetables. Only time will tell whether the intervention will increase their consumption of vegetables.

(Bhattarai et al. 2015; Schreinemachers, Bhattarai et al. 2017; Schreinemachers, Rai et al. 2017)

Healthy Diets

This flagship targets in particular poor households, women and children that have insufficient access to nutritious food, low dietary diversity, undernutrition and micronutrient deficiencies. Behavior change communication strategies and our work on promoting traditional vegetables will have positive spillover effects to those affected by overnutrition and obesity.

Healthy diets are a global priority to reduce malnutrition and noncommunicable diseases. Vegetables are one of the five major food groups (staples, legumes/nuts, vegetables, fruits and animal source foods) essential to fulfill human nutritional requirements. Adequate nutrition relies not only on diversified food systems, but also on well-informed consumers with access to health services and clean environments.

WorldVeg will research and promote vegetable gardens in rural and urban settings that provide safe products to close dietary gaps and partner with health organizations to raise consumer awareness about the importance of vegetables for health. We will seek to expand our knowledge base of traditional vegetables, a vastly underused genetic resource, and in particular knowledge about their best-fit growing and market environments and their nutritional and functional properties. We will actively promote their inclusion in agriculture and food systems to build resilience of poor households to extreme climate and market shocks.

WorldVeg is well placed to work in this area because of its experience in combating malnutrition at the household level through its *garden, nutrition* and *health* approach. The approach aims to improve dietary quality and the nutritional status of people vulnerable to micronutrient malnutrition by increasing the year-round supply of a diverse range of fruit and vegetables from a household-managed garden linked to complementary training in nutrition and health and to necessary support systems.

In this flagship, WorldVeg will lead or contribute to innovative partnerships aiming to provide vulnerable population groups, in particular children and women, with more diversified and healthier diets. We will continue improving and expanding our rural *garden, nutrition* and *health* approach by better matching vegetable crops and other productive components such as fruit trees and small-scale fish ponds to dietary gaps in the target population. More insight is also needed regarding the most effective and efficient models for scaling household garden interventions leading to sustainable impact. We will expand the garden approach to urban areas, in particular targeting the urban poor living in and around major cities in Asia and Africa. Innovative city gardens and vertical gardens, adapted to limited space and water availability and with crops addressing major dietary gaps will be needed for such situations. Vegetable crops have short growth cycles and often allow for multiple harvests. This mean that vegetable growers can generate income quickly after a crisis. Vegetable farming can, therefore, contribute to disaster recovery and build resilience among affected populations to extreme weather and market shocks.

MALI SCALES UP

The **USAID/Mali Scaling** project aims to strengthen understanding of the links between agriculture, nutrition, health and WASH (water-sanitation-hygiene) through garden and nutrition training in a country beset by food insecurity and hunger. Dialé, a satellite village linked to the Molobala Best Practice Hub in Sikasso, Mali, was not among the initial target villages selected for project activities. However, after learning about the project, Dialé's village leaders strongly felt their community needed to be involved, and made a formal request to join the project in 2016. People from Dialé even attended nutrition and production training in Molobala well before the project activities were scheduled to begin to ensure they would be prepared and ready to assist their neighbors. Dialé allocated a two-hectare plot for vegetable production and mobilized community members to involve themselves in all project activities. The community also created its own support group to host activities and deliver messages about the importance of nutrition and WASH to maternal and child health. The Mali Scaling project truly lives up to its name: In 2016 alone, more than 10,000 people received nutrition and WASH training; more than 15,000 learned vegetable production and processing methods; more than 15,000 home garden nutrition seed kits were distributed; and field day activities engaged more than 3,600 farmers and their families.

RAISE CONSUMER AWARENESS ABOUT THE VALUE OF VEGETABLE CONSUMPTION

Consumers may not know about the nutritional benefits of locally available **traditional vegetables**. To promote the consumption of traditional African vegetables, the WorldVeg Eastern and Southern Africa team set up a tasting booth during Tanzania's Nane-Nane Agricultural Fair in August 2016. Visitors sampled pumpkin soup, amaranth cake, an African eggplant and okra curry, and black jack (*Bidens pilosa*) with coconut milk. The hit of the day was the black jack recipe, because many couldn't believe that what they considered a weed could become a tasty addition to a meal. "I have been pulling this out of my field for many years but never realized I could eat it!" said local farmer Ombeni Elias. More than 200 people tasted the dishes at the event. The tasting was one of several events organized by the USAID-supported AfricaRISING project to raise awareness about consuming a diverse range of vegetables—the health insurance everyone can afford.

Consumers need to understand the nutritional qualities of food. Promotion of school and home gardens linked to awareness raising about the importance of nutrition, clean water, sanitation and hygiene will help promote food safety and security at the household level. Consumers' demand for safe food in combination with regulatory frameworks and effective monitoring systems will drive markets to adopt food safety standards. We will develop effective nutrition messages and behavior change communication strategies to fill knowledge gaps, create demand for healthy diets, and stimulate healthier food choices and habits.

Long-term underinvestment in research and development of traditional vegetables has obscured their many benefits, despite their nutritional and income-generating potential. Traditional vegetables such as amaranth (*Amaranthus* spp.), cowpea (*Vigna unguiculata*) leaves and pods, African nightshade (*Solanum scabrum* and *S. villosum*), spider plant (*Cleome gynandra*) and moringa (*Moringa oleifera*) provide much higher amounts of provitamin A, vitamin C and other important minerals than staples and other vegetables. They also contain antioxidants and other health-promoting phytochemicals that may prevent chronic diseases such as cancer and cardiovascular disease. Traditional vegetables are also great income generators. WorldVeg experience in Tanzania demonstrated that net income per hectare for some traditional vegetables is equal to or even much higher than tomato. Besides addressing malnutrition and providing income, traditional vegetables have many additional benefits compared to other vegetables. They are often more resilient to climate change than global vegetables and relatively easy to grow because they are adapted to local growth conditions.

World Vegetable Center. 2016. The World Vegetable Center's Approach to Household Gardening for Nutrition. World Vegetable Center, Shanhua, Taiwan. Publication No. 16-803. 35 p. https://avrdc.org/download/publications/medium-term_and_strategic_plans/strategy/eb0270.pdf

HOME GARDENS NOURISH FAMILIES

Families can thrive on vegetables harvested from well-designed and managed household gardens. Home gardens are especially effective when combined with awareness campaigns about nutrition and health and targeted at households vulnerable to malnutrition. Although the potential of home gardens in reaching nutritional outcomes has been recognized, evidence that home gardens are a cost-effective method to combat micronutrient deficiency has been lacking. WorldVeg conducted a study to quantify the impact and cost-effectiveness of training poor rural women in Bangladesh in home gardening and nutrition. WorldVeg and local partners BRAC and PROSHIKA trained more than 8,000 Bangladeshi women in vegetable gardening methods and nutrition between 2012 and 2013. Using data for a control and intervention group, the researchers showed that the intervention significantly increased vegetable production and vegetable consumption. Most of the increase was due to leafy vegetable production, which led to a significant increase in the micronutrient supply.

Home gardens are a useful strategy to promote better balanced diets among poor rural households, and may complement other health interventions. To foster the spread of household gardens, in 2016 WorldVeg published ***The World Vegetable Center's Approach to Household Gardening for Nutrition***, a concise guide based on the Center's experience and available evidence. The approach emphasizes gardening skills, nutrition and health, and support systems for successful garden interventions.

We will actively expand the knowledge base of traditional vegetables, and in particular knowledge about their best-fit growing and market environments and their nutritional and functional properties. We will work closely with other flagships to promote inclusion of these crops in food systems, making use of genetic resources in the WorldVeg genebank and making seeds available to farmers in collaboration with public and private sector partners. From the demand side, consumption of traditional vegetables will be promoted through contributions to national health awareness campaigns, school garden programs, and mass media.

HEALTHY DIETS
Strategic Objectives for 2025

Rural and urban households have increased access to and use a diverse range of vegetables contributing to healthier lives and more resilient livelihoods.

INNOVATION CLUSTER: RURAL AND URBAN GARDENS, NUTRITION AND HEALTH

Product package: Rural household gardens

Vision: The WorldVeg approach to household gardening for nutrition is being used by leading NGOs, improving the nutrition and health of hundreds of thousands of women of reproductive age and children below the age of five. Seed companies produce and distribute seed kits containing seeds of a variety of traditional and other vegetables, with minimum subsidy from donors. Partner organizations use training manuals to train their field workers and community-based trainers to scale out the WorldVeg household garden concept to combat malnutrition.

Product package: Urban gardens

Vision: Urban garden systems to supply safe and affordable sources of nutrient-dense vegetables are tailored to the preferences of and constraints experienced by poor people in urban environments. There is a clear and well-documented approach to WorldVeg urban gardens that is applied in several development projects in Africa and Asia and there is robust evidence for impact on nutritional outcomes, specifically for women of childbearing age and children under the age of five.

Product package: Disaster response and preparedness

Vision: Household gardens help rehabilitate livelihoods after drought and flood disasters. Assistance is provided in selecting and sourcing germplasm and garden technologies appropriate for local conditions, cultural habits and preferences. Adaptation and resilience of household gardens in chronically flood-prone areas is evaluated through impact studies during periods of rehabilitation.

INNOVATION CLUSTER: TRADITIONAL VEGETABLES TO ENRICH DIETS

Product package: Decision support tools for assessing the potential of traditional vegetables

Vision: Database of traditional vegetables containing information on agroecological adaptation, nutritional properties including health-promoting bioactive/phytonutrient values, and traditional knowledge/utilization developed for at least 200 crops and made available through the WorldVeg website. The data are widely used by researchers and extension workers from the public and private sector to understand the potential uses and promote traditional vegetables. Web-based decision support tools to select potential traditional vegetables for fresh markets and processing, and for specific dietary/nutrition/health needs are proven to be effective and are frequently used by the Center and by other researchers and project partners to develop value chains.

Product package: Cost-effective and sustainable nutrition message delivery systems to stimulate demand

Vision: Step-by-step protocols on how to identify nutrition knowledge gaps in target populations, select approaches and strategies to develop nutrition messages, and how to pre-test and validate messages are published as technical bulletins and made available on the WorldVeg website. The protocols are frequently used in the Center's nutrition education programs and by other researchers, particularly those from developing countries. The protocols enhance the effectiveness and efficiency of research and development in promoting and creating demand for healthy diets.

Product package: Gender sensitive value chain interventions

Vision: A set of protocols for product development and food safety and quality assessments, investigation of the role of traditional vegetables in dynamic food systems, and intervention tools to test and demonstrate gender sensitive value chain approaches for income and nutrition are readily available on the WorldVeg website. They are frequently used in the Center's value addition programs and by other researchers, particularly from developing countries.

Vegetable Diversity and Improvement

This flagship targets farmers as the ultimate users of quality vegetable seed. Intermediate users of breeding lines include seed companies, some of which may have their own breeding programs, and farmer organizations. A range of public and private sector partners collaborate with WorldVeg to maintain and expand our genebank collections to safeguard vegetable biodiversity, test advanced breeding lines and advance our seed knowledge base.

Improved cultivars are one of the cheapest, simplest and most effective technologies for farmers because they are seed-based and do not require special knowledge to deploy. Cultivars must cope with increasing climate variability, in particular tolerance to heat and resistance to newly emerging pests and diseases, withstand rough postharvest handling and meet the quality and nutritional requirements of markets and consumers. Healthy and quality vegetable seed is the foundation for any crop grown for home consumption or for urban or rural markets.

We will contribute to enhancing knowledge of the genetic basis of important traits and using such knowledge to improve the performance of a range of vegetable crops of regional or global significance. Traits include tolerance/resistance to a range of biotic and abiotic stresses that are becoming more erratic and prominent due to climate change, and enhancing shelf life because of the perishable nature of vegetables. Selection for improved nutrient content and quality is an important part of WorldVeg breeding programs. WorldVeg will strengthen its strong linkages with the private seed sector to facilitate scaling of products and to get feedback on uptake and performance.

WorldVeg is well placed to work on cultivar improvement because it harbors the world's largest and most widely consulted vegetable germplasm

A TRULY STRATEGIC PARTNERSHIP

Having its headquarters in **Taiwan** brings the World Vegetable Center many advantages—including access to some of Asia's most advanced agricultural researchers and research institutions. WorldVeg works closely with the Taiwan Agricultural Research Institute, the Council of Agriculture, the Bureau of Animal and Plant Health Inspection and Quarantine, and local District Agricultural Research and Extension Stations on pest and disease management issues important to Taiwan agriculture, such as tomato resistant to leaf curl viruses. Academia Sinica, National Taiwan University and other institutes of higher education provide access to advanced laboratories where vital genomic data is processed and analyzed; this work supports research to benefit farmers in developing countries. Through WorldVeg internships, students from these universities can conduct research in an international, multicultural setting. WorldVeg works with the Taiwan Seed Trade Association, ensuring that the country's vegetable seed producers benefit from the Center's pre-breeding work, which leads to improved, resilient vegetable varieties.

CONSORTIUMS FOR THE CHALLENGES AHEAD

As advances in biotechnology and genomics accelerate the pace of vegetable cultivar development, seed companies of all sizes must have a robust understanding of the latest vegetable breeding research, the practical skills to apply new breeding methods, and access to a diverse collection of vegetable germplasm to remain competitive in turbulent markets. Through the **Asia & Pacific Seed Association (APSA)/WorldVeg Vegetable Breeding Consortium**, participating companies and WorldVeg researchers have opportunities to discuss and evaluate breeding approaches and discover new avenues to share data and progress. The consortium's initial focus is collection, has breeding programs in different parts of the world, and has strong connections with the formal and the informal seed sector.

WorldVeg is committed to maintain and expand its germplasm collection (currently about 61,000 accessions from 151 countries representing 440 species) using internationally agreed standards and protocols, and to provide access to these accessions in line with the International Treaty for Plant Genetic Resources. We will expand our phenotyping capability to identify new sources of abiotic stress tolerances and pest and disease resistance from landraces and wild relatives of cultivated vegetable species in our genebank through combinations of high throughput phenotyping, genotyping, bioinformatics and other innovative approaches in close collaboration with advanced research institutions, particularly in Taiwan. Genetic sequence information will be made available to facilitate bioinformatics 'big data' searches. All information will be shared with global databases and data depositories. We aim to genotype our entire tomato, pepper and eggplant collections and tag important agronomic traits with markers. We will start similar work for amaranth, okra and African eggplant. WorldVeg will continue investing efforts in mapping disease and insect resistance genes and eventually develop marker systems for all our target crops.

on tomato, pepper and cucurbits, which may broaden to other crops later. WorldVeg offices in Africa aim to establish similar networks with seed organizations and companies on the continent. The Center's global Cucurbit Breeding program receives some support from the private seed sector and more seed companies have expressed interest in this program after observing the potential of WorldVeg bitter gourd breeding lines for direct use in their hybrid breeding programs. Through public-private partnerships such as these, WorldVeg can extend the reach of its germplasm throughout the world, thus increasing its impact.

However, particularly in Africa, vegetable seed is still mostly produced and disseminated through informal seed systems. Most national seed laws were developed with staple crops in mind, and thus are not well-suited to traditional African vegetables or vegetables in general. WorldVeg is working with policymakers and farmers' groups to strengthen the informal and formal vegetable seed sectors.

There are many important global and regionally important vegetable crops and WorldVeg must be selective in which crops it will breed, taking into account multiple factors such as: 1) economic importance of the crop and potential to increase farmer incomes; 2) potential crop contribution to human nutrition; 3) availability of genetic resources for breeding; 4) potential to solve significant problems cost-effectively through breeding; 5) WorldVeg's comparative advantage in breeding versus the private sector; 6) ease of seed production and other technical considerations; 7) costs of research and the likelihood of attracting funding. Based on these criteria WorldVeg breeding programs target a few global vegetables (tomato, chili and sweet pepper, and onion), legumes (mungbean, urdbean, and vegetable soybean) and traditional vegetables (amaranth and African eggplant).

All WorldVeg breeding programs address key production constraints and the dietary needs of populations of the tropics and subtropics; consequently, tolerance to high temperatures, salinity and other abiotic stresses required for high yield; multiple disease and insect resistances, quality factors such as taste, shelf life, eye appeal; and enriched nutrient contents are common features across our breeding programs. Breeding will be conducted

using cost-effective combinations of conventional field breeding, marker-assisted selection, greenhouse screening methods, and multilocation testing involving multidisciplinary teams.

Vegetable crops vary in the specificity of their physiological adaptation to different environments and cropping systems, and the extent of market segmentation based on fruit/leaf/grain colors, shapes, sizes, and end-uses. These factors determine whether the products of WorldVeg breeding programs are likely to be adopted globally or regionally. Our breeding programs seek to design strategies that broaden the adaptation of our lines by surmounting major production constraints or by developing lines that expand market or processing opportunities. Heat tolerant and multiple disease resistant WorldVeg tomato and chili pepper lines have been tested and released throughout the tropics and subtropics and lines improved for these and other traits will be beneficial in many regions and be useful to public and private sector partners all over the world. WorldVeg short day onion lines, on the other hand, have shown strong adaptation (flowering, seed set) to the region in which the breeding was conducted and future onion lines with long ambient storage, rainy season adaptation, disease resistance and heat tolerance will likely be best adapted to West Africa.

BEANS WITH BENEFITS

Farmers across South and Central Asia increasingly appreciate **mungbean** to diversify rice and wheat systems: short-duration mungbean provides additional income without affecting their main crops, it contributes to gradual improvements in soil fertility, and crop residues can be used to feed livestock.

In Uzbekistan's hot and dry summers, a lack of water limits cultivation of vegetable crops and intensive wheat production has caused soil fertility to decline. WorldVeg is developing cereal-mungbean crop rotation systems for Uzbekistan's Fergana valley. Uzbekistan's mungbean production area expanded to 1000 hectares in 2016, supported by local mungbean seed production of cultivars 'Durdona,' 'Zilola, 'Marjon' and 'Turon' developed from WorldVeg germplasm.

WorldVeg worked with partners in Pakistan to develop short-duration and disease-resistant mungbean varieties for Pakistan's rice-wheat systems. Demonstration plots of high yielding mungbean cultivars 'NM-11' and 'AZRI-6' were planted in Bhakkar and Layyah districts of Punjab in 2016. The use of improved production practices including line sowing, use of Rhizobium + PSB (Phosphorus Solubilizing Bacteria), post-emergence chemical weed control, and integrated pest management methods led to a significant increase in yield and farmers' incomes.

Our bitter gourd and pumpkin genetic improvement program emphasizing high yield, fruit quality, and high nutritional content with multiple disease resistance is mainly regional (South and Southeast Asia) but there is great potential for our lines to have impact in Sub-Saharan Africa and other regions. WorldVeg mungbean lines achieved great success by combining synchronous and early maturity (60-75 days) and mungbean yellow mosaic disease (MYMD) resistance, allowing them to fit into rice-wheat systems of the Indo-Gangetic plains. Popularity of vegetable soybean is mainly in parts of East Asia. WorldVeg legume breeding is currently mostly regional (South and Southeast Asia for mungbean, East Asia for vegetable soybean) but we will start exploring the potential of our breeding lines in other parts of the world, particularly in sub-Saharan Africa.

Sweet pepper is a high value, nutritious but heat sensitive crop and current production is limited to the highland tropics or cool periods. Our sweet pepper breeding will emphasize heat tolerance and multiple disease resistance to boost tropical adaptation. Amaranth (*Amaranthus* spp.) is popular in sub-Saharan Africa and Asia, mainly for the fresh leaves, but the nutritious grain is also increasingly popular. Our amaranth breeding program currently targets lines for east and southern Africa, and will

However, soil salinity in parts of South and Central Asia is constraining mungbean growth. To identify salt-tolerant mungbean, WorldVeg researchers selected 296 accessions for a mini-core collection that represents a large portion of the diversity available in the whole WorldVeg mungbean collection (about 8,000 accessions). This germplasm panel was challenged with salt (sodium chloride) during seed germination and seedling growth. Seventeen highly tolerant accessions were detected. Researchers are now investigating the traits underlying tolerance at different growth stages, and combining seed germination and seedling salt tolerance in mungbean lines.

A UNIQUE GLOBAL RESOURCE

The World Vegetable Center is justifiably proud of its **genebank**, which holds the world's largest public sector collection of vegetable seed in trust for humankind. With more than 61,000 accessions, the WorldVeg genebank contains the depth of genetic resources plant breeders need to develop vegetable varieties with improved pest and disease resistance, tolerance to heat, drought, flooding and other adverse climatic conditions, and the color, fruit shape, and nutritional content farmers, markets and consumers demand. In 2017, WorldVeg tomato breeders crossed hundreds of tomato lines with wild relatives from the genebank. Although wild tomato species tend to have small, unpalatable fruit, some also have characteristics such as dense trichomes (hairs) that repel insects. One cross of a wild relative with a cultivated tomato resulted in a line with resistance to whitefly (one of the most destructive pests of tomato) that also produced good tasting, market-sized fruit.

develop amaranth cultivars that offer small-scale farmers options to produce high foliage, high grain yields or both and that are resistant to major pests/diseases. African eggplant (*Solanum* spp.) is a popular traditional vegetable in Africa mainly grown for its fruit. We will develop pest and disease resistant determinate and indeterminate type cultivars with the right fruit type for target consumers of east and southern Africa.

Inbred lines and to a lesser extent, hybrids, will be the main products of WorldVeg breeding. In large parts of Asia, many seed companies readily take up and use WorldVeg products in their breeding programs and they have the human resources, capital, and know-how to capably produce and commercialize high quality vegetable seed. The vegetable seed industry is relatively less developed in Africa and some parts of Asia. Most African seed companies only trade seed (market seed/varieties purchased or licensed from outside sources). Establishing a vegetable breeding R&D program can be a large and somewhat risky investment for most small seed companies and WorldVeg will take an active role to build R&D capacity in vegetable breeding and allied disciplines, jointly develop hybrids and inbred line cultivars, and strengthen large-scale seed production capability of selected companies with technical staff, capital, land and infrastructure willing to invest in breeding R&D. WorldVeg breeders based in Africa will also give special attention to improvement of seed systems so that sufficient quantities of high quality seed of improved cultivars are available to farmers.

Grafting tomato to tomato/eggplant rootstocks can overcome some tomato production constraints, especially in the off-season. WorldVeg genebank tomato, eggplant and other *Solanum* accessions will be systematically assessed for abiotic tolerance (flooding, salinity) and disease resistance. The application of grafting methods will be expanded to other crops such as cucurbits to overcome abiotic and biotic stresses.

VEGETABLE DIVERSITY AND IMPROVEMENT
Strategic Objectives for 2025

Vegetable growers have increased access to a diverse range of high quality, climate-resilient vegetable seed.

INNOVATION CLUSTER: VEGETABLE BIODIVERSITY

Product line: Diverse and well characterized germplasm collection

Vision: The world's most-widely consulted vegetable germplasm collection with fully functional genebanks in Taiwan and Tanzania is entirely backed up to safeguard vegetable biodiversity for future generations.

Product line: Special populations for trait capture and breeding

Vision: Vegetable germplasm populations are amenable to rapid and cost-effective screening to identify genotypes with desired properties available to breeders and the scientific community.

Product line: Traits, marker-trait associations and pre-breeding lines

Vision: The entire tomato, pepper and eggplant collections are genotyped and important agronomic traits tagged with markers, and advanced work on amaranth, okra, and African eggplant is underway. New sources of pest and disease resistance and abiotic stress tolerances are identified through combinations of high throughput phenotyping, bioinformatics and other innovative approaches. Critical genes are introgressed into elite lines, which are made available to breed improved vegetable varieties.

Product line: Phytosanitary and quarantine support

Vision: A strategy and procedures are in place that significantly reduce or extinguish seed contamination. HQ and Regional Offices routinely distribute seed lots locally and to other countries with appropriate Phytosanitary Certificates or controls in place.

INNOVATION CLUSTER: HIGH PERFORMANCE VEGETABLE LINES

Product line: Dual purpose tomato lines

Vision: Tropically-adapted dual purpose lines are widely used in breeding and derived varieties become popular in fresh markets. WorldVeg tomato hybrids targeting high temperature dominate off-season tomato production in South/Southeast Asia; varieties facilitate competitive and profitable tomato processing in India, East and West Africa.

Product line: Fresh market tropical tomato lines and hybrids

Vision: WorldVeg fresh market tomato lines provide a major source of heat tolerance, insect and multiple disease resistance and are used in 30% of South/Southeast Asia seed company varieties. Some WorldVeg tomato hybrids are marketed by seed companies in parts of sub-Saharan Africa and profits used to jump-start vegetable breeding research programs. Pesticide use on tomato in South Asia plummets due to varieties with combined insect and multiple disease resistances.

Product line: Multiple disease resistant chili pepper lines

Vision: High quality WorldVeg chili lines featuring resistance to anthracnose, Phytophthora blight, and multiple viral diseases are found in the pedigrees of >50% of varieties marketed in South Asia.

Product line: Tropical sweet pepper lines

Vision: Improved WorldVeg sweet pepper lines open the path for seed companies to develop tropically-adapted sweet pepper varieties. Sweet pepper production season and area in the tropics expands and market supplies increase.

Product line: Bitter gourd lines and hybrids

Vision: WorldVeg bitter gourd lines boost the hybrid vigor and performance of seed company varieties grown in South Asia.

Product line: Multiple virus resistant pumpkin lines

Vision: WorldVeg pumpkin lines are a major source of multi-virus resistance to improve seed company varieties and result in reduced pesticide use by growers.

Product line: Amaranth

Vision: Seed companies develop and market amaranth varieties throughout Africa and Asia using WorldVeg improved lines. Amaranth varieties adapted to heat/drought expand vegetable supplies, especially in the off-season, and grain amaranth supplies become available for use in fortifying maize meal and other cereal products.

Product line: African eggplant

Vision: Seed companies develop and market seed of determinate and indeterminate African eggplant pure lines and hybrid cultivars leading to wide availability of African eggplant in markets.

Product line: Mungbean

Vision: Improved mungbean lines are developed by pyramiding resistance to mungbean yellow mosaic disease (MYMD) from different sources with resistance to bruchids and powdery mildew, along with salt and heat tolerance. The best mungbean lines are scaled up in Bangladesh, India, Pakistan, Myanmar, Uzbekistan and Kenya.

Product line: Urdbean

Vision: WorldVeg urdbean lines improved for resistance to yellow mosaic disease and powdery mildew are adopted by 30% of farmers in Bangladesh, India and Myanmar.

Product line: Vegetable soybean

Vision: Basmati flavored vegetable soybean with glabrous pods and with resistance to MYMD facilitates scaling of the crop in India.

Product line: Onions

Vision: WorldVeg onion breeding develops short-day onion lines with high marketable yields that are resistant to major onion diseases of West Africa, yielding low-bolting bulbs with extended shelf life under ambient storage. West African-adapted open pollinated onion lines with high yield potential, early maturity, long ambient storability, uniform bulb color, size, and shape, and resistance to Stemphylium blight, purple blotch, and thrips significantly boost farmer productivity and competitiveness.

Product line: Rootstocks

Vision: High performance rootstock-scion combinations tolerant/resistant to abiotic and biotic stresses significantly boost off-season production of tomatoes and other vegetables, reducing farmer risks and tripling farmer incomes.

Enabling Impact

This flagship program supports the three other flagship programs in their intervention design, monitoring, evaluation and learning activities and impact evaluation, and data management to achieve faster, greater and longer-lasting impact. The activities are part service provision and part research.

The program aims to stimulate continuous learning at the organizational level by sharing experiences across projects and regions, by documenting outcomes, impact and lessons learned, by storing research data in a central repository that is easily accessible to all staff, and by using this to continuously refine research priorities and intervention designs.

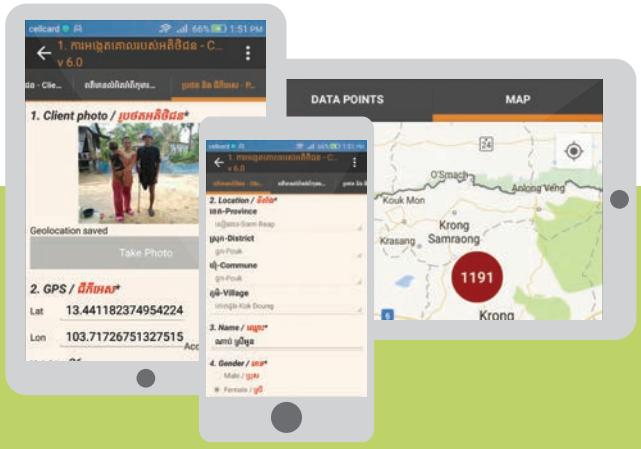
We will create strong partnerships with leading organizations in the field of impact evaluation. We will leverage this knowledge to advance the capacity

NETWORKING AT ALL LEVELS

International, national, local: The many-faceted, complex challenges of vegetable production and marketing among and within countries demand attention both at the highest levels of government as well as in village farmer's groups. WorldVeg nurtures **partnerships** to ensure discussions about the vegetable sector occur when policymakers meet, such as through AARNET, the AVRDC-ASEAN Vegetable Research Network that engages government representatives from 10 countries in Southeast Asia, and the International Mungbean Improvement Network, which aims to develop the potential of mungbean to improve global crop system productivity and livelihoods. Innovation platforms, or networks, set up as part of many WorldVeg projects bring together producers, traders, consumers and researchers to discuss ideas, share progress, and smooth out problems to enhance vegetable value chains.

of our local partners in designing and implementing high quality impact studies. Higher-level partnerships with, for example, APAARI in Asia and FARA in Africa, will be used to influence policy makers on vegetable sector development, for which we will conduct policy-oriented country- or regional-level studies.

This flagship will apply impact evaluation to ensure that the Center's interventions are based on solid evidence of what works. The flagship will also facilitate the development of scaling strategies for innovation clusters, contribute to their implementation and conduct empirical research to refine them further.



GROWING WITH BIG DATA

The sustainable intensification of horticulture in the developing world requires **open access to data** in a format that is accessible and timely to promote immediate action. But often data is inaccessible to the most important in-country project partners. The USAID Feed the Future/WorldVeg project "Deploying Vegetable Seed Kits to Tackle Malnutrition in Cambodia" partnered with Akvo to use Akvo Flow as a survey tool to monitor the training, technical assistance and uptake of technologies by household garden project clients. In Year 1 (2016) more than 1,300 households took up improved agriculture and nutrition activities and were monitored through Akvo, which captured 13,000 individual data records about client characteristics, training activities, and the technical assistance they received. Data collected with Avko Flow helped WorldVeg to quickly evaluate the immediate situation in the field, allowing project staff to adjust their approach to meet client needs. An example: The rapid data analysis indicated IPM assistance was in high demand, while there was less need for help with garden bed preparation and variety selection. The feedback enabled the project to adjust internal resources to focus more on IPM technical awareness. Project partners will have access to "snapshots" of the data for their own immediate response strategies in the field and for longer term planning and reporting. For example, GIS linked project data have been harnessed to identify locations or hubs with sufficient clients for seed and other input supplies. East West Seed used this intelligence to guide the establishment of their seed distribution network, with each store requiring a certain threshold of sales to ensure a sustainable supply of seeds with high vigor.

The flagship will develop a web-based application to monitor the Center's progress toward its short- and long-term goals contributing to the fulfilment of its mission. The application will help scientists, project coordinators, flagship program leaders, regional directors and other senior managers to track progress at various levels and identify possible bottlenecks.

We will consolidate training materials globally to increase efficiency and avoid "reinventing the wheel", and ensure that all WorldVeg staff and partners can easily access these materials. We will guide the development of new state-of-the-art materials to satisfy the learning needs of our target groups and create impact.

We will create an interactive vegetable knowledge platform on the WorldVeg website as a discussion forum of vegetable related issues. Platform members will include WorldVeg staff, many of our local partners and other people interested in vegetable production and consumption. WorldVeg staff will post regular updates of their products or write brief opinion pieces related to their work. New information will be added regularly.

We will redesign the International Vegetable Training Course (IVTC) using fit-for-purpose methods and demand-driven topics to showcase key interventions, technologies, products and innovations. Participants will become acquainted with one another, familiar with the mandate and activities of WorldVeg and its partners, and after returning to their home countries will continue to engage with fellow participants through an alumni network and dedicated web portal. We will aim to also organize the IVTC in Africa.

We will develop a Center-wide data and information repository to provide scientists easy access to research data and related research protocols, project reports and publications. This will support world-class research, ongoing learning and foster innovation.

THE COURSE THAT COVERS IT ALL

Launched 36 years ago, the World Vegetable Center's intensive **International Vegetable Training Course (IVTC)** continues to evolve based on input from participants and partners. Conducted at the WorldVeg Research and Training Station in Kamphaeng Saen, Thailand in partnership with Kasetsart University and other leading research and development organizations, the IVTC has trained more than 900 participants from Asia, Africa, the Middle East and the Pacific Islands to increase the production and consumption of vegetables according to the specific demands and opportunities in their countries. In 2016 an online community was established to encourage course graduates to develop their own information-sharing, problem-solving network: https://ivtc.avrdc.org

ENABLING IMPACT
Strategic Objectives for 2025

WorldVeg and partners make a positive and lasting impact through strong partnerships, sound scaling strategies, and robust M&E systems.

INNOVATION CLUSTER: M&E AND IMPACT ASSESSMENT

Product line: Impact studies

Vision: All of the Center's interventions are based on solid evidence of what works and impact evaluation is routinely applied on all innovations. The World Vegetable Center is recognized as one of the leading international agricultural research organizations in its application of impact assessment in project cycles.

Product line: Situational studies

Vision: The situational studies (describing a system, problem or situation with the objective of raising awareness or identifying entry points for intervention) conducted by the Center are of high quality and are regularly published in peer-reviewed journals. There are standard protocols for conducting situational studies. The Center has a clear and tested approach for conducting country policy studies on vegetable sector development.

Product line: Center-wide monitoring system

Vision: This centralized, easy-to-use tool, accessible by all staff members, shows the Center's progress toward meeting its deliverables and larger goals and is an integral part of the Center's management at various levels.

INNOVATION CLUSTER: CAPACITY TO INNOVATE

Product line: Scaling strategies

Vision: The Center has clear scaling strategies for all of its innovation clusters and these are regularly applied in its projects and tested and refined through empirical research.

Product line: Consolidated and new capacity development materials

Vision: The Center has consolidated existing capacity development materials globally to increase efficiency and avoid "reinventing the wheel", and these materials are easily accessible for all WorldVeg staff. New state-of-the-art materials are continually being developed based on the latest scientific results and training methods, to satisfy learning needs of and create impact among our different target groups.

Product line: Interactive vegetable knowledge platform

Vision: The interactive vegetable knowledge platform on the WorldVeg website is a lively discussion forum of vegetable related issues. Platform members include WorldVeg staff, many of our local partners and other people interested in vegetable production and consumption. For each scalable product, an Innovation Brief is available along with an interactive blog which enables end-users to post comments, videos and photos. There are regular opinion pieces written by WorldVeg staff.

Product line: International Vegetable Training Course

Vision: The International Vegetable Training Course (IVTC) uses fit-for-purpose methods for demand-driven topics to showcase key interventions, technologies, products and innovations. Participants become acquainted with one another, familiar with the mandate and activities of WorldVeg and our partners, and on return to their respective countries are empowered, through an alumni network and a dedicated web portal, to invigorate the vegetable sector.

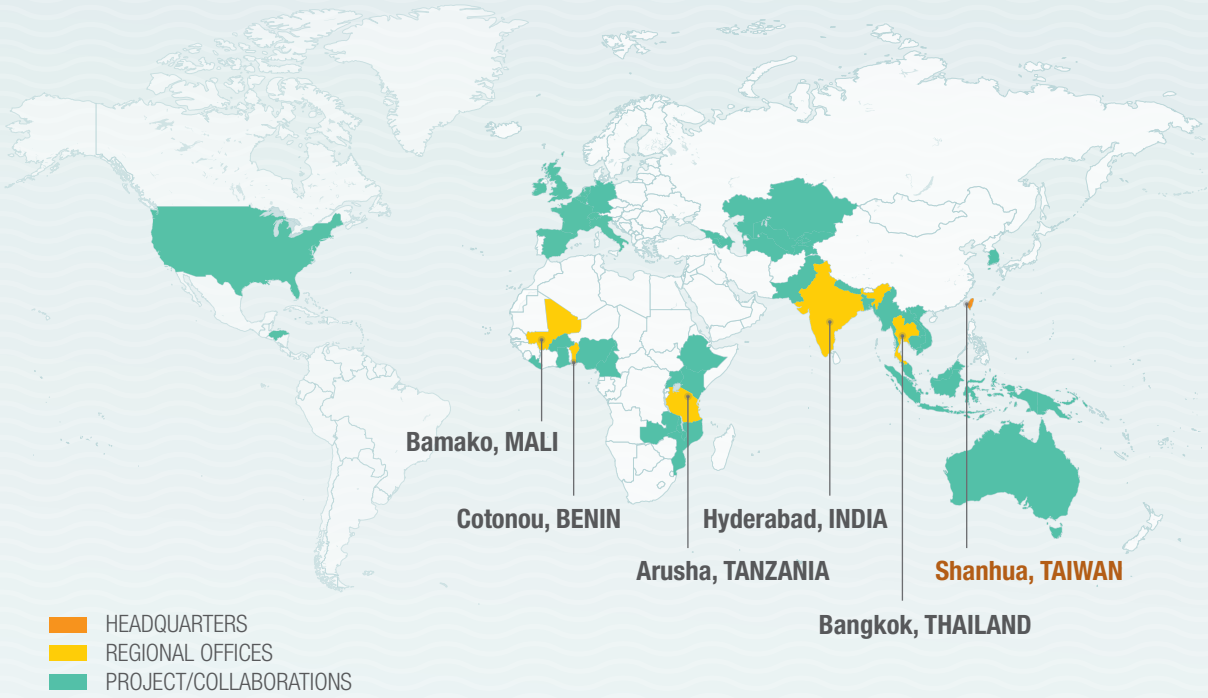
INNOVATION CLUSTER: KNOWLEDGE MANAGEMENT

Product line: Linked and searchable database

Vision: All staff are regularly using HARVEST, a searchable archive of datasets, surveys, maps, tables and other research materials including all documents produced by the Center (journal articles, reports, training materials, videos, images, presentations, apps, etc.). The system includes tools for data mining to find new links and knowledge between diverse datasets, supports ongoing learning, and fosters innovation.

Product line: Biometrics support

Vision: Biometrics services including experimental design, field plotting techniques, plot sampling methods, remedial measures for problem data, statistical analysis of data, presentation and interpretation of results lead to scientifically reliable, high quality research.



Global presence

Through its partnerships and seed distribution efforts, WorldVeg's research efforts truly have a global reach.

Field operations in Africa are coordinated from three regional centers:

- Arusha, Tanzania: focusing on Eastern and Southern Africa
- Bamako, Mali: focusing on West and Central Africa - Dry Regions
- Cotonou, Benin: focusing on West and Central Africa - Coastal and Humid Regions

Field operations in Asia are coordinated from:

- Shanhua, Taiwan (WorldVeg Headquarters): focusing on East and Southeast Asia and Oceania
- Hyderabad, India: focusing on South and Central Asia
- Bangkok, Thailand: focusing on East and Southeast Asia and Oceania

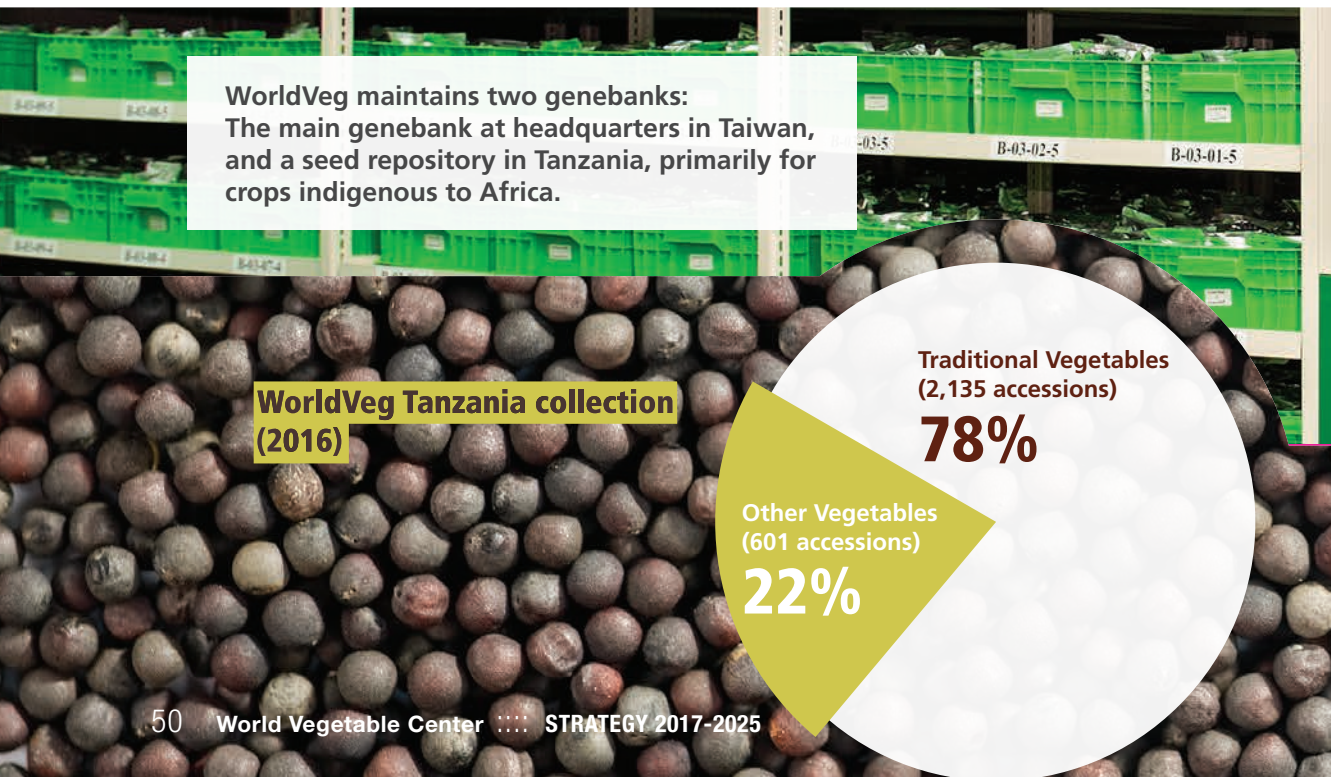
WorldVeg in brief

WHO WE ARE

-- The only international research and development center with a unique and specialized focus on vegetables
-- Nonprofit
-- Founded in 1971 by the Asian Development Bank, Japan, Korea, Philippines, Taiwan, Thailand, USA and Vietnam
-- Headquarters in Taiwan; five regional offices in Thailand, India, Tanzania, Mali and Benin; ongoing projects in over 30 countries

THE WORLD VEGETABLE CENTER GENEBANK

-- Houses the **world's largest public sector collection of vegetable seed** for global and local vegetables

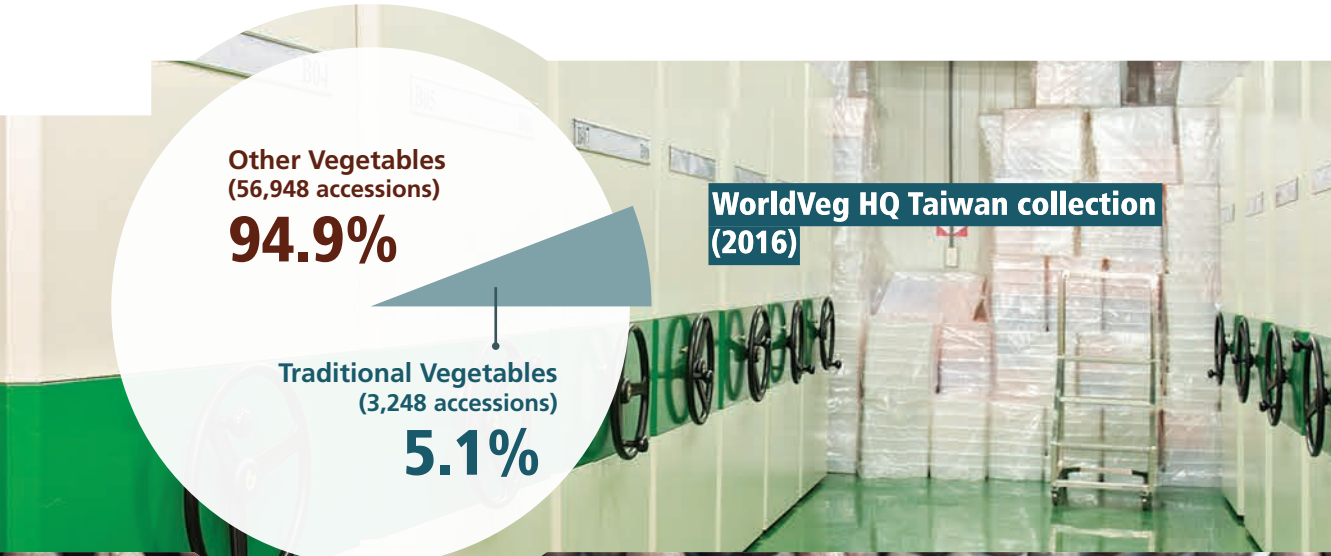


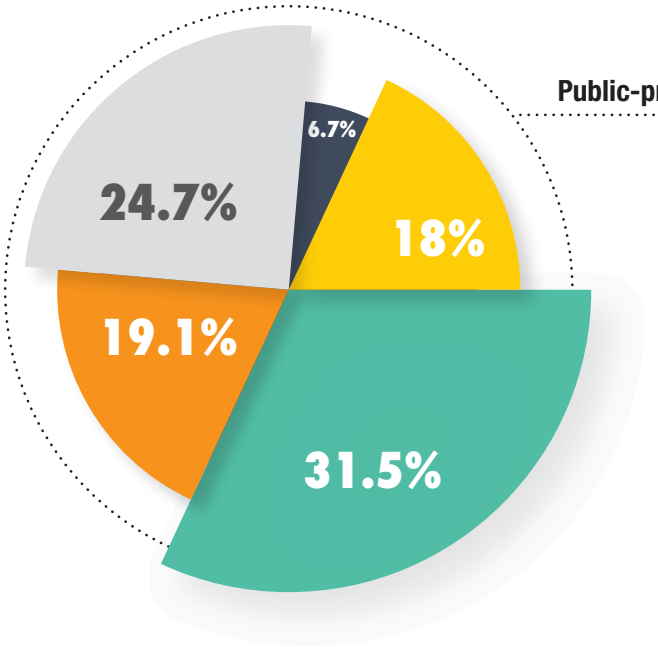
WorldVeg maintains two genebanks: The main genebank at headquarters in Taiwan, and a seed repository in Tanzania, primarily for crops indigenous to Africa.

WorldVeg Tanzania collection (2016)

SEED DISTRIBUTION
Global reach: 52 countries received seed from the WorldVeg genebank in 2015 - 2016
-- **6,000-8,000 genebank accessions and breeding lines distributed annually worldwide**
-- **More than 300,000 accessions distributed over the last 40 years**

PARTNERSHIPS
89 public-private partnerships established from 2014-2016





Public-private partnerships 2014-2016, by region

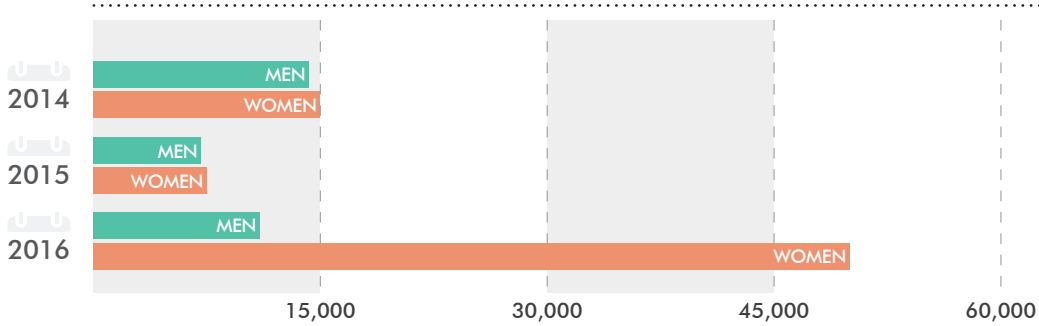
- East and Southeast Asia / Oceania
- Eastern and Southern Africa
- South Asia / Central Asia
- Headquarters
- West and Central Africa

TRAINING

-- From 2014-2016, WorldVeg and partners trained 105,675 farmers in vegetable production skills across Asia and Africa

-- 108 master's and PhD candidates received WorldVeg training from 2014-2016 (40% women)

Farmers trained by WorldVeg and partners, 2014-2016



Reaching out, scaling up with partners

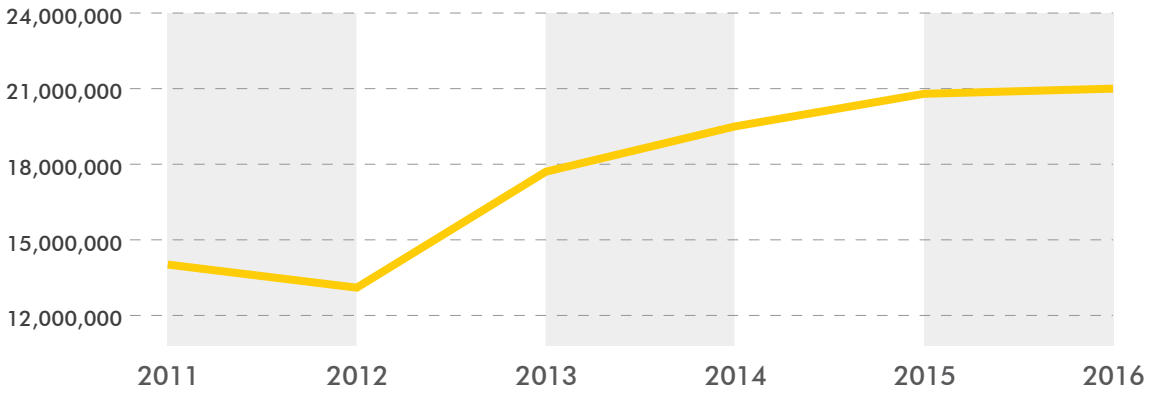
-- More than 60,000 healthy diet seed kits distributed for home and school gardens from 2014-2016
-- 370,000 disaster relief seed kits ready in storage in 2016
-- 63 technologies made available for transfer/dissemination in 2016
-- 10 new vegetable varieties (5 mungbean, 2 sweet pepper, 1 cucumber, 1 eggplant, 1 vegetable marrow) released in 2016

COMMUNICATIONS

-- Monthly unique visitors to avrdc.org: 20,000+
-- Subscribers to *Fresh*, the WorldVeg newsletter: 4,800
-- Twitter followers: 3,100+
-- Facebook followers (English + Chinese pages): 5,000 + 3,100 = 8,100

BUDGET

WorldVeg Annual Revenue, 2011 - 2016 (USD)



The World Vegetable Center is a founding member of the **Association of International Research and Development Centers for Agriculture (AIRCA)**

www.airca.org

AIRCA members

- CAB International (CABI), UK
- Tropical Agricultural Research and Higher Education Center (CATIE), Costa Rica
- Crops For the Future (CFF), Malaysia
- International Center for Biosaline Agriculture (ICBA), United Arab Emirates
- International Centre for Integrated Mountain Development (ICIMOD), Nepal
- International Center for Insect Physiology and Ecology (*icipe*), Kenya
- International Fertilizer Development Center (IFDC), USA
- International Network for Bamboo and Rattan (INBAR), China
- World Vegetable Center (WorldVeg), Taiwan

Acronyms & Definitions

AARNET	AVRDC-ASEAN Regional Network on Vegetable Research and Development
ADB	Asian Development Bank
AfDB	African Development Bank
AIRCA	Association of International Research and Development Centers for Agriculture
APAARI	Asia-Pacific Association of Agricultural Research Institutions
APSA	Asia & Pacific Seed Association
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ASEAN	Association of Southeast Asian Nations
AVRDC	Asian Vegetable Research and Development Center
CGIAR	Consultative Group on International Agricultural Research
CORAF	West and Central African Council for Agricultural Research and Development
FARA	Forum for Agricultural Research in Africa
GAP	Good Agricultural Practices
GIS	Geographic Information System
ICT	Information Communication Technology
IPM	Integrated Pest Management
IVTC	International Vegetable Training Course
MYMD	Mungbean yellow mosaic disease
QDS	Quality Declared Seed
SDGs	Sustainable Development Goals
USAID	United States Agency for International Development
WASH	Water, sanitation and hygiene
WorldVeg	World Vegetable Center

Food system	The set of activities, processes, people, and institutions involved in supplying a population with food and agricultural products. The food system encompasses the provision of farming inputs and services; production at farm level; postharvest marketing, processing, packaging, distribution and retail; and the policy, regulatory, environmental, and broader economic environment in which these activities take place.

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What's in a name?

The **World Vegetable Center (WorldVeg)** was established in 1971 as the **Asian Vegetable Research and Development Center (AVRDC)** in Shanhua, Taiwan.

To reflect its activities in Asia and beyond, in 2008 the institution began using the name **AVRDC – The World Vegetable Center**.

In 2017, recognition of the Center's expanding global reach led to a new strategy, a new logo, and a shorter, more memorable name: **World Vegetable Center**.

World Vegetable Center

Healthier lives, more resilient livelihoods

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