



Understanding Agriculture-Nutrition Linkages

Cecilia Gonzalez

In recent years, much attention has been given to the connections between agriculture and nutrition in the development sector as a whole. These connections may seem obvious: we get nourishment from the food we eat, and we eat food produced by agriculture. However, the claim that agriculture interventions (e.g. home gardens) can improve nutrition has come under scrutiny, because of the lack of evidence to substantiate it (Masset *et al.* 2012; Girard *et al.* 2012).

At the same time, recent efforts have helped us to better understand these linkages and to begin to close the evidence gaps. Agriculture plays an indispensable role in development, and though it doesn't automatically improve nutrition, its potential to do so is undeniable. The recent efforts have provided important frameworks for program design and for implementing agriculture interventions that aim to improve the nutrition of vulnerable populations. These frameworks for "nutrition-sensitive agriculture" interventions help us make sense of complex problems and identify pathways to solutions.

These "new ways" compel us to better understand the problem of malnutrition, to learn about the complexity of improving nutritional outcomes, to understand the role agriculture can play, and to collaborate across disciplines and sectors in order to design and implement interventions that can truly make an impact in improving the nutrition and well-being of the people we serve.

Malnutrition: Why Care?

Every country on earth has a malnutrition problem. In fact, malnutrition in its various

Global Malnutrition Burden in Children Under Five

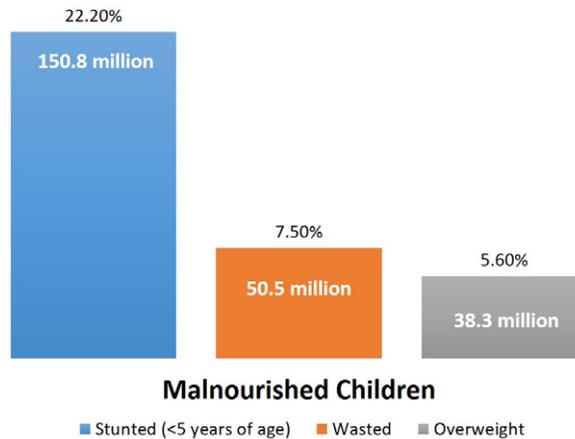


Figure 1: Global malnutrition burden in children under five. Source: Adapted from 2018 Global Nutrition Report. Development Initiatives; 2018. p. 12.

forms is the leading cause of poor health in the world! Many populations suffer from multiple malnutrition problems, such as stunting, wasting, overweight, and micronutrient deficiencies (Development Initiatives 2018a).

Undernutrition alone was found to be the direct cause of 45% of all child deaths in low and middle-income countries—almost half of child deaths (Black *et al.* 2013). According to the 2018 Global Nutrition Report, 150.8 million children under five are stunted, 50.5 million are wasted, and 38.3 million are overweight (Figure 1). 20 million babies are born with low birth weight each year. One-third of all women of reproductive age are anemic—a debilitating condition caused primarily by micronutrient deficiencies. Moreover, 39% of adults globally are overweight or obese (Development Initiatives 2018a). In 2015, there were 4 million deaths related to overweight and obesity; two-thirds of those were due to cardiovascular disease (GBD 2015 Obesity Collaborators *et al.* 2017).

Malnutrition in early childhood can irreversibly damage physical and cognitive

development, affecting a child's capacity to learn and succeed in school, increasing a person's risk of infection and disease, and generally diminishing performance and earning potential throughout the lifetime. This damage represents a great cost in terms of healthcare expenses and lost productivity. Ultimately, it affects an entire country's development and the well-being of its population (ThousandDays.org 2018).

Understanding Malnutrition

The World Health Organization (WHO) defines malnutrition as: "...deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients. The term malnutrition covers two broad groups of conditions. One is 'undernutrition'—which includes stunting (low height for age), wasting (low weight for height), underweight (low weight for age) and micronutrient deficiencies or insufficiencies (a lack of important vitamins and minerals). The other

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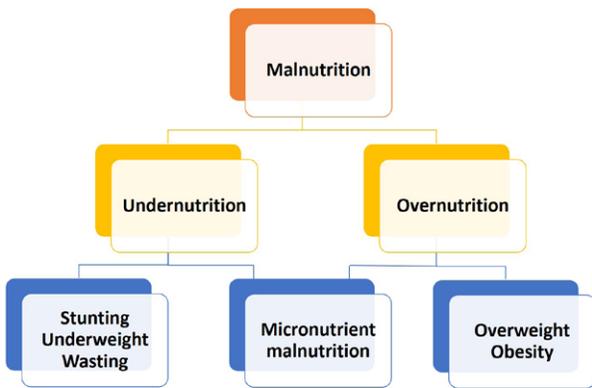


Figure 2: The various forms of malnutrition. *Source: Adapted from 2018 Global Nutrition Report. Development Initiatives; 2018. p. 3.*

is [overnutrition, which includes] overweight, obesity and diet-related non-communicable diseases (such as heart disease, stroke, diabetes and cancer)” (WHO 2016; Figure 2).

Even though malnutrition can affect anyone, certain groups are more vulnerable. These include young children, pregnant and lactating women, adolescent girls, the elderly, the immuno-compromised (e.g. people with HIV/AIDS), indigenous people, and people living in poverty. People also become vulnerable to malnutrition during or after conflicts, disasters, and famines, or when other problems affect their food and nutrition security (Development Initiatives 2018a). Malnutrition is especially dangerous for women of reproductive age and for children in their first thousand days of life (i.e. from conception to two years of age), because malnutrition in these

situations can have irreversible consequences.

UNICEF’s Conceptual Framework (Figure 3) helps us understand the complexity of malnutrition, including its causes and consequences. Immediate causes have to do not only with nutrient intake, but also with health status [someone who is sick is more vulnerable to malnutrition]. Underlying causes have to do with household food insecurity and with inadequate care practices and an unhealthy environment. Basic causes are broader than the household level; they relate to the sociocultural, economic, and political context, and also to access to services and resources, such as healthcare, education, employment, infrastructure, etc. In this framework, we can see that the consequences of malnutrition feed back into the underlying and basic causes, resulting in a vicious cycle of malnutrition and poverty (Herforth and Harris 2014; UNICEF 2013).

Nutrition-specific and Nutrition-sensitive Approaches to Malnutrition

Approaches to address malnutrition can be described as being nutrition-specific or nutrition-sensitive. *Nutrition-specific* interventions address the immediate causes of malnutrition, and some of the

underlying causes (UNICEF 2017). [The Lancet 2013 Series on Maternal and Child Nutrition](#) reported that stunting (an indicator of chronic undernutrition) can be reduced by 20% if core nutrition-specific interventions are scaled up to reach 90% of the target population (Bhutta *et al.* 2013). Examples of core nutrition-specific interventions include micronutrient supplementation for children and for women of reproductive age (e.g. zinc, iron, vitamin A, calcium and folic acid); promotion of exclusive breastfeeding during the first six months of life and of adequate complementary feeding from six months to two years of age; and prevention and treatment of severe acute malnutrition (SAM) and moderate acute malnutrition (MAM) in children (Bhutta *et al.* 2013).

Nutrition-specific interventions are essential, but on their own they are not enough to reduce chronic malnutrition to more “acceptable” levels, much less to achieve a world free of hunger. This is why *nutrition-sensitive* interventions are also necessary. Nutrition-sensitive interventions address underlying and basic causes of malnutrition by integrating nutrition goals into interventions from other sectors, such as agriculture, education, health and WASH (water, sanitation and hygiene) (UNICEF 2017).

Agriculture to Nutrition Pathways and Principles

Figure 4 depicts the current framework that helps us understand the pathways that link agriculture and nutrition (Herforth and Harris 2014). The pathways are interconnected rather than linear. An understanding of how these interactions function in a particular context would help change agents know how nutrition-sensitive agriculture activities could improve access to food and healthcare, promote adequate caring practices and contribute to an enabling environment. These could eventually improve the nutrition of the entire household, not just mothers and children.

The main pathways from agriculture to nutrition are through:

1. Food production
2. Agricultural income
3. Women's empowerment

Food Production Pathway

Food production may seem an obvious pathway from agriculture to nutrition,

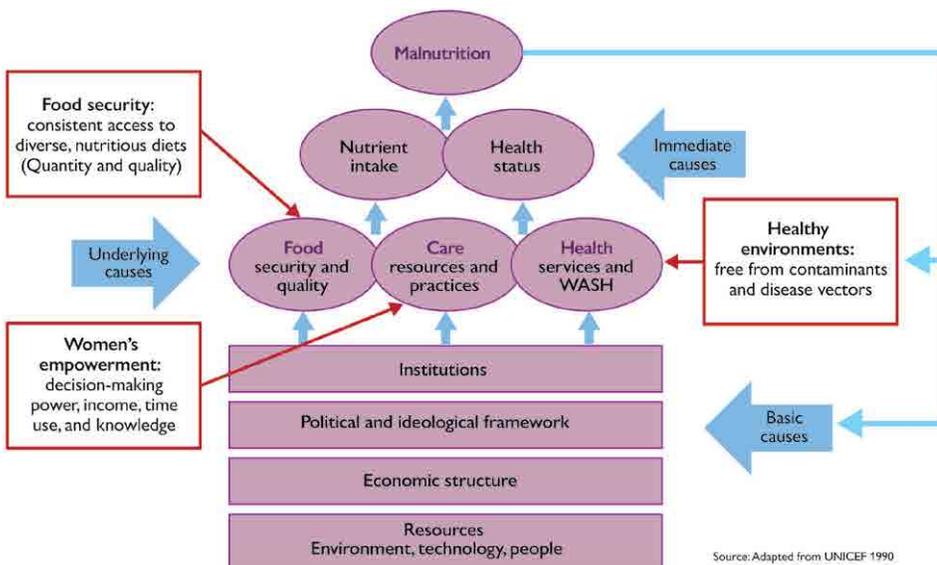


Figure 3: UNICEF’s Malnutrition Conceptual Framework. *Source: Adapted from Understanding and Applying Primary Pathways and Principles. Herforth & Harris. USAID/SPRING Project; 2014. p. 11.*

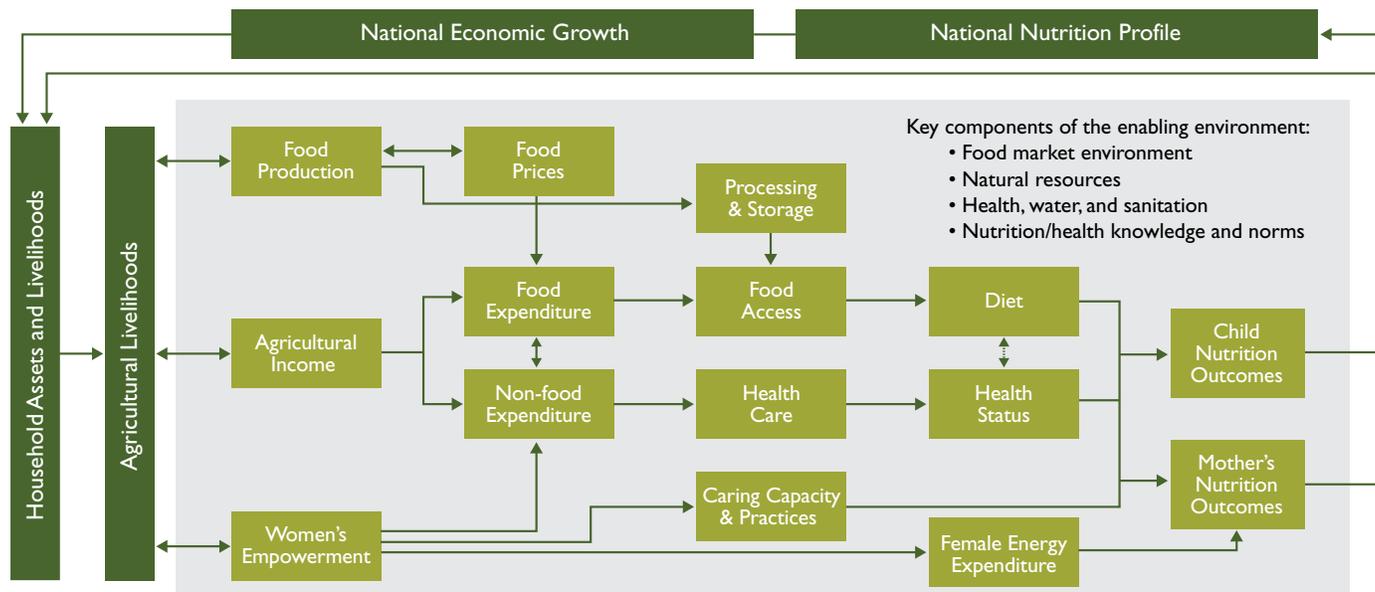


Figure 4: Conceptual Pathways between Agriculture and Nutrition. Source: *Understanding and Applying Primary Pathways and Principles*. Herforth & Harris. USAID/SPRING Project; 2014. p. 3.

because it can directly affect the quantity and kinds of food available for consumption in smallholder households. It can also affect food availability and prices in local markets due to the sale of some farm produce. Farming families do not necessarily aim to produce all the food that would meet their dietary needs, or to consume all the food they produce. While many smallholder farmers do consume a large portion of the food they produce at their farms (Figure 5), they also spend a significant amount of their income to purchase food. If we account for food produced and consumed from the farm, plus food that is purchased, many smallholder farmers are net consumers; sometimes they spend more than half of their household budget on food (Rapsomanikis 2015).

Farming families consider many factors when producing crops or livestock: costs,

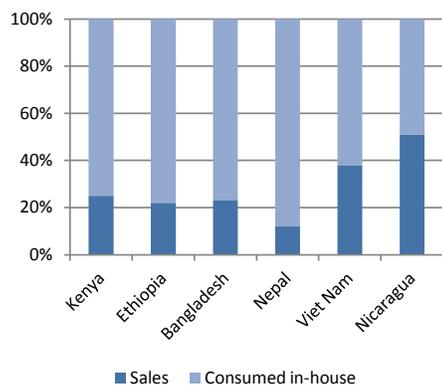


Figure 5: Smallholder agricultural production sold in markets and consumed in-house. Source: *The economic lives of smallholder farmers*. Rapsomanikis. FAO; 2015. p. 28.

risks, market prices, productive assets (e.g. land, farm tools), and their own household needs and preferences. When preferred foods are not consistently available, affordable or accessible in markets, the production pathway could be a good option to address both food and nutrition security (Herforth and Harris 2014).

Here are some examples of interventions that follow the food production pathway:

- Improving the production of a staple crop. This would increase its availability for household consumption, which would in turn increase dietary intake of protein and energy, which could result in improved nutritional outcomes.
- Promoting the cultivation and consumption of micronutrient-rich foods (e.g. from home gardens) among households that depend mainly on staple crops. This could improve the quality and diversity of the family's diet.
- Substituting a known crop or variety with a similar one that contains more iron or Vitamin A, more protein, or better-quality protein. Examples include orange-fleshed sweet potato, quality protein maize, and beans biofortified with iron.

These interventions could increase food access in farming households, if they are thoughtfully designed and if they successfully meet food production goals.

Food processing and storage, one of the steps in the food production pathway, can affect—for good or ill—how much food is available, and for how long. It can also

affect the health of the family. Post-harvest management can affect food's shelf-life, nutrient content, and safety. For example, drying a crop can increase its shelf life. However, if dried improperly, mold can grow on the crop and produce mycotoxins; when consumed, these can have acute and/or chronic effects on people's health.

Improving food access alone does not guarantee improved nutrition outcomes. As mentioned above, the pathways are not linear, and their components are interrelated. As illustrated in Figure 6, a nutrition-sensitive program needs to also consider access to healthcare and child care practices, because healthcare influences health status, and caring practices influence nutrition outcomes. Improving nutrition outcomes is the ultimate goal, so all three need to be addressed. Key components of the enabling environment also need to be considered; these include markets; natural resources; health, water, sanitation; and nutrition and health knowledge/practices.

All these pathways might seem overwhelming. You may wonder how this can possibly all be accounted for in your small agriculture program. One single organization does not need to address every aspect in the pathway. Instead, seek to understand the pathway and its interactions within this framework, and then look for ways to collaborate and partner with people who work in other areas of influence. As you complement each other's work among a target population, your joint efforts can achieve your mutual goals for improved nutrition outcomes.

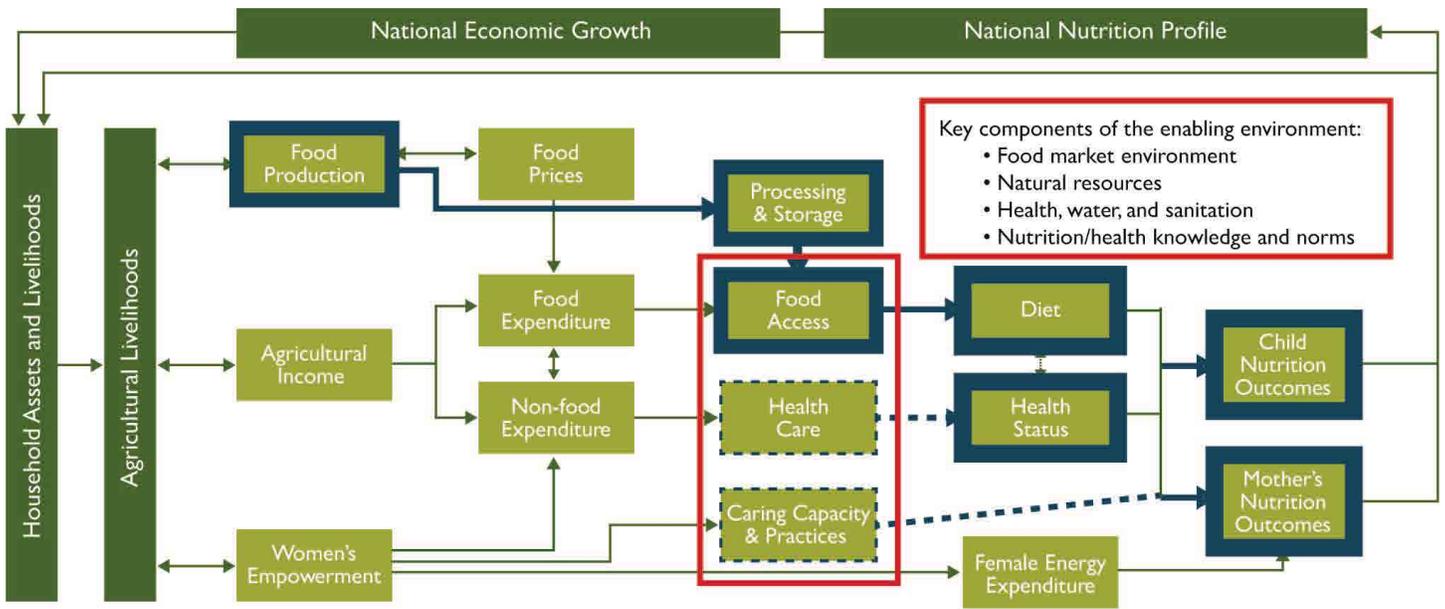


Figure 6: Food Production Pathway. Source: *Understanding and Applying Primary Pathways and Principles*. Herforth & Harris. USAID/SPRING Project; 2014. p. 3.

An example of this is the Home Gardens Program that [Maya Health Alliance \(MHA\)](#) is piloting in Guatemala. Globally, Guatemala has the sixth-highest rate of chronic malnutrition; 47% of children under five are stunted (USAID 2018; Development Initiatives 2018b), and this number rises to 70-80% among the Mayan communities that MHA serves. After implementing nutrition-specific interventions that helped reduce chronic malnutrition by 15-20% in these communities, MHA decided to design and pilot a home gardens program with the goal of improving access to a more diverse diet for better nutrition outcomes.

In 2018, MHA teamed up with ECHO and other organizations to bring diverse perspectives into the program design phase, including people with backgrounds in nutrition, public health, agriculture, and program management. Having diverse perspectives equipped the team to identify foods already being produced by the households, to understand home garden methods used by the communities, to develop a seasonal calendar, to recognize water needs (e.g. irrigation, household use), to respect women's use of time (e.g. child care), to create training tools, and to adapt the nutrition education component, among other things. All these important elements required time, mutual learning and adaptation, in order to design an evidence-based home gardens program that would complement the nutrition-specific interventions and reduce the incidence of chronic malnutrition among these communities. If successful, the

results of the process and the impact of this pilot program will be shared and scaled up to reach more communities.

Agricultural Income Pathway

The agricultural income pathway aims to increase household income, so that more money is available to meet the nutritional needs of the household—in terms of food purchases, but also of non-food purchases (for example, related to clean water and sanitation facilities) that would improve living conditions and support good nutrition.

This pathway is appropriate when diverse foods are available and affordable locally, to meet the nutritional needs of the family—women and children in particular. The pathway is best used when inputs, resources and markets work well to meet nutritional needs throughout the year. These conditions may not be optimal, and require collaborations and consideration into program design; for example, using value chain approaches (discussed below). Moreover, many smallholder farmers sell at least part of their farm products for household income (see Figure 5), and many produce cash and/or non-food crops, making the agriculture income pathway necessary for improving nutrition.

As with the food production pathway, be sure to look at the different aspects and interactions within the framework, and design programs carefully. Do not assume that increased income will automatically be spent on nutritious foods and healthcare. Consider using social and behavior change

(SBC) approaches to improve knowledge and practices related to nutrition. The [USAID Health Communication Capacity Collaborative \(HC3\) Website](#) is an excellent toolkit and training resource in this subject (USAID/HC3 2018).

Women's Empowerment Pathway

The women's empowerment pathway gives the agriculture-to-nutrition framework a gender lens. It describes the impact of women's spending power; of their responsibilities for childcare and housekeeping; and of the amount of time and energy women spend. When a program aims to increase women's income from agriculture, the women's empowerment pathway connects to the agricultural income pathway.

Studies have shown that when women have decision-making power over the household income, they are more likely than men to spend it on food and healthcare, particularly for their children. Women's ability to control household economic and productive resources (including their own time) positively correlates with improved self-care and child care practices. In general, it correlates with better decisions to invest in the nutrition, healthcare and well-being of children (Smith *et al.* 2003). This means that an initiative to increase women's control of agricultural income can enhance the income pathway to nutrition, since money will be spent for things like food and health care, which directly affect

children's nutritional status. Training that helps female and male farmers to gain farm management and business skills could also enhance this pathway (Herforth and Harris 2014).

When planning for a project that involves women, be sure to consider how much time and energy they will need to spend on agricultural activities, and also consider when the work must be done. In many parts of the world, women participate in agriculture activities, but also bear the main responsibility for child care and household care. Be careful to ensure that your agriculture program does not unduly burden women with overwhelming expectations of time or energy.

For a more in-depth explanation of the agriculture-to-nutrition pathways, please read the ["Improving Nutrition through Agriculture Technical Brief Series"](#) produced by the USAID/SPRING Project.

Value Chains for Nutrition: Expanding the Pathways

Another important aspect of agriculture to nutrition is the pathway that farm produce takes from the farm to the consumer, known as a *value chain*. A value chain is the set of steps, processes and participants that relate to a specific product (or related products), including production, transformation, transportation and sale to the consumer.

Value chains have great potential to contribute to the nutrition of vulnerable populations. For example:

- Those employed within the value chain earn income that can be used to buy food or to pay for health care, improving nutrition and health.
- A value chain can yield new and/or improved nutritious foods and products for vulnerable populations to access and consume.
- Some processes used in a value chain can reduce waste and nutrient loss, or can increase the availability of nutrients (e.g. fortification).
- Nutrition-sensitive activities can be incorporated within the value chain. For example, the value chain can include nutrition education; facilities that allow and promote breastfeeding; and marketing messages to improve the nutrition knowledge and practices of the consumer.

With the inclusion of agribusiness and markets in the agriculture-to-nutrition pathways, some have suggested that the terminology be changed from "nutrition-sensitive" agriculture to "nutrition-smart" agriculture. The latter term might encourage producers and value chain actors to adjust their business strategies, to consider the nutrition and health of vulnerable populations and of society in general, in addition to considering their own profits (Arias and Htenas 2018). Whichever term is used, *nutrition-sensitive* or *nutrition-smart*, the value chain pathway includes tools such as market and value chain analysis, and also principles and program design strategies for value chain development.

You can read more on these concepts from IFPRI's (International Food Policy Research Institute) brief, ["Value Chains for Nutrition"](#) (Hawkes and Ruel 2011). Some great resources for practitioners are MEDA's (Mennonite Economic Development Associates) toolkits for [market research](#) (MEDA 2007a) and [value chain program design](#) (MEDA 2007b), available online.

Agriculture-Nutrition Programming Principles

Now that we better understand the agriculture-nutrition pathways and nutrition-smart investments through value chains, we also need to consider the current guiding principles. These are necessary for effective program design and implementation.

1. **Incorporate explicit nutrition objectives and indicators into program design.** This ensures that improving nutrition is a priority from the beginning.
2. **Assess the local context.** What challenges and resources already exist in the community?
3. **Target the vulnerable and improve equity.** Malnutrition hits some groups harder than others.
4. **Collaborate and coordinate with other sectors.** Malnutrition has many underlying causes.
5. **Maintain or improve the natural resources base.** Safeguard water resources especially.
6. **Empower women.** The women's empowerment pathway explains why this is so important.

7. **Facilitate production diversification, and increase production of nutrient-dense crops and small-scale livestock.** Diversity contributes to resilience and to better nutrition.
8. **Improve processing, storage and preservation.** These can help retain nutrients, reduce crop losses, and decrease the time it takes to prepare nutritious meals.
9. **Expand markets for nutritious foods and market access for vulnerable groups.** This might be done through farmers' associations and/or creating value-added products.
10. **Incorporate nutrition promotion and education.** Try to build on local knowledge.

These guiding principles, the result of a multi-year consultative process led by the Food and Agriculture Organization of the United Nations (FAO), can be found in their publication, ["Key Recommendations for Improving Nutrition Through Agriculture and Food Systems"](#) (FAO 2015b).

The FAO also has an in-depth report of the consultative process results, and a checklist and guidance document for program design:

- [Synthesis of Guiding Principles on Agriculture Programming for Nutrition](#) (FAO 2013).
- [Designing Nutrition-Sensitive Agriculture Investments](#) (FAO 2015a).

Conclusion

Malnutrition is a widespread problem, with irreversible and generational consequences—especially for vulnerable populations like women and young children. Malnutrition's causes are complex, related to an individual's diet, but also to her health status and to household conditions that include food (in)security, childcare practices, and the environment. At a more basic level, the causes of malnutrition are even more complex, affected by the education system, kind of infrastructure, and availability of resources.

We need both nutrition-specific and nutrition-sensitive interventions in order to address these complex causes. Nutrition-sensitive agriculture programs can contribute to the solutions, but improving agriculture production does not automatically improve nutrition for farming families. When we

understand the agriculture-to-nutrition pathways and principles, we can design and implement programs that are more effective.

No single organization can adequately address malnutrition. We need to learn about the connections and interactions within these pathways, collaborate with other individuals and organizations that work in complementary areas (e.g. nutrition, gender equity, health, agribusiness, etc.), and become bridge builders. Only then will we be able to unleash agriculture's potential to improve the nutrition and well-being of the most vulnerable.

Training and Other Resources

If you want to dig deeper into agriculture-nutrition linkages, here is a list of free training resources:

- [Nutrition-Sensitive Agriculture Training Resource Package](#), produced by the [USAID/SPRING Project](#). This package includes the themes covered in this article and more, such as [developing a seasonal calendar](#) and [behavior change concepts](#) (USAID/SPRING Project 2018).
- USAID's Online Training Course on Nutrition-Sensitive Agricultural Programming. This interactive 3-hour video course has modules on basic nutrition concepts, agriculture-to-nutrition pathways, and nutrition-sensitive programming (USAID n.d.).
- The New Extensionist Learning Kit (NELK) by the Global Forum for Rural Advisory Services (GFRAS) recently added [Module 16: Nutrition-Sensitive Extension](#). The new module includes a manual, workbook, presentation and guide that cover some basics about nutrition and that also refer to topics discussed in this article (GFRAS 2018).
- The USAID "Integrating Gender and Nutrition within Extension and Advisory Services" (INGENAES) Project has an extensive library of documents online. Their training manuals include:
 - [Introductory Workshop on Integrating Gender and Nutrition within Agricultural Extension Services: Facilitators Guide](#) (USAID/INGENAES Project 2016b).
 - [Integrating Gender-Responsive & Nutrition-Sensitive Approaches When Working with Farmer Groups Engaged in Markets: A Training of Trainers Manual](#) (USAID/INGENAES Project 2016a).

Other helpful online resources include:

- [The Key Nutrition Resources](#) collection on [ECHOcommunity.org](#).
- [Linking Agriculture and Nutrition](#), which is a main theme of the [USAID/SPRING Project](#). This article includes many references to USAID/SPRING materials, including their agriculture-to-nutrition pathways framework.
- A [Toolkit on Nutrition-Sensitive Agriculture and Food Systems](#) has also been made available by the [FAO](#), which includes the previously mentioned [key recommendations](#) and [program design documents](#), as well as a [compendium of indicators](#) for nutrition-sensitive agriculture, [programmatic options](#), and [guidelines on understanding the causes of malnutrition](#).

Many online communities of practice are a good source of expertise and information; some also offer occasional opportunities for in-person interactions. For example:

- [The Agriculture-Nutrition Community of Practice \(Ag2Nut CoP\)](#) is an independently run and diverse community. The Ag2Nut Community platform allows members to connect with each other via its online platform, email, and webinars.
- [The Agriculture, Nutrition & Health \(ANH\) Academy](#) is a global research network that helps academics and practitioners connect through their learning and sharing platform.
- [Innovative Methods and Metrics for Agriculture and Nutrition Actions \(IMMANA\)](#) is a research initiative trying to close evidence gaps and to generate new scientific evidence in agriculture-to-nutrition linkages.

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2018 ECHO International Agriculture Conference: Topic Summaries

by ECHO Staff

ECHO's 25th Annual International Agriculture Conference was held in November 2018. Below are brief descriptions of a few of the morning plenary sessions. For these and other talks, video and slide presentations are available on ECHOcommunity.org.

Seed2Save—an 'old school' approach to vegetable seed development (Mike Mueller)

Mike Mueller, Founder and Executive Director of [Hope Seeds](http://HopeSeeds.org), has been involved in the vegetable seed industry for 40 years, much of it involving seed development. Since Hope Seeds began in 1999, Mike has put his extensive knowledge of the seed industry to use in providing over 10 million packets of seed through 400 ministries and agricultural workers in 60 countries, and in the USA.

Mike described characteristics to look for when evaluating "good seed." Good seed



Figure 7. Mike Mueller training gardeners in Haiti how to save seed of bell pepper. Source: *Hope Seeds*

will be appropriate to the local land, climate, day length, and culture. It will be free of weed seed. Good seed will germinate well and will grow into plants that are true to their type and that grow with vigor.

Mike's talk on "Seed2Save" emphasized two simple and time-tested methods that farmers can use to select and develop vegetable varieties. The first, called random mass selection, involves saving seeds from the best plants in a garden or field. Farmers walk their fields, selecting plants with traits they like (marking such plants so later the seed may be saved), and removing plants with traits they do not like. By saving seeds from intentionally-selected plants, over time a farmer will end up with his or her own selection that has qualities suited to the local context. Helpful qualities to select for include disease resistance, insect tolerance, good flavor, high productivity, local marketability, and a pleasing appearance.

The second method is called population breeding. A farmer plants multiple selections of seed of a specific target species at the same time. When the plants grow, the farmer removes any selections that perform poorly, then allows the remaining selections to cross pollinate. The resulting seeds are planted, grown out, and seeds saved from the most desirable plants. Over time, this method allows a farmer to breed his or her own strain of plants with a unique combination of traits from each selection. Examples of these and other breeding techniques are available in Mike's talk.

The Answer is in the Room (Dr. Karen Stoufer)

Dr. Karen Stoufer, director of training and Asia area director for Christian Veterinary Mission, outlined twelve principles of dialogue-led adult education that can

help any trainer to disseminate content effectively, and to also respect and connect with the people being trained.

The principles shared by Karen were developed by Dr. Jane Vella. They encourage agricultural development workers to approach training in a new way: facilitating the learner's own self-discovery of answers rather than delivering information from the "top down." The principles, briefly described below, were modeled during Karen's talk, as delegates were periodically encouraged to discuss a topic in small groups. Keywords of each principle are in bold font.

1. Spend time conducting a **needs assessment**. Ask learners what they would like to learn. Before teaching anything, observe the learners' context to discover and respect what is already known.
2. People need to feel a sense of **safety** in order to participate in the learning process. Trainers can establish a safe environment by being inclusive and giving non-judgmental affirmation.
3. Training must be seen as an exchange in the context of **sound relationships**. While a trainer offers information, the learners offer insight into the problems they face, what local resources are available, and how the trainer can better train within their context.
4. Learning happens best when it takes place in **sequence**, meaning that a learning task is done in small steps that progress from simple to complex. **Reinforcement** is also important in that trainees are exposed to the same information in various ways in order to retain their interest and lead them to a mastery of the material. Sometimes this includes games, or having trainees correct their own work.
5. The Greek word **PRAXIS** means "action with reflection." This

encapsulates how adults learn. Ask learners about what they saw, why it happened, and what they're going to do about it.

6. Instead of viewing learners as objects that passively receive education, trainers can show **respect for learners** by treating them as subjects, and as the ones who are responsible for their own education. Don't do something for the learner that the learner can do for themselves.
7. Any topic has three components that need to be taught: head **knowledge**, practical hands-on **skills**, and a heart **attitude**.
8. Adult learners put effort into learning what is relevant. **Immediacy** affects what trainers teach and when they teach it. For example, training on harvesting and storage makes the most sense shortly before harvest season.
9. Since many trainees might be used to viewing a trainer as being on a different level than themselves, **clear roles** are important--in this case, making clear that trainers and trainees are equals. To help with this, trainers might choose to call themselves facilitators rather than teachers. Trainers can also sit with trainees during meals and assist with chores.
10. Since everyone attending a training has different gifts, **teamwork** is an important principle for learners to experience. Positive, non-divisive competition can be a good technique to encourage collaboration in problem solving.
11. **Engagement** refers to the passion and excitement that learners experience when the aforementioned principles intersect in a training setting.
12. **Accountability** is necessary. In particular, trainers are accountable to trainees to provide the learning environment they said they would offer.

Other Resources

Learning to Listen Learning to Teach: The Power of Dialogue in Educating Adults by Dr. Jane Vella

Christian Veterinary Mission has a free E-learning curriculum available at <https://cvmusa.org/elearning/>. Look up

"participatory learning." You will need to sign up for a free account in order to access the online course.

Adoption of amaranth in the local context of Oaxaca, Mexico (Pete Noll)

Pete Noll, executive director of [Puente a la salud comunitaria](#) (Bridges to Community Health), has promoted amaranth for 10 years. He started his plenary talk by expressing deep admiration for those who farm, because it is not an easy job. He also shared his belief that solutions to existing problems are often closer than we might think.

Amaranth can be one solution. Pete stressed that amaranth is not a "silver bullet," but that it does have multiple helpful attributes. He described the way that amaranth can be part of many related initiatives, including improved nutrition, economic development, sustainable agriculture, and social equity.

Puente is located in Oaxaca, Mexico, which Pete described as being rich in diversity, culture, community, and social values. Puente's amaranth (*Amaranthus cruentus*) initiatives take place primarily in two areas of Oaxaca. Amaranth is a context-appropriate crop to promote in Oaxaca for many reasons. It is culturally and historically significant to the region; the ancient Aztecs prized amaranth and used it extensively. Amaranth is very nutritious, with both grains and leaves supplying needed protein, minerals and vitamins--and Pete mentioned a variety from which a portion of leaves can be harvested without decreasing grain yields. Amaranth is a C4 plant, well-adapted to hot, dry environments. It also integrates well into local milpa systems (traditional Mesoamerican polycultures). In Oaxaca, amaranth has economic potential.

Puente works towards a local, healthy food system by 1) prioritizing the farming of amaranth in ways that sustain agroecosystems, 2) educating families to

increase local consumption of amaranth and to improve families' nutrition, and 3) building access to markets and commercialization (Figure 8). Puente consciously puts families at the center of their approach, rather than money; Pete referred to this as "social and solidarity economics."

Puente is involved in many different activities in pursuit of a healthy local food system. Farmer-to-farmer exchanges spread knowledge about production practices. [Chromatography](#) is used to evaluate soil health; results give farmers information about organic matter content, microbial health, minerals, and nutrient accessibility and assimilation. Farmers take samples every six months. Over time, farmers are able to see evidence of soil health improvement. Puente has developed a curriculum for a three-week summer nutrition program for children. Puente also has other initiatives, including seed banks, bio-factories (for production of compost), mineral rock processing (a microenterprise that yields agricultural inputs), and appropriate technologies. Puente's "systems thinking" approach has led them to establish partnerships with organizations that work in public policy.

Other Resources:

Amaranth institute <http://www.amaranthinstitute.org/>

Collection of Amaranth resources: <http://edn.link/amaranth>

15 underutilized crops for improving the lives of smallholder farm families (Josh Jamison)

Josh Jamison from [HEART](#) (Hunger Education and Resources Training) Village gave a plenary talk about underutilized crops. Using the potato as an example, he reminded delegates that introduction of a new crop can significantly impact food security (as the potato did when it was introduced in Europe), but cautioned that crop diversity is essential for food security (crop diversity was lacking in Ireland when the blight hit that led to the Irish potato famine).

For the majority of his talk, Josh shared 14 perennial crops that have great potential to improve the lives of smallholder farm families. Some, like chaya and katuk, ECHO has promoted for years. Others would have been less familiar to those in ECHO's network. For example:



Figure 8. Parts of Puente's approach to a healthy food system.
Source: Courtesy of Pete Knoll

***Mulberry** (*Morus* spp.), some cultivars of which produce early and have very large fruits. Mulberry leaves are extremely nutritious and are edible--though some taste much better than others. [Varieties with long fruits are cultivated and sold in Southeast Asia, but may be difficult to find elsewhere. To find varieties with good-tasting leaves, Josh suggests that you pick young leaves from several different mulberry plants, steam the leaves, and taste and compare them. Continue until you find ones you like. The species *Morus alba* is known for edible leaves.] The leaves also make excellent animal forage. Mulberry grows in



Figure 9. Mulberry varieties yield fruits of differing shapes and sizes. Source: Josh Jamison

almost every climate. Josh suggested that it could potentially be for cold climates what moringa is in the tropics.

***Papaya** is a well-known tropical fruit, but Josh shared that careful management of good varieties can result in huge amounts of fruit, available year-round. This kind of targeted management requires planting new papaya trees every year. Josh shared a trick for controlling fruit flies: put sticky glue on a green ball and wedge it between two branches; the fruit flies will mistake it for a papaya and try to lay eggs on it.



Figure 10. Photos showing a poorly managed papaya tree (left) and a carefully managed papaya tree (right). Source: Josh Jamison

***Breadfruit** and **breadnut** (*Artocarpus* spp.). Breadfruit trees produce large starchy fruits, and breadnuts produce life-sustaining nuts. Both can yield for decades, with low labor input. Breadfruit can be grafted onto breadnut rootstock. [This is helpful because breadnut plants are easier to propagate and have a taproot--so grafting breadfruit onto breadnut rootstock makes it easier to multiply breadfruit and may make the resulting plant more drought-tolerant.]

***True yams** (*Dioscorea* spp.) will continue to grow as long as they are in the ground, and are excellent to have growing for an emergency food. Once dug up, tubers can often be stored for months. More than 60 edible species exist.

Josh stressed the importance of looking for improved varieties of crops that have larger fruits, better taste, and higher yields. He ended his talk by encouraging delegates to experiment and find their own favorite perennial, underutilized crops. The world is full of amazing diversity, so get curious!

ECHOES FROM OUR NETWORK

Intercropping Native Shrubs: A Local Resource that Bioirrigates Adjacent Crops, Increases Yields and Remediate Degraded Soils

Ibrahima Diedhiou, Univ. of Thies, Senegal
Nathan Bogie, Univ. of California, Merced, USA
Teamrat Ghezzehei, Univ. of California, Merced, USA
Amanda Davey, Ohio State Univ., USA
Richard Dick, Ohio State Univ., USA

More than 4 million people in the West African Sahel are facing hardship following dry spells and increased food prices. In June, the FAO sent nearly \$10 million in aid for drought-stricken farmers in the region, who depend upon rainfed agriculture. Recurring drought, increased populations, and degraded landscapes are ongoing threats for the semi-arid region. Throughout the Sahel, total production has dramatically decreased over the last 50 years, leading to a loss in resiliency for farming communities. The land consists of nutrient-poor soils with low fertilizer inputs. Farmers desperately need agricultural systems that can improve yields and conserve soil using locally available resources.

Fortunately, a shrub-intercropping system has been scientifically validated that meets

the ecological and food security challenges of the Sahel. The system is based on two shrubs that dominate and co-exist with crops throughout the Sahel (though their densities are low): *Guiera senegalensis* and *Piliostigma reticulatum*. Although farmers recognize the value of shrubs, they typically coppice them in the spring to clear fields, then burn the residue, depriving soils of needed organic inputs. Our research, funded by the National Science Foundation, has shown multiple benefits of an Optimized Shrub System (OSS; Figure 11) in which shrub density is increased from current levels (<200-350 shrub/ha) to about 1500 shrubs/ha, and in which coppiced shrub biomass is annually incorporated into the soil. With the OSS, we have seen that



Figure 11. Millet intercropped with *Guiera senegalensis*. Source: Matthew Bright

soil quality improves, more carbon (C) is sequestered, microbial diversity and activity increase, more nutrients are available, water availability improves, and yields increase up to three-fold (28 peer-reviewed articles [See the further reading section for publications with more information on how shrubs were integrated with grain crops.]). A truly remarkable finding, and the focus of this article, is that **the shrubs “bio-irrigate” crops via hydraulic lift at night**; combined with improved soil quality, this significantly reduces crop water stress during in-season drought.

The process called hydraulic lift (also known as hydraulic redistribution) occurs when shrubs move water from the wet deep subsoil up through their root systems. The roots release water into the dry upper soil layers at night when leaf stomata close and photosynthesis stops. Hydraulic lift has been found in environments that undergo periodic droughts. It has been shown to increase the ability of shallow roots to take up nutrients and to maintain higher levels of transpiration and photosynthesis.

We hypothesized that each day, nearby pearl millet (*Pennisetum glaucum*) crops take advantage of some of the water that is drawn to the surface by the shrubs. To test

our hypothesis, we set up an experiment in Senegal during the dry season. This allowed us simulate drought conditions and, in the absence of rainfall, to precisely control the timing and amounts of water delivered via low-volume irrigation (Figure 12). We monitored the soil moisture with sensors. Once we observed the daily drying and nightly re-wetting of the soil that is characteristic of hydraulic lift, we began our study. First, we attached bottles---with deuterium-labeled water---to the deep roots of the shrub as shown in Figure 13. The deuterium (“heavy hydrogen”) in the water could then be measured in plant tissue to trace the movement of the labeled water. Then, over a five-day period, we collected above ground leaf samples from the shrub and from adjacent millet plants. The leaves were analyzed for the tracer (deuterium). We found evidence of the tracer in a shrub on the first day after injecting the labeled water, and just one day later we found the tracer in the nearby millet. This finding confirms that water lifted hydraulically by shrubs can be transferred to the adjacent millet crop. We do not yet know the exact route of the water from the shrub roots to the crop, but we are confident that a pathway exists. Although hydraulic lift has been documented in many ecosystems, this study was the first to show that interplanted woody species in an agricultural field could “irrigate” adjacent crops with water obtained through hydraulic lift.



Figure 12. Millet grown for a hydraulic lift tracer study under irrigation midseason 2014. Note the contrast between millet grown without (left) and with (right) shrubs. *Source: Nathaniel Bogie*

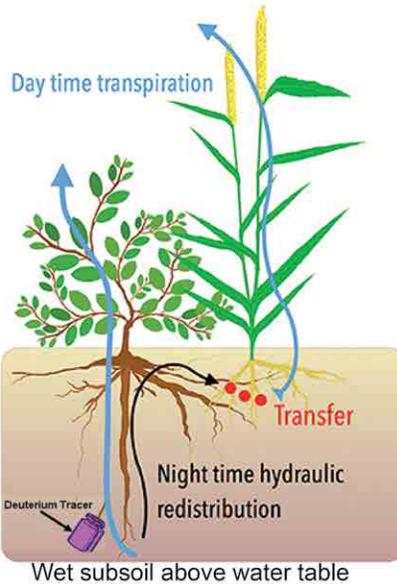


Figure 13. Diagram showing the hydraulic lift, and transfer to millet plants, of deuterium-labeled water from a vial attached to shrub roots about 1 m below the soil surface. *Source: Bogie et al. 2018*

We have conducted long-term studies on *Guiera senegalensis* and *Piliostigma reticulatum* interplanted with a groundnut-pearl millet rotation. Crops interplanted with the shrubs have shown dramatic yield increases, with or without added fertilizers. The system has also helped remediate degraded soils, as shown by a doubling of the total amount of carbon in the topsoil with 10 years of shrub intercropping. The sequestration of carbon in the soil is an important mechanism for capturing atmospheric carbon dioxide to offset global climate change.

We now understand many fundamental mechanisms of the OSS rhizosphere hydrology and soil microbiology. With that knowledge base, we are ready to pilot

and begin to scale the system. To that end, we created the [Agro-Shrub Alliance](#), a non-profit organization that provides on-farm research and technical training on shrub-based farming to smallholder farming families across the West African Sahel. Our Alliance of researchers, extension specialists, and farmers is currently working on designing OSS Farmer Field Schools for first-ever, on-farm trials of the. In conjunction with these initial trainings, we will conduct the necessary socio-economic analyses and incorporate indigenous knowledge for locally adapted OSS. Our ultimate objective is to work collaboratively with farmers to develop outreach platforms that enable widespread adaptation and adoption of the OSS from Senegal to Chad, with the potential to reach 5 million smallholder farm families and regenerate the natural resource base for future generations. Please visit our website and the resources below to learn more about the OSS.

Further reading:

Bogie, N.A, R. Bayala, I.Diedhiou, M.H. Conklin, M.L. Fogel, R.P. Dick, and T.A. Ghezzehei. 2018. [Hydraulic Redistribution by Native Sahelian Shrubs: Bioirrigation to Resist In-Season Drought](#). *Front. Environ. Sci.* 6:98.

Bright, M., I. Diedhiou, R. Bayala, K. Assigbetse, L. Chapuis-Lardy, Y. Ndour, and R.P. Dick. 2017. [Long-term *Piliostigma reticulatum* intercropping in the Sahel: Crop productivity, carbon sequestration, nutrient cycling, and soil quality](#). *Agriculture, Ecosystems and Environment* 242:9–22.

Dossa, E.L., I. Diedhiou, M. Khouma, M. Sene, A. Lufafa, F. Kizito, S.A.N. Samba, A.N. Badiane, S. Diedhiou, and R.P. Dick. 2012. [Crop Productivity and Nutrient Dynamics in a Shrub \(*Guiera senegalensis*\)–Based Farming System of the Sahel](#). *Agron. J* 104:1255–1264.

FROM ECHO'S SEED BANK

Sorting Out the Annonas

by Gene Fifer

The ECHO Online Seed Catalog is offering an addition to our collection of Annonas, which are in the pawpaw/sugar apple family, Annonaceae. [Rollinia mucosa](#), commonly called biriba, rollinia, or wild sugar apple, can grow in either sun or shade and is a larger tree than many in this family. Biriba's fruit turns yellow when ripe, unlike the light green color of other Annonas (Figure 14). The fruits' white flesh is sweet, juicy, and creamy. However, it rapidly over-ripens,

causing the flesh to turn clear and slimy; this limits its use for home consumption.

ECHO's seed bank carries several other Annonas. Sweetsop, sugar apple, or anon ([Annona squamosa](#)), a dessert fruit, is best pureed or used in juices after the many seeds are removed. Custard apple ([Annona reticulata](#)) produces large fruits that are eaten fresh or made into smoothies, milkshakes, and custards. Soursop or guanabana ([Annona muricata](#)), another large-fruited Annona, is best suited to the hot, humid tropics; the small size of the tree makes harvesting easy, and the

fruit is used in a wide variety of desserts and drinks. The [atemoya](#), a hybrid between



Figure 14. Ripe biriba. *Source: Tony Rodd, Creative Commons Attribution License*

Annona cherimola and *Annona squamosa*, is heat sensitive but cold tolerant, making it suitable for higher elevation production

in the tropics. Atemoya is eaten fresh and made into ice cream.

Annonas are an excellent addition to a family home garden, food forest, or

smallholder market garden. Follow the links and choose the species that best suits your climate, available space, and culinary preferences.

BOOKS, WEB SITES AND OTHER RESOURCES

Nic Dexter leads the [Feed the Future Mozambique Resilient Agricultural Markets Activity](#)--Beira Corridor project. Through the support of the American people and the United States Agency for International Development (USAID), the project helps producers in Mozambique increase their productivity and profitability while increasing their resilience to climate change through conservation agriculture. Nic recently shared several technical briefs developed by the project, which have been translated from the original Portuguese. The documents are concisely written and include attractive photos and graphs. We have posted them (with permission) on [ECHOcommunity.org](#). The documents include the following:

"Push and Pull" in Combatting Fall Army Worm and Witchweed (Striga)

In the Push-Pull system, crops that repel pests and/or attract pests' predators are intercropped with maize, to 'push' pests away from the main crop. Plants that attract pests are planted around the field, to 'pull' pests away from the maize. Incorporating legumes in this system means that soil fertility gradually increases over time.

This brief also explains how a farmer in Mozambique managed her pigeon pea plants to repel fall armyworms. She tried sowing maize between pigeon pea plants that, after a previous season's growth, were cut to a height of 50 cm and allowed to regrow. For reasons explained in the brief, this worked better than starting pigeon pea from seed each season.

How to Process Jack Bean (and other types of Beans) as Human Food

Jack bean is an excellent plant for enriching soil, because it grows under very difficult conditions. However, the beans contain toxins that normally make them unsuitable for human consumption. This document describes how to germinate jack bean to remove the toxins and increase the beans' nutrition. Germinated beans also cook more quickly, saving time and money. [Note: Feed the Future also has a more extensive document on this subject, which we hope to summarize in a future issue of *EDN*.]

Minimal Soil Disturbance and its Effect on Soil Moisture Availability

This short document contains graphs that show how zero tillage leads to increased water infiltration and increased water retention in soil.

The Green Manure/Cover Crop Approach in RAMA-BC

This document distinguishes between 'anchor' cover crops (that are intercropped with a main crop such as maize) and 'secondary' cover crops (that don't compete with the main crop because they have a short life cycle, and that can help cover the soil at the start of the growing season). The document also includes short summaries of five cover crops: jack bean, pigeon pea, lablab bean, cowpea, and mung bean.

[Farmers'] Own Soil Fertility Analysis

Four nutrient deficiencies--phosphorus, potassium, nitrogen, and magnesium--can be diagnosed by observing maize leaves. This document includes photos of a healthy maize leaf and of maize leaves demonstrating each of these nutrient deficiencies. It also contains suggestions for how to address each type of deficiency.

UPCOMING EVENTS

ECHO Florida Events:

Location: ECHO Global Farm, USA

Agroforestry

July 22 - 26, 2019

Seed Saving & Banking

September 16 - 20, 2019

TAD I: The basics

October 28 - November 1, 2019

26th Annual International Agriculture Conference

November 19 - 21, 2019

ECHO East Africa Event:

5th ECHO East Africa Symposium on Sustainable Agriculture and Appropriate Technologies

February 12 - 14, 2019

Location: Naura Springs Hotel, Arusha, Tanzania

ECHO Asia Event:

Agriculture & Community Development Conference

October 1-4, 2019

Chiang Mai, Thailand

ECHO West Africa Workshops:

Tamale, Ghana

February 19-21, 2019

Beating Famine

February 26-27, 2019

Bamako, Mali

March 5-7, 2019

Gbarnga City, Liberia

April 2-4, 2019

Bouake, Cote D'Ivoire

May 7-9, 2019

Jos, Nigeria

May 21-24, 2019

Please contact Noemi Kara (knoemi@echonet.org) for information on trainings.

This issue is copyrighted 2019. Selected material from *EDN* 1-100 is featured in the book *Agricultural Options for Small-Scale Farmers*, available from our bookstore (www.echobooks.net) at a cost of \$19.95 plus postage. Individual issues of *EDN* may be downloaded from our website (www.ECHOcommunity.org) as pdf documents in English (51-142), French (91-141) and Spanish (47-141). Earlier issues (1-51 in English) are compiled in the book *Amaranth to Zai Holes*, also available on our website. ECHO is a non-profit Christian organization.

PLEASE NOTE: At ECHO we are always striving to be more effective. Do you have ideas that could help others, or have you experimented with an idea you read about in *EDN*? What did or did not work for you? Please let us know the results!