FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative

Feed the Future Learning Agenda Literature Review: Improved Nutrition and Diet Quality

August 2013

USAID
FROM THE AMERICAN PEOPLE

This publication was produced for review by the United States Agency for International Development. It was prepared by Douglas Taren with Halima Alaofè for the Feed the Future FEEDBACK project. The authors' views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or of the United States Government.

Prepared for the United States Agency for International Development, USAID Contract Number GS-23F-8144H/AID-OAA-M-12-00006, Feed the Future FEEDBACK

Recommended Citation:

Taren, D. and Alaofè, H. August 2013. Feed the Future Learning Agenda Literature Review: Improved Nutrition and Diet Quality. Rockville, MD: Westat.

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LIST OF ACRONYMS

ANH	Agriculture, nutrition, and health
BFS	Bureau for Food Security
BMI	Body mass index
CBP	Community-based program
CBPR	Community-based participatory research
CCT	Conditional cash transfer
CHW	Community health worker
FAO	Food and Agriculture Organization
GAIN	Global Alliance for Improved Nutrition
GDP	Gross domestic product
HKI	Helen Keller International
ICT	Information and communication technology
IEC	Information, education, and counseling
LMIC	Low and middle income countries
M&E	Monitoring and evaluation
NGO	Non-governmental organization
NUSSDI	Nutrition-Sensitive Social Development Index
OFSP	Orange-fleshed sweet potato
REACH	Renewed Efforts against Child Hunger (Sierra Leone)
RUTF	Ready-to-use therapeutic food
SUN	Scaling Up Nutrition
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
WASH	Water, sanitation, and hygiene
WFP	World Food Programme
WHO	World Health Organization

MAIN FINDINGS AND CONCLUSIONS

To ensure that impact evaluations the U.S. Government's Feed the Future initiative is undertaking are well-conceived, build on existing evidence, and fill critical evidence gaps, the Bureau for Food Security (BFS) of the United States Agency for International Development (USAID) is providing resources for a comprehensive assessment of existing evidence and gaps in knowledge for each of six themes covered by the Feed the Future Learning Agenda. Concerned staff of USAID in headquarters and country missions and staff of USAID's implementing partners are expected to be the primary users.

The stated aim of Feed the Future is to tackle the root causes of global hunger and poverty through inclusive agriculture sector growth and improved nutritional status. This paper summarizes available evidence that relates to key questions for the Feed the Future Learning Agenda theme on nutrition and dietary quality.

The review integrates evidence from clinical, community, and national studies that link agriculture interventions with nutritional status, dietary diversity, and health. Studies included in this review provide data on what is known and, by omission, the gaps in knowledge about what works and why some programs do not work. These studies include survey data and data from various experimental models, evaluation data from national and sub-national interventions, and outcomes from a variety of systematic reviews of interventions. The focus of the review is on what is happening in low and middle income countries (LMICs).

The primary goal for this review is to provide decision makers with information on how to move forward with future policies and interventions. It will identify gaps that need to be filled by basic, applied, and operational research and will help in prioritizing new information that is needed from monitoring and evaluation (M&E) activities.

Integrated agriculture, nutrition, and health approaches. In the last few years, there has been growing recognition that agriculture, nutrition, and health are interrelated, and a convergence of thought on how to use a food systems lens to combine agriculture, health care, and nutrition interventions that have demonstrated individual impact so as to provide for large-scale improvements in nutritional status, particularly for mothers and children. Biofortification, increasing the consumption of animal products, and horticulture interventions are the most common methods that are being used to increase nutrition and dietary diversity of smallholder farmers and the nonfarming poor.

Biofortification interventions are starting to show how they can improve health and nutrition. Orange-fleshed sweet potato (OFSP), orange corn, and other plants can significantly increase the β-carotene (which the body converts into vitamin A), iron, and zinc status of target populations. There is also the potential to increase the protein content of diets with high-protein maize. However, there is still insufficient evidence to assess the nutritional impact of biofortification interventions at the community level. In addition, little is known about how well farmers and consumers will accept biofortified crops and limited comparative evidence is available on how these crops impact overall yields and farm profits. Only a few studies report evidence on the nutritional impact of biofortification programs, although these results tend to be positive. There is still a need to conduct additional impact evaluations of biofortification under different climatic and socio-economic conditions in order to assess its acceptance by farmers and its effectiveness in improving nutritional status for at-risk populations within community settings in sustainable ways. Additional studies also need to be done on the consumer response to biofortified foods to determine local factors affecting consumers' willingness to pay for more nutritious foods.

Livestock and aquaculture interventions (including aquaponics) have the potential to improve diet quality and increase micronutrient intake. The range of livestock and aquaculture interventions that have been evaluated with respect to their impacts on nutrition include poultry, milk production from cows and goats, and small fish production. Livestock and aquaculture interventions can impact dietary diversity and nutritional status through smallholder households' consumption of their own production and through new income from sales that is used to purchase a greater variety of foods. There is little information on how decisions are made regarding which pathway is taken.

The livestock and aquaculture interventions associated with marked improvement in dietary intake and nutritional status have several common characteristics: (1) women have a critical role in the intervention, (2) the intervention includes a nutrition education component, (3) the intervention targets the least nourished, and (4) the beneficiaries have some familiarity with the agriculture systems being proposed.

Both livestock and horticulture interventions are more likely to increase food diversity when nutrition is explicitly part of the planned outcomes. Dietary diversity also is more likely to occur when the fruits and vegetables that are planted are already familiar to the targeted populations. Despite the existence of a wide variety of fruit and vegetable production systems, only homestead garden production systems have been implemented and evaluated with explicit nutrition objectives at the household level. These interventions generally have been designed to impact nutrition by producing food for household consumption and, secondarily, from increased income by selling the produce. Small horticulture programs include fruits, vegetables, herbs, condiments, and sometimes secondary staples like legumes and sweet potatoes. The positive nutritional impact of homestead gardens has been well documented, but results have not been consistent. Positive results depend on targeting vulnerable populations with the appropriate intervention.

Many gaps in knowledge still remain about how agriculture and nutrition programs can work together. More studies are needed to determine how to maintain the biodiversity of crops and to incorporate identification and measurement of nutritional outcomes into programs promoting biodiversity. There is a need to determine how to increase the role of women in developing programs and have them be partners in implementing and evaluating interventions.

Water and sanitation interventions need to be planned together with agriculture interventions so as to decrease the incidence of disease and improve nutritional status. Other integrated agriculture and nutrition programs that use multidisciplinary and cross-sector approaches need to be evaluated more systematically to determine which combinations of interventions work best together. Factors associated with farm household decisions about selling versus consuming additional foods produced need to be better described so they can be incorporated into integrated interventions. Finally, more formative and qualitative research with community input is needed to determine how programs can be better disseminated within communities.

Baseline and followup measures for any programs that integrate agriculture, health, and nutrition need to include the growth and micronutrient status of children and women's nutrition and health outcomes such as iron status and reproductive health outcomes. Studies need to be long term, over numerous years, and incorporated into the evaluation plans.

<u>Impact of value-chain investments on dietary diversity</u>. Agriculture value-chain interventions have so far focused on enhancing productivity to improve food security and increase farming income. It is assumed this would lead to improvements in the nutritional status of producers and consumers. To date, however, value-chain concepts and approaches have not been applied in the field of nutrition in a consistent or comprehensive way and most value chain studies do not report on whether farmers and nonfarming households are improving their nutritional status. It is not known what production, transportation, processing, or retailing practices related to food will increase nutritional status. Introduction of new, more nutrient-dense, and profitable crops may be one consequence of value-chain development. Dual cropping for human and animal consumption and even for biofuels can increase farm

income, with possible beneficial impacts on nutritional status. Both these hypotheses need to be rigorously tested.

Few value-chain projects have examined the economic and biological effects of the pathway from production to consumption. What is known is that the focus on adding value to food often makes products more expensive for consumers. In addition, value chains commonly focus on single food commodities whereas a healthy and high-quality diet consists of a combination of different foods. Value-chain approaches focus on private competitive markets and have given little attention to making nutritious foods available in institutional settings like food aid distribution points or schools, which are potentially important for specific at-risk groups.

Meeting regulatory and certification standards can increase the sale value of products for smallholders. This can be done by providing the required technical assistance, credit, and greater access to the marketplace. Education and training for smallholders on business skills are also needed to get them more involved in the value chain. Infrastructure inputs, especially roads, are needed to enable smallholders to get product to the marketplace. With the advent of urbanization and a consumer-driven market, smallholders can benefit from the growing market for high-value fruits, vegetables, and animal products. Contract farming and formation of marketing cooperatives are two approaches that can help smallholders take advantage of these new market opportunities.

More research is needed to identify opportunities where the nutritional benefits of agriculture interventions can be improved by addressing constraints at various points along the value chain. Although there are examples of local processing by farmers, more research is needed to determine the cost-benefit for farmers of adding value to their products at the farm or local level. An important opportunity to add value to the yields that are already being produced is to increase the use of technologies to decrease post-harvest loss of product before and after food enters the marketplace. In both instances, the nutritional benefits of these forms of value addition still need to be evaluated.

Impact of agriculture technology interventions on diet and nutrition. Several agricultural technologies have been developed, tested, implemented, and evaluated with regards to crop production, but these have not always been tied to nutritional outcomes for producers. The major efforts have focused on soil and plant health including irrigation, fertilizer, and pesticides. There also has been a growing interest in how to use modern communications systems to provide information and skills to rural farmers.

Small-scale irrigation shows promise for breaking the cycle of low productivity that characterizes the persistent poverty found in agricultural communities in LMICs. By enabling year-round cultivation of high-value crops, irrigation can improve incomes and food security, and alleviate both chronic and seasonal malnutrition that is prevalent in food-insecure areas. More environmentally sustainable methods for irrigation, e.g., solar-powered drip irrigation, are now being developed that have been shown to increase food production and dietary diversity.

Small-scale irrigation systems increase agricultural production, mainly through diversification of crops grown. Positive impacts on food security have been documented, e.g., through increasing consumption of irrigated vegetables. Irrigation systems can also contribute to stabilizing and improving intake of food staples and animal-source foods as a result of higher incomes from irrigated crop sales. Enhanced access to fresh vegetables and animal-source foods, in turn, contributes to improvements in nutritional status and health.

On the other hand, irrigation can lead to increased mono-cropping, which may have a negative nutritional impact. Also, irrigation systems may enhance water-related diseases by increasing vector-breeding habitats. There is a need for more studies on the risk of toxicity from pesticides, arsenic, or wastewater that can contaminate irrigation water and affect the health of people exposed. Smallholders who initiate new irrigation projects need to be able to access and use economic and nutrition education so they can optimize the outcomes from more diverse and increased crop production and prevent unwarranted negative outcomes.

Fertilizers and pesticides are also important inputs that can increase crop production per unit area and increase the quality and nutrient content of crops. However, both inputs need to be accompanied by training at the local level to decrease their potential harm to the environment, agricultural workers, and consumers.

Using new information and communication technologies (ICTs) can aid in disseminating agriculture and nutrition information. Mobile phones and computer centers are the most targeted channels to provide technical and scientific information on crop production and nutrition. They also can be used to support the marketing of products, which can help level the playing field between small producers and traders. Women need to access these new ICTs and a strong institutional infrastructure needs to be created to maintain them. However, there is still a lack of data on how these modern ICT methods are increasing the nutritional status of users.

<u>Development of human capacity for large-scale nutrition outcomes</u>. The most common explicit investments to build human capacity for improving nutritional status have revolved around recruiting and training community health workers (CHWs). Each successful capacity-building program has spent significant resources in this area in one form or another, whether the CHWs are part of the paid health care system or volunteers. CHWs are mostly incorporated into community-based programs (CBPs). The most successful plans for building human capital have been those that target the poor, especially women and children, by household income and/or by geographic area. The greatest impact has occurred when programs target the most malnourished who suffer from chronic and acute malnutrition.

Investments in agricultural extension workers are another important avenue that has been used to increase nutrition and dietary diversity. Extension programs enable farmers to increase yields, expand and increase the stewardship of land, prevent losses along the value chain, and increase the adoption of biotechnology. One of the primary ways that extension workers can support nutrition indirectly is by targeting women farmers. Currently, the information given to women farmers is often different than that provided to men; women have more limited access to resources than do men in many LIMCs, and women farmers have less access to extension workers. By supporting the uptake of new technologies by women farmers and potentially decreasing the unbalanced access to resources, extension workers can help women farmers gain the nutritional benefits that accrue from increasing production, consumption, and sale of nutrient-dense foods.

The training of CHWs and extension workers can occur at the local level and be enhanced by creating better training methods at universities for trainers. It is also important that CHWs and extension workers have cultural competency and behavior change communication skills in addition to technical skills.

<u>Development of institutional capacity for large-scale nutrition outcomes</u>. Successful programs also build institutional capacity for developing and sustaining national programs that target behavior change through education, micronutrient interventions, and feeding programs to prevent and treat moderate and severe protein-energy malnutrition. These programs are characterized by committed and capable leadership at the national level, and by effective multisector and multilevel coordination across government ministries, various nongovernmental organizations (NGOs), community leaders, and the private sector.

Effective social mobilization strategies at the national and local levels are key inputs for building institutional capacity. Using community-based participatory research (CBPR) to develop and implement community-based nutrition programs has been shown to be effective. In all these cases, there was a phased implementation in which the program started in a few provinces or districts and then expanded nationwide.

Successful large-scale programs. The most successful large-scale nutrition programs are targeted CBPs and, more recently, the expanding number of conditional cash transfer (CCT) programs. CBPs usually combine a set of inputs at the local level and often use CHWs to deliver these services. Evidence shows that the most successful CBPs with a food and nutrition focus involved food and nutrient supplementation, iodization of salt, other centralized fortification programs that are delivered locally or provided at home, and various education programs including promoting breastfeeding and appropriate complementary feeding practices.

CCTs provide financial incentives to families linked to specific beneficial social behaviors. CCT programs have been most effective when they target women as being responsible for making the behavioral changes that benefit themselves, their families, and their children. Successful CCT programs involve a sequence of activities that require human and institutional capacity.

The implementation of programs needs to be done carefully and with clear goals and objectives. Starting small and expanding has allowed for proper scaling up of programs. It is also necessary to include the resources to implement appropriate M&E plans so modifications to programs can be made as needed. Finally, strong leadership and national commitment are critical and need to be in place for the long term if programs are to become sustainable.

I. ABOUT THE LEARNING AGENDA

The objective of this paper is to summarize available evidence on key questions for the Feed the Future Learning Agenda theme on nutrition and diet quality, and document expert opinion on gaps in the scientific literature for this theme that are in most urgent need of attention.

Feed the Future is an initiative of the U.S. Government, undertaken in response to the commitment of global leaders at the G8 Summit in L'Aquila, Italy in July 2009, to "act with the scale and urgency needed to achieve sustainable global food security." Feed the Future aims to tackle the root causes of global hunger and poverty through inclusive agriculture sector growth and improved nutritional status, especially of women and children. Feed the Future aims to achieve these objectives through several intermediate results detailed in the *Feed the Future Results Framework*: sustainably increasing agricultural productivity, expanding markets and trade, promoting increased public and private investment in agriculture and nutrition, supporting vulnerable communities and households to increase resilience, increasing access to diverse and quality foods, promoting improved nutrition-related behaviors, and improving use of maternal and child health and nutrition services. The Feed the Future approach focuses on smallholder farmers, especially women.

An important objective of the Feed the Future M&E component is to generate evidence to address unanswered questions in the development literature pertaining to the causal linkages in the *Feed the Future Results Framework*. In line with USAID's new Evaluation Policy launched in January 2011, Feed the Future's M&E approach emphasizes generating, learning from, and sharing evidence and results that can inform future programming and investments, increasing the chance that future investments will yield even more results than previous investments.

In order to organize this work, USAID's BFS led the development of a Feed the Future Learning Agenda in the first half of 2011 (USAID, 2011a), comprised of a set of key evaluation questions related to the causal linkages in the *Feed the Future Results Framework*. These questions were designed to be answered using evidence-based hypothesis-testing, primarily through impact evaluations but also through performance evaluations, economic analysis, and policy analysis. In June 2011, a meeting was held with key experts from implementing partners and other stakeholders (U.S. Government agencies, universities, research centers, NGOs, think tanks, the private sector, and others) to review and validate the key questions and the thematic groupings into which they had been organized to form the *Feed the Future Learning Agenda.* These stakeholders also provided preliminary design ideas for impact evaluations to be conducted to address these questions.

To ensure that Feed the Future impact evaluations are well-conceived, build on existing evidence, and fill critical evidence gaps, BFS is providing resources for a comprehensive assessment of existing evidence and gaps in knowledge within the framework of the Feed the Future FEEDBACK project. This assessment includes development of annotated bibliographies and literature review papers organized around the six themes of the Learning Agenda:

1. Improved Agricultural Productivity
2. Improved Research and Development
3. Expanded Markets, Value Chains and Increased Investment
4. Improved Nutrition and Dietary Quality
5. Improved Gender Integration and Women's Empowerment
6. Improved Resilience of Vulnerable Populations

Annotated bibliographies for each of the Learning Agenda themes have already been prepared. Literature review papers for each theme, including this one, present expert analyses of the current state of the scientific evidence for the key questions related to each theme and offer additional guidance on the gaps remaining to be filled by the impact evaluations. At a later stage, the assessment will also include activities aimed at articulating and demonstrating how new evaluations and studies conducted under the auspices of the Feed the Future M&E program contribute to filling the gaps in the body of evidence identified in this and the other five expert papers on the Learning Agenda themes.

II. ABOUT THE THEME: IMPROVED NUTRITION AND DIET QUALITY

Nutritional status in low and middle income countries. Chronic and acute malnutrition continue to persist in the world even though there have been important advances on how to increase agricultural production and nutritional status in poverty-stricken areas. Currently, about 1 billion people suffer from hunger in the world and 2 billion regularly experience periods of food insecurity (FAO, 2012; Sasson, 2012). The Food and Agriculture Organization (FAO) estimates that 12.5 percent of the world's population (868 million people) is undernourished in terms of energy intake, but these values may only be a fraction of the global burden of undernutrition (FAO, 2013). Young children and women, especially pregnant and lactating women, continue to be the most vulnerable in LMICs where undernutrition is most prevalent (Koletzko, Shamir, & Ashwell, 2012; Blumfield, Hure, Macdonald-Wicks, Smith, & Collins, 2013). An estimated 26 percent of the world's children are stunted (UNICEF, WHO, & World Bank, 2012). Undernutrition in the aggregate, including fetal growth restriction, stunting, wasting, and deficiencies of vitamin A and zinc along with suboptimum breastfeeding, has been associated with 45 percent of all child deaths in 2011 (Black et al., 2013; FAO, 2013).

Vitamin A deficiency may be present in as many as 40 percent of children less than 5 years of age and is associated with mortality due to diarrhea and measles (Black et al., 2008). Iron deficiency is also present in 40–60 percent of children aged 6 to 24 months in LMICs. Iron deficiency anemia causes about 50,000 deaths of women a year during pregnancy and childbirth (Osungbade & Oladunjoye, 2012). Iodine deficiency continues to put women and children at risk for impaired brain and cognitive development. Zinc deficiency is now more observable than before and its consequences on growth and immune function more quantifiable.

These numbers clearly show the magnitude of undernutrition that exists on the planet, even if their absolute accuracy may be limited by reporting error and faulty assumptions of the methodology. The direct costs of undernutrition and micronutrient deficiencies are estimated at 2–3 percent of global gross domestic product (GDP) (FAO, 2013). The cost to the global economy caused by undernutrition may decrease global GDP by as much as 5 percent as a result of lost productivity and direct health care costs (FAO, 2013).

More recently, there has been a greater recognition of how hunger and undernutrition affect the life course, leading to intergenerational undernutrition, impaired growth and development, and an increased risk of chronic noncommunicable diseases (Kolčić, 2012; Shetty, 2013). In addition to the advent of the epidemiological and demographic transitions over the past several decades, there also has been a nutrition and agriculture transition. These transitions, combined with economic development and urbanization in LMICs, have changed the composition of food supplies and dietary patterns. This has resulted in a double burden of malnutrition, characterized by the co-existence of undernutrition (low birth weight, poor growth) and overnutrition (mainly overweight/obesity) (FAO, 2006; Shafique et al., 2007; Winichagoon, 2013; Nugent, 2011; Omoleke, 2013; Shetty, 2013; Marquez & Farrington, 2013).

In the last few years, the development community has moved toward consensus on the framework of pathways and linkages between agriculture and health care-based interventions and how these might work together through a broader lens of food systems to provide for a more large-scale impact on nutrition, particularly for mothers and children (USAID, 2011b; Hoddinott, 2011; Herforth, 2012). This is a natural progression since agriculture, nutrition, and health are related and they can bring together synergistic strategies to create more sustainable programs with greater impact. Agricultural production and primary care interventions at the household level together are able to provide essential food and nutrients to poor populations. Many aspects of the agriculture component of food systems have been identified as fundamental determinants for food security, adequate dietary patterns, nutritional status, and health (Arimond et al., 2011; Headey, 2011).

The World Bank (2007) identified five important pathways that link agriculture with food consumption and nutrition. This work confirmed hypotheses that led to identification of these pathways, which include: (1) increasing agriculture production can increase the consumption of food, (2) increasing income also leads to an increase in food consumption, (3) engaging women is essential for improving food security and nutrition outcomes, (4) real food prices can be decreased with increasing food availability, and (5) an overall increase in food production can help alleviate national levels of poverty and thus improve nutritional status. Similar ways of showing this linkage were used for an analysis of the food systems in India. (Gillespie, Harris, & Kadiyala, 2012). Furthermore, World Bank (2007) also found that classifying food commodities as staples (grains, roots and tubers, and legumes); fruits and vegetables; and animal-derived foods proved useful for measuring the impact of agriculture on nutrition.

Recent reviews of agriculture from Africa and Asia support the use of biofortification of staples, home gardening to increase fruit and vegetable consumption, and small-scale animal production as viable approaches to improve household nutrition and to increase dietary diversity (Arimond et al., 2011; Talukder et al., 2010; Burchi, Fanzo, & Frison, 2011; Bouis & Islam, 2012). Improvements in agriculture and increasing food availability and agricultural incomes are not sufficient to combat undernutrition, however. Due to the multiple factors that lead to undernutrition, multisectoral interventions are required (Pauw & Thurlow, 2010; Ecker, Breisinger, & Pauw, 2011; Gulati, Ganesh-Kumar, Shreedhar, & Nandakumar, 2012). Complementary programs in nutrition, health, water, sanitation, and behavior change communication also need to be implemented and targeted to vulnerable populations, especially women and young children. It is essential to consider gender issues to achieve program objectives (Leroy & Frongillo, 2007; Ruel & Levin, 2000). In this regard, access to health care and family planning, female education, and reductions in poverty will help increase the impact of nutrition interventions (Headey, 2011). Results reported in these reviews complement findings discussed in the remainder of this paper. These support the hypothesis that integrated agriculture and nutrition programs stand a better chance of combating the double burden of malnutrition (persistence of undernutrition, especially among children, along with a rapid rise in overweight, obesity, and diet-related chronic diseases) than do either agriculture or nutrition programs on their own (Henson, Humphrey, McClafferty, & Waweru, 2012).

Available evidence on agriculture, nutrition, and diet quality. Despite the clear potential for agricultural change to improve nutrition and diet quality in LMICs, there is limited experimental and rigorous evaluation data that provide evidence on the kinds of actions in agriculture that do or do not support nutrition and health for impoverished segments of the population and groups passing through vulnerable life stages. There is a need for more and better designed research to identify how specific components of interventions work independently and together to improve nutritional status (Masset, Haddad, Cornelius, & Isaza-Castro, 2011; Girard, Self, McAuliffe, & Olude, 2012; Webb & Kennedy, 2012). When successful health interventions have occurred, they have been shown to be cost effective as summarized by the World Bank Report on *Scaling Up Nutrition* (Horton, Sheker, McDonald, Mahal, & Brooks, 2010). The database for this report includes survey data and reports on a series of projects starting in the 1970s that have been implemented in Africa, Asia, and Latin America. A similar systematic review of the nutritional and health impacts of agriculture interventions is lacking, however.

The Nutrition-Sensitive Social Development Index (NUSSDI) described by Headey (2011) provides insight on what human and institutional capacity-building efforts support improved nutrition. Lower poverty rate, improved health status, higher rate of female education, and greater use of family planning would all contribute to raising a NUSSDI score, and, by association, to improving nutritional status. As will be seen from evidence presented in the remainder of this paper, agriculture has an essential role to play in poverty reduction, and increased incomes in turn have an important, though not sufficient, role to play in improving dietary diversity and nutrition.

III. KEY QUESTIONS FOR THE THEME

1. Integrated Agriculture, Nutrition, and Health Approaches

What have been the impacts of different approaches linking Agriculture, Nutrition, and Health (ANH) on dietary diversity and nutritional status (i.e., geographic co-location of programs, integration of interventions, what combination of A, N, and H)? Have programs to increase farmers' incomes resulted in improved nutrition when not coupled with nutrition programming?

Evidence

Introduction

Only some aspects of this question can be answered because there are still many gaps and relatively few well-designed studies that bring agriculture, nutrition, and health together and have objective measures of nutritional outcomes and health. Agriculture interventions have the potential to influence nutrition through various pathways. First, they can influence the nutrition of household members directly by increasing production of nutrient-dense foods for family consumption. They can also impact on nutrition and health indirectly by increasing income from the production and sale of high-value agricultural products. This, in turn, makes it possible for households to purchase more and better food and/or to acquire other goods and services that contribute to nutritional well-being and health, such as improved housing, health care, and education (Hawkes & Ruel, 2006; Arimond et al., 2011; Hawkes, Friel, Lobstein, & Lang, 2012).

Three main approaches that have been used to link agriculture, nutrition, and health directly are reported in this review. These include: (1) biofortification, (2) small livestock production and aquaculture, and (3) horticulture interventions. Each of these approaches specifically links agricultural interventions with nutrition outcomes, and may be considered a technological approach to linkage. Moreover, there is a growing body of evidence that documents the positive impacts of these interventions on nutrition and dietary quality. In addition, agriculture interventions with other primary objectives may also have a positive influence on nutritional status and health through their impact on household income and expenditure.

Interventions associated with marked improvement in dietary intake and nutritional status had at least one of two key characteristics in common: women played a critical role in the intervention and/or the interventions included a nutrition education component. For example, Masset, Haddad, Cornelius, & Isaza-Castro (2011) reported that homestead gardening interventions succeeded in improving diets, nutrient intakes, and/or child nutritional status if they incorporated communication and nutrition education activities targeting behavior change and if they incorporated gender considerations in their design.

The interventions covered in this section are predominantly agricultural in nature, but they integrate nutrition into their objectives and activities. Providing a nutrition education component is the most common nutrition activity that is integrated with horticultural interventions, especially home gardens. Berti, Krasevec, and FitzGerald (2004) used a sustainable livelihood model based on five capital investments to determine which investments resulted in the best nutritional outcomes. The parameters for the inputs were (1) physical (increases in land, tools, livestock, etc.); (2) financial (access to credit, other sources of funds and value added products); (3) social (using community based approaches and involving women and other social and participatory processes), (4) human (training and education, and gender considerations); and (5) natural (e.g., sustainable practices). Their review found that out of 30 agricultural programs, 19 included nutrition education and reported positive outcomes on dietary diversity, anthropometry, nutritional biomarkers or morbidity. Furthermore, when nutrition outcomes were positive, 14 of the 19 positive programs invested in at least four of livelihood framework inputs. However the sample size was not sufficient to link any specific input with nutritional outcomes. Results from this review strongly suggest that there needs to be a comprehensive approach rather than single approaches to linking agriculture to nutrition. There is also a need to have improved nutrition as an explicit outcome when making decisions about agriculture inputs.

Horticultural programs have also been implemented together with programs that promote livestock production for meat, eggs, and milk (Ayalew, Kassa, & Gebriel, 1999; Kassa, Ayalew, Habte, & Gebre, 2003; English & Badcock, 1998; Langworthy & Caldwell, 2009; Helen Keller International (HKI), 2004a, 2004b, 2004c, 2010; Talukder et al., 2010) and with aquaculture for increasing fish consumption (Kumar & Quisumbing, 2010). Each of these combined programs has measured improvement in nutritional status, including dietary diversity and improvements in the growth of children, and these results are reported here. However, given the design of these programs it is not possible to disaggregate the individual effect that each portion had on nutritional outcomes, nor to know whether it was more efficient to implement the programs in combination than individually. Examples of co-location of autonomous agricultural and nutrition interventions have not been covered, as the literature reviewed did not document such cases.

Agriculture, income growth, and nutrition

Unfortunately, many agriculture interventions have not measured or considered nutritional status. Most projects have relied on food-related indicators such as production, availability, and price as indicators of potential nutritional impact or took no measure at all (Ruel, 2001; Leroy & Frongillo, 2007; Kawarazuka & Béné, 2011; Masset et al., 2011; Masset & Gelli, 2013). However, when the evaluations do address nutrition, the majority of projects with nutrition measures have some positive impact on household food consumption, dietary diversity, nutrient intake, and child growth.

The majority of agriculture projects with explicit nutrition objectives focus on direct impact pathways leading from agriculture interventions to nutrition through increased household production and the consumption of home-grown foods. Several studies of agriculture interventions have documented consistent positive impacts on household income and/or food expenditures that could lead to improvements in dietary diversity and nutrition (Alderman, 1987; Marsh, 1998; Ahmed, Jabbar, & Ehui, 2000; Hoorweg, Leegwater, & Veerman, 2000; Schipani, van der Haar, Sinawat, & Maleevong, 2002; Nielsen, Roos, & Thilsted, 2003; Bushamuka et al., 2005; Iannotti, Cunningham, & Ruel, 2009; Olney, Talukder, Iannotti, Ruel, & Quinn, 2009; Swanson, 2009; Murshed-e-Jahan, Ahmed, & Belton, 2010; Talukder et al., 2010; Hotz et al., 2012). These studies, however, did not consistently measure how increased income changed behaviors with respect to the purchase or consumption of food and other factors associated with nutritional status such as health care and education.

For the different agriculture interventions studied by Leroy and Frongillo (2007) and the World Bank (2007), increases in income were clearly accompanied by increases in food expenditures, but impacts were also dependent on changes in relative prices. Dietary diversity and micronutrient intake increased in most cases, as food expenditures shifted to more expensive items such as meat, fish, and fruits.

Babatunde and Qaim (2010) reported that increased farm income had a positive effect on dietary quality, estimated by measuring the percentage of calories from fruits, vegetables, and animal sources. Nevertheless, Bhagowalia, Headey, and Kadiyala (2012) concluded that the association between income and stunting and wasting was small except for comparisons between the lowest and highest income quintiles, where the differences were more pronounced.

A recent report provided country fixed-effects regressions that indicated a 10 percent increase in GDP per person would result in a 5.9 percent reduction in stunting and an 11 percent decrease in number of individuals living on $1.25 per day (Ruel et al., 2013). The association between prevalence of child underweight and GDP growth was slightly stronger than the association reported between GDP and stunting, as underweight prevalence rates decreased by 7 percent with a 10 percent increase in GDP. The association with women underweight (body mass index [BMI] <18·5 weight in kilograms divided by height in meters squared [kg/m^2]) was less—only a 4 percent decrease in prevalence with a 10 percent increase in GDP. On the other hand, a 10 percent increase in GDP was associated with a 7 percent increase in obesity (overweight) among women.

Anemia, defined as hemoglobin concentrations below 109 grams per liter (g/L), decreased at an even slower rate; a 10 percent improvement in income was associated with a decrease in child anemia rates of only 2.4 percent and in maternal anemia rates of just 1.8 percent. However, a 10 percent increase in GDP was associated with a significant decrease in the rate of severe anemia (hemoglobin < 70 g/L) for both mothers (6.5 percent) and children (9 percent). This report emphasizes that the association between GDP and undernutrition as measured by prevalence of stunting was not linear and that small changes in GDP among the poorest countries (e.g., <2,000 GDP per person using 2005 international dollars) had the greatest effect on decreasing undernutrition and increasing overweight prevalence rates for women.

Impacts of biofortification

The magnitude of micronutrient malnutrition is increasingly taking center stage in policy discussions on food and nutrition security. It is recognized that food security needs to refer not only to adequate energy intake, but also needs to encompass the sufficient intake of essential micronutrients (Black et al., 2008). Public health interventions that address micronutrient malnutrition include food fortification and food and nutrient supplementation programs. Unfortunately, numerous governments do not have the resources to fund such programs on a continuing basis (FAO, 2013).

Biofortification, which uses plant breeding techniques to enhance the micronutrient content of staple and horticultural foods, is increasingly seen as a method to combat micronutrient malnutrition (Masset et al., 2011; Bouis & Islam, 2012). The proof of concept that biofortified crops can have an impact on public health is beginning to emerge from efficacy studies where trials are conducted under controlled settings. The primary nutrients that have been addressed so far include vitamin A, iron, zinc, and protein.

<u>Iron and zinc fortification of wheat, rice, and beans</u>. Rosado et al. (2009) compared zinc absorption between common wheat tortillas and tortillas prepared from zinc-biofortified wheat among adult women. Over a 2-day period, zinc absorption was 0.5 milligrams (mg) per day greater for the biofortified tortillas compared with diets using the control tortillas. Haas et al. (2005) measured the efficacy of consuming high-iron rice during a 9-month feeding trial with a double-blind dietary intervention in 192 adult women of metro Manila in the Philippines. Women were randomly assigned to consume either high-iron rice (3.21 mg/kg of iron [Fe]) or a local variety of control rice (0.57 mg/kg Fe), and daily food consumption was monitored. The greatest improvements in iron status were seen in those anemic women who had the lowest baseline iron status and in those who consumed the most iron from rice. The authors concluded that consumption of biofortified rice, without any other changes in diet, is efficacious in improving iron stores of women with iron-poor diets. Donangelo et al. (2003), after feeding 12 women with two varieties of beans (one common and the other with high zinc and iron concentration), concluded that high-zinc bean genotypes may improve zinc status, but high-iron genotypes had little effect on iron status.

<u>Vitamin A fortification of maize and sweet potato</u>. An intervention involving six women was implemented to test the feasibility of maize biofortification as a promising intervention to combat vitamin-A malnutrition in developing countries. Some women consumed standard porridge and others consumed porridge prepared with biofortified maize. The results showed good bioavailability of β-carotene (which the body converts into vitamin A) from the biofortified maize (approximately 6.5 micrograms of β-carotene equivalent to 1 microgram of retinol) (Li, Nugroho, Rocheford, & White, 2010).

Varieties of OFSP with very high levels of vitamin A have also been bred to combat vitamin-A deficiency in regions of Africa where sweet potato is a staple food. One trial tested the efficacy of OFSP among 180 children in South Africa and found a good level of absorption of vitamin A (van Jaarsveld et al., 2005). In randomized community-based studies in Mozambique and Uganda, the introduction of OFSP to farming households increased the vitamin A intake among children and women who were given OSFP vines and was associated with improved vitamin-A status among children (Hotz et al., 2011, 2012). In Mozambique, the consumption of OFSP also led to increased intake of iron and vitamin-A rich fruit, vegetables, and tubers in the intervention area compared with comparison groups. OFSP introduction with nutrition education was also associated with a significant reduction in underweight and wasting for the children, probably due to increased consumption of this starchy staple (Hagenimana, Oyunga, Njoroge, Gichuki, & Kabira, 1999; Hagenimana et al., 2001; van Jaarsveld et al., 2005; Low et al., 2007; Laurie & Faber, 2008; Hotz et al., 2011, 2012; Coote, Tomlins, Masingue, Okwadi, & Westby, 2011). Agriculture programs that introduced vitamin A-rich OFSP for small landowners in Bangladesh and Cambodia have reduced the prevalence of anemia and night blindness among children in those countries (Iannotti et al., 2009; Talukder et al., 2010).

High protein maize. Gunaratna, De Groote, Nestel, Pixley, and McCabe (2010) conducted a meta-analysis of nine unpublished results of randomized trials in Africa and Latin America. The interventions consisted of introducing modern varieties of maize with improved protein quality (quality protein maize). The meta-analysis concluded that consumption of quality protein maize versus conventional maize increased the growth velocity of children by 12 percent for weight and by 9 percent for height.

Impacts of livestock and aquaculture interventions

The consumption of household livestock improves micronutrient status because animal-source foods are nutrient dense and they increase the bioavailability of several nutrients compared with plant-source foods. Most livestock and aquaculture interventions have focused on income generation through the sale of products, rather than on family consumption, however. The range of livestock and aquaculture interventions that have been evaluated with respect to their impact on nutrition is limited. Most of the projects evaluated have resulted in a positive impact on production of animal-source foods and household income but their impacts on diets, nutrient intakes, and nutritional status have had mixed results.

Uncertainties remain regarding which pathway towards improving nutritional status dominated in livestock and aquaculture interventions, i.e., direct consumption, new income, changes in prices, or changes in the control that women had over resources. Further, concerns with design limitations add a final cautionary note and limit the strength of the conclusions that can be drawn from these studies. Many evaluations of livestock and aquaculture interventions had weak designs. Self-selection was an issue in a number of studies, as was a lack of baseline information, small sample size, and lack of an appropriate control for confounders in the analyses. However, taken together, these studies suggest that well-designed animal production interventions can improve nutritional status through multiple mechanisms.

Aquaculture and aquaponics. Thompson and Subasinghe (2011) reported that 80 to 100 percent of fish produced by rural Asian households is marketed. On the other hand, Murshed-e-Jahan et al. (2010) reported that an aquaculture intervention increased the consumption of fish among project households. Fish farming has also decreased the prevalence of underweight in Malawian children (Aiga, Matsuoka, Kuroiwa, & Yamamoto, 2009). Households that participated in an aquaculture intervention in Bangladesh also appeared to have consumed more fish, but the analyses were not subject to statistical testing (Thompson, Sultana, Nuruzzaman, & Firoz Khan, 2000).

In Bangladesh, fish farming projects with nutrition education significantly improved the iron intake of women over a 10-year followup period relative to a comparison community (Kumar & Quisumbing, 2010). Fish farming projects without home gardens have also increased the vitamin A intake of women (Kumar & Quisumbing, 2010). However, there is a report from one intervention that aquaculture may have decreased dietary quality because it led to a switch from the consumption of small fish to a greater consumption of larger fish with poorer micronutrient density (Bouis et al., 1998). In another study, there was no difference in the total fish consumption between the fish-producing and non-fish-producing households (Roos, Islam, & Thilsted, 2003). However, the amount of nutrition education that accompanied these interventions is not known.

A relatively new extension of the integrated agricultural systems concept is the development of aquaponics. This system combines aquaculture (fish farming) and hydroponics (growing vegetables in a soilless environment, e.g., water) within a closed system. This integrated system uses less water and is able to produce animal and plant products in a relatively small space by optimizing the use of fish waste as nutrients for plants, and the use of plant material as nutrients for fish (Nichols & Savidov, 2012). Aquaponics is used to produce small fish such as tilapia, providing protein and micronutrients (Kawarazuka & Béné, 2011) and also nutritious green leafy plants such as spinach, pudina, and okra, as was done in Bangladesh (Salam, Asadujjaman, & Rahman, 2013). This system is now available in mobile containers and can be implemented in any environment, as water use is less than traditional aquaculture systems.

<u>Dairy</u>. A variety of results have been reported with dairy interventions. Milk Matters programs by the USAID have increased dairy intake of pastoralist children during the hunger season in Ethiopia with cost-efficient interventions (Sadler et al., 2012). In one intervention in India, households in villages with milk cooperatives increased their overall nutrient intake but consumed less milk than households in villages without cooperatives. This may have occurred because there was an increase in income from the milk and the income was spent on other items, including other foods (Alderman, 1987). In another intervention in India, children in households that produced more than 5 liters of milk daily had higher protein intakes compared with those who produced less milk and compared with non-producers (Begum, 1994). An intervention in Ethiopia found that households with cross-bred cows (draft and dairy) consumed more energy, fat, protein, retinol, and iron than non-adopters (Ahmed et al., 2000). A study in Kenya that introduced cross-bred cows and promoted fodder production found that participating women increased their milk consumption relative to baseline and spent more of their funds on food and schooling for their children (Mullins, Wahome, Tsangari, & Maarse, 1996). The promotion of intensive dairy farming among rural smallholders also lowered the prevalence of stunting, wasting, and underweight in the participant group (Hoorweg et al., 2000).

<u>Poultry</u>. Poultry interventions in Bangladesh did not lead to increased egg or chicken consumption, but participating households did eat more fish, suggesting that the intervention led to increased income and subsequent positive dietary changes (Nielson, 1996). Interestingly, participants in another participatory poultry project in Bangladesh apparently consumed nearly double the amount of fish compared with controls at followup, again possibly due to increased income. This finding did not meet statistical significance and was most likely due to very small sample sizes (Nielson et al., 2003). These findings also suggest that egg consumption may have already been high and additional production led to income that was spent on higher-demand foods such as fish.

<u>Goats</u>. A dairy goat project in Ethiopia coordinated by Farm Africa and the International Center for Research on Women provided women with training on finance and goat husbandry. Those completing the training received credit for purchasing local goats (Ayalew et al., 1999; Kassa et al., 2003). Women who demonstrated appropriate care of their goats and repaid their microcredit loans additionally received a higher-producing, mixed-breed goat. An evaluation of this project reported that children from households with goats had a significantly greater consumption of milk and vitamin-A rich foods,

though they still consumed less than what was recommended. A strength of the study was that it targeted very poor households. However, comparison groups were not balanced since participation in the intervention was self-selected and the comparison group consisted of randomly-selected households without livestock.

Impacts of horticulture interventions

Despite the existence of a wide variety of fruit and vegetable production systems, only homestead garden production systems have been systematically implemented and evaluated with explicit nutrition objectives. These interventions generally have been designed to impact nutrition by increasing a family's own production of food for consumption and, secondarily, by increased income from sales. The most common products include fruits, vegetables, herbs, condiments, and sometimes secondary staples such as legumes and sweet potatoes. The nutritional impact of these homestead gardens has been well documented in previous reviews, which report that they increase the consumption of fruits and vegetables and improve dietary diversity, nutritional status, and income (Ruel, 2001; Berti et al., 2004; World Bank, 2007; Bhutta et al., 2008; Masset & Gelli, 2013; Arimond et al., 2011; Girard et al., 2012).

Many of the evaluations of these interventions had weak designs including no baseline data, which limits the strength of conclusions and generalizability. While a number of studies included control groups, selection of appropriate comparison groups remained a challenge or was poorly described, and inter-group differences were not always accounted for in the analyses. Results from credible studies on the impacts of homestead gardening interventions on dietary diversity, nutrient intake, child growth, and morbidity are reported below.

Dietary diversity. Home horticulture has been shown to increase dietary diversity scores and lead to better nutritional outcomes (Cabalda, Rayco-Solon, Solon, & Solon, 2011). In most studies, home gardens with or without animal production strategies were associated with greater consumption of vitamin A-rich fruits and vegetables, pulses, and other fruits and vegetables, and with improved dietary diversity scores (Ayalew et al., 1999; English & Badcock, 1998; Faber, Venter, & Benadé, 2002b; Greiner & Mitra, 1995; Kidala, Greiner, & Gebre-Medhin, 2000; Hagenimana et al., 1999, 2001; HKI, 2004a, 2008, 2010; Hotz et al., 2011; Jones, Specio, Shrestha, Brown, & Allen, 2005; Kaufer et al., 2010; Faber, Phungula, Venter, Dhansay, & Benadé, 2002a; Laurie & Faber, 2008; Low et al., 2007; Marsh, 1998; Olney et al., 2009; Taher et al., 2002; Talukder et al., 2000).

Several projects highlight the benefits from the production of vitamin-A rich fruits and vegetables in home gardens without the addition of animal production strategies. These projects consistently reported higher intakes of vitamin A-rich fruit, vegetables, and tubers with the intervention compared with comparison groups. An older study, however, did not find any statistically significant differences between beneficiaries of interventions and control groups (Vijayaraghavan, Nayak, Bamji, Ramana, & Reddy, 1997).

Garden projects can also lead to an increase in the consumption of animal-source food (Hagenimana et al., 2001; HKI, 2004a, 2004b, 2008; Ayalew et al., 1999; Jones et al., 2005; Kassa et al., 2003). The homestead food production projects coordinated by Helen Keller International (HKI) in Bangladesh, Nepal, Cambodia, and the Philippines promoted and supported poultry-raising in addition to improved home gardens (HKI, 2004a, 2004b, 2004c; Talukder et al., 2010; Olney et al., 2009). These projects included intensive nutrition education components and targeted women. Consumption of vitamin A-rich foods and pulses, as well as egg consumption by children, in the intervention areas increased substantially (from 36 percent to 150 percent). Dietary diversity scores were also significantly greater in intervention areas. Similar findings were also reported for the Jibon O Jibika project in Bangladesh when a homestead gardening and poultry production program was integrated with health and nutrition education and improved water and sanitation (HKI 2010, 2008; Langworthy & Caldwell, 2009). The HKI homestead food production programs that included a small animal production component increased egg consumption among women in Bangladesh (HKI 2004b, 2008; Talukder et al., 2010) and egg and pulses consumption in Nepal (HKI, 2004a; Talukder et al., 2010).

A home gardening intervention was implemented in Nepal with an intensive nutrition information, education and counseling (IEC) campaign that promoted and provided technical support for farming of high value crops for sale, as well as for growing nutrient-dense crops in kitchen gardens. Jones et al. (2005) reported that this program increased the proportion of pregnant women who consumed eggs, meat, milk, nuts, and dried fruits. Three years after the study began, milk consumption among intervention households was significantly greater than among control households; however, no baseline data were available for comparison. In Nepal, there was also an improvement in the timing and type of complementary foods fed to infants when home production was combined with nutrition education (Jones et al., 2005).

In western Kenya, a program to promote the production and consumption of OFSP reported a significant increase in the consumption of vitamin A-rich plants, OFSP, and egg yolk in intervention areas compared with control children (Hagenimana et al., 2001). The program took gender considerations into account and implemented a social marketing strategy using IEC techniques to increase production and consumption of vitamin A-rich foods.

Nutrient intake. Whereas dietary diversity measures consumption patterns, studies of nutrient intake report on the intake of nutrients contained in the foods consumed. The macro- and micronutrient intakes for women were significantly increased in five studies that involved home gardens and nutrition education (Taher et al., 2002; Smitasiri et al., 1999a, 1999b; Attig, Smitasiri, Ittikom, & Dhanamitta, 1993; Kumar & Quisumbing, 2010; Kaufer et al., 2010). In Vietnam, a home garden program with an IEC component reported significant increases in energy, iron, vitamin A, and protein intakes among children in intervention households compared with control households after 2 years of implementation (English et al., 1997; English & Badcock, 1998). Similarly, projects in Kenya and Mozambique that promoted the production and consumption of OFSP significantly increased iron and vitamin A intakes of individuals, in particular women, in the intervention households (Hotz et al., 2011; Low et al., 2007).

In Mozambique (Low et al., 2007) and South Africa (Faber et al., 2002a, 2002b), the promotion and support for household production of OFSP resulted in significantly increased serum retinol concentrations and significant reductions in the proportion of children with low serum retinol concentrations compared with control communities. Furthermore, the promotion of low-cost vegetable gardens combined with nutrition education reduced vitamin A deficiency from 2.3 to 1.2 percent among target children in Ethiopia and Bangladesh. These reductions were associated with reductions in the prevalence of Bitot's spots and night blindness (Marsh, 1998). These later studies did not include comparison groups.

Not all home gardening programs have improved the nutritional status of children. Home gardening programs in South Africa (Faber et al., 2002a, 2002b) and Thailand (Kumar & Quisumbing, 2010) reported no significant changes in protein, fat, or iron intakes. Despite a lack of improvement in other nutrients, the South African home gardens study reported a significant increase in dietary intake of vitamin A in the intervention communities compared with control communities at a 1-year followup.

Home gardening programs in Bangladesh, India, and Tanzania reported no significant effects on vitamin A status (Baker & Talukder, 1996; Vijayaraghavan et al., 1997; Kidala et al., 2000). Several other projects in Bangladesh with fish farming or poultry production strategies reported no significant effects from these interventions on the energy, protein, vitamin A, or iron intake of children (Nielsen et al., 2003; Kumar & Quisumbing, 2010). It should be noted that these later projects had income generation as their primary objective and did not report having a nutrition education component as a major input.

A limited number of studies have examined the impact of household food production strategies on women's iron status and BMI (Talukder et al., 2010; Olney et al., 2009; Kumar & Quisumbing, 2010). In the HKI homestead food production programs in Nepal and Bangladesh, women in intervention households showed significant declines in anemia prevalence whereas women in control communities did not (Talukder et al., 2010; Olney et al., 2009). Differences in the rates of decline for anemia between intervention and control groups were not reported in the homestead food production program in Cambodia (Olney et al., 2009). The prevalence of anemia decreased significantly among early adopters of household fish farming compared with late/non-adopters (Kumar & Quisumbing, 2010). Within the same evaluation of three different food production strategies in Bangladesh, BMI was significantly greater among early adopters of improved home garden technologies compared with late or non-adopters. Only one study assessed the effects of household food production strategies on morbidity in women. In the HKI homestead food production program in Cambodia, no significant differences in diarrhea morbidity between women in the intervention and comparison groups were observed (Olney et al., 2009).

No significant differences were observed for serum retinol, ferritin, and hemoglobin concentrations among Thai children whose families sold excess fruit and vegetables for income (Schipani et al., 2002). The lack of substantial impacts on the nutritional status of women and young children in this study could be attributed to poor comparison groups and less than optimal nutrition education programming to promote behavioral changes relevant to nutrition objectives. The lack of nutrition education has also been identified by others as a limiting factor for the impact of home gardens on nutritional status (Pauw & Thurlow, 2010; Ecker et al., 2011; Gulati et al., 2012).

<u>Child growth</u>. Three studies reported changes in child growth measures (English & Badcock, 1998; Low et al., 2007; Kassa et al., 2003). Overall, home gardens were significantly associated with decreasing the prevalence of stunting, underweight, and wasting. The home gardening project in Thailand (English & Badcock, 1998) reported significant reductions in stunting from baseline in the intervention group; however, differences between groups were not significant. In the Farm Africa dairy goat project in Ethiopia, both stunting and wasting were reduced in the intervention group (Kassa et al., 2003). Significant reductions in underweight and wasting were also observed among intervention children in an OFSP intervention in Kenya (Low et al., 2007; Kassa et al., 2003). A community-based research program in rural Malawi promoted intercropping with legumes and intensive nutrition IEC (Bezner Kerr, Berti, & Shumba, 2010). After the intervention, the weight-for-age and height-for-age z-scores increased significantly among children whose households participated the longest and in those communities where project involvement was greatest. In Bangladesh, Kumar and Quisumbing (2010) reported that children of early adopters of improved home gardening, community fish farming, or household fish-farming technologies had significantly greater improvements in BMI for age z-scores compared with late adopters and non-adopters of these technologies. On the other hand, homestead gardening projects in South Africa and an HKI homestead food production program in Bangladesh reported no significant effects on child malnutrition (Faber et al., 2002a, 2002b; Baker & Talukder, 1996). Later iterations of the Bangladesh project added small animal production, nutrition education, and gender considerations; evaluations of this integrated mode reported significant reductions in wasting among intervention communities after 4 years of followup (Olney et al., 2009; HKI, 2010; Talukder et al., 2010).

<u>Morbidity in children</u>. Three studies reported findings for morbidity outcomes in children who participated in home gardening programs. In the homestead food production program in Cambodia, participating households reported significantly reduced prevalence of fever but not of diarrhea or measles (Olney et al., 2009). In a home gardening project in Vietnam, the incidence of acute respiratory infection and diarrhea decreased significantly over time in the intervention community but not in the control community (English & Badcock, 1998; English et al., 1997). In a study in South Africa, kitchen gardening with vitamin-A rich fruits and vegetables was associated with significant reductions in vomiting, diarrhea, and runny nose (Laurie & Faber, 2008). However, it is not clear to what extent the effects can

be attributed to the food from home gardens or to improved child-feeding practices since two of the programs included education on breastfeeding and appropriate and hygienic preparation of complementary foods (English et al., 1997; English & Badcock, 1998; Olney et al., 2009). A program in Vietnam resulted in increased consumption of fruits, vegetables, energy, protein, vitamin A, and iron and a decrease in the number of respiratory and diarrheal infections in participants when compared to controls (Webb, 2000).

Evidence gaps

Although biofortification interventions are starting to show that they can improve health and nutrition, there is still insufficient evidence on the extent to which methods for producing biofortified crops are environmentally sensitive. Studies on how to increase the mineral uptake of biofortified plants and how to determine which strains will produce best under various climatic and socio-economic conditions will support the scaling up of biofortified foods. Additional evidence is also needed on how biofortified crops impact yields and farm profits. These studies should assess how biofortified crops can be brought to scale and be widely adopted as a primary crop (De Groote, Gunaratna, Ergano, & Friesen, 2010; Chowdhury, Meenakshi, Tomlins, & Owori, 2011; de Brauw, Eozenou, Gilligan, Kumar, & Meenakshi, 2012; Gilligan, 2013).

At the same time that new technology is providing avenues for increased production of high quality foods, research continues to be needed on how to sustain and increase biodiversity of indigenous crops. Studies on biodiversity are needed to determine how multiple crops can be produced to support soil fertility, develop niche markets, mitigate the impact of climate change, minimize the impact of food shortages, and increase dietary diversity by producers and consumers (Frison, Cherfas, & Hodgkin, 2011). Research also is needed on how to maintain biodiversity of sustainable indigenous crops that are associated with improved nutritional status (Kuhnlein, Erasmus, & Spigelski, 2009).

Larger community-based studies are needed to determine the community-level effect of biofortified foods. Existing studies of consumer acceptance have focused on β-carotene-rich foods and protein-enriched maize. Studies of consumer acceptability need to include data on: (1) perceived personal benefits, (2) perceived societal benefits, (3) socio-cultural differences, (4) differential assessments of risks and benefits, (5) ethical concerns such as those related to the environment, (6) issues related to regulatory systems, (7) cognitive associations, (8) overall public awareness, (9) perceived scientific knowledge, (10) perceived naturalness, (11) controllability of choice, and (12) level of public involvement in the technology development and trust in science and regulations (Frewer et al., 2011).

Recent experience with biofortification suggests that more information is still needed on what factors affect consumers' willingness to pay for biofortified food and whether nutrition information affects willingness to pay (Meenakashi et al., 2012; Chowdhury et al., 2011; de Brauw et al., 2013). Operational research needs to consider how these factors should be accounted for in strategies and programs to distribute new biofortified varieties and how these strategies can be integrated most effectively with other public health approaches to address micronutrient malnutrition (de Brauw et al., 2013; Hotz et al., 2011).

It is also not known which combinations of agriculture and nutrition interventions are best matched. It is important to fill the knowledge gap with information about what type of education is best incorporated into agriculture programs, including nutrition and health education, time management, and home economics, using appropriate behavioral theories. There is also a need to determine which nutrition education topics are best matched to interventions (including topics such as food preparation, using dietary patterns to promote nutrient absorption, food preservation) and the theoretical frameworks that should be used to guide the interventions (Arimond et al., 2011). The lack of information and conceptual underpinnings may be a cause for the inconsistent results regarding outcomes of agriculture interventions and integrated agriculture and nutrition programs, as measured by dietary diversity, nutritional status, and other health outcomes.

Although increased food production of high value foods is a potential method to provide rural and urban communities with these foods, there is still not enough evidence to show that increasing fruit and vegetable production within country and getting these foods to market can decrease the prevalence of noncommunicable chronic diseases. Similarly, there is need to determine how to prevent an increase in chronic diseases due to any lowering of prices of high energy foods as a result of increased production. Given the current evidence regarding the nutrition transition, it will be necessary to determine how agricultural interventions and nutrition education can be combined to prevent an increase in chronic diseases that have usually paralleled increases in GDP.

More generally, the literature lacks studies of the impacts of deliberate co-location of unrelated agricultural and nutrition interventions, as testing of this approach is still in its infancy. At a minimum, this could include retrospective studies that map out over time how policy and programmatic decisions have coincided with changes in nutritional status indicators such as dietary diversity scores, growth of children, and micronutrient status of women and children. It will also be necessary to conduct prospective studies with planned out data collection to determine how nutritional status changes when various interventions overlap. This will require that ministries and other national and regional organizations communicate and share information regarding the extent of their interventions, participant information, and work together to collect the appropriate outcomes measures.

More information is also needed on what is the tradeoff between using homestead production for consumption or for income, and how families can make optimal decisions regarding what they do with the food they produce to improve nutritional status. Peterman, Behrman, & Quisumbing (2010) suggested that yield is a primary factor for foods that are taken to market and factors such as taste, postharvest storage, and the ability to process foods at home are related to home consumption. This is an important avenue of study to pursue in order to determine how families choose what crops to grow and the effect that these two different pathways (home consumption and sale) collectively have on nutritional status and dietary diversity.

There is also a gap in the literature on how nutrition interventions affect women's nutrition beyond their role in reproductive health. Most projects target women during pregnancy or while they are breastfeeding with the main outcomes related to child health. It is not known if incorporating a life span approach that focuses on pre-conceptual health will improve the nutritional status and economic development of communities. It is not known how various agricultural systems affect women's time use and their efforts to seek out health and educational services for themselves and their children. It is also important to determine how to get women more involved at the outset of projects so their input can be part of a formative approach to developing interventions.

One additional area for new operational research is on how to integrate water, sanitation, and hygiene (WASH) with agricultural practices at the household level. WASH problems continue to be a major cause for enteric infections for children through home environments, brought about in part by agricultural contamination of water supplies (Brown, Cairncross, & Ensink, 2013). This nexus between health and agriculture is an area that can bring together community health and agricultural extension workers when they target their efforts on smallholders. There is also a need to determine specific roles for these specialists and how they integrate information and activities so that their interactions with small farmers are linked and coordinated from the time that thought and effort is put into soil preparation and planting to the time that households are making decisions about food preparation and consumption.

Together, these groups can help reduce two-way contamination between human-transmitted infections and zoonotic infections by creating inter-sectoral links that focus on irrigation and animal husbandry practices (Tsegai, McBain, & Tischbein, 2012; Rabinowitz & Conti, 2013).

Our findings are consistent with those of Ruel et al. (2013) who identified several types of evidence that will assist with scaling up nutrition programs. The most relevant research issues drawn from their review suggest the need for the following evidence:

- Sex-disaggregated impact indicators;
- Intermediary outcomes along the impact pathway (e.g., household consumption, food security and dietary diversity, dimensions of women's empowerment, and maternal physical and mental health);
- Detailed dietary intake or simpler measures such as dietary diversity for target individuals;
- Detailed costing for assessment of cost-effectiveness;
- Research to rigorously test the feasibility and desirability of integration of interventions from several sectors;
- Research to test and document the scalability of newly-released biofortified crops; and
- Assessment of effectiveness of large-scale programs combining early child development and nutrition interventions in different contexts and assessment of synergies both in programming and outcomes; and
- Assessments of stand-alone school nutrition programs compared to programs that combine agriculture programs with nutrition and health programs.

2. Impact of Value Chain Investments on Dietary Diversity

What activities have enabled value chain investments to lead to improved consumption of diverse diets?

Evidence

Introduction

Value chains bring together various stakeholders (producers, transporters, traders, processors, retailers, etc.) who work together to increase the value of food in planned activities (Asian Development Bank, 2012). Interventions so far have focused mainly on enhancing productivity to improve food security and increase farmers' yields at the farm end of the value chain, and on linking farmers to markets. It was assumed this would lead to improvements in nutrition. Only recently has nutrition really been considered in the early program planning stages of agriculture project design and value-chain concepts. Approaches have not yet been applied in the field of nutrition in a consistent or comprehensive way.

Hawkes and Ruel (2011) reported that there have been scattered attempts to apply value-chain approaches in a nutrition context. These cases studies indicated that participation in value chains increases income but there was no evidence that dietary diversity increased for smallholders who were involved in these programs. For example, they showed that increasing the demand for beans could be accomplished with better handling that resulted in a less damaged product and by having extension agents work with consumers on cooking methods that increased the product's desirability. The value of OFSP would also increase when the health benefits were marketed. Their brief report on the Renewed Efforts Against Child Hunger project jointly funded by FAO, World Health Organization (WHO), United Nations Children's Fund (UNICEF) and World Food Programme (WFP) indicated that there were seven important inputs required to increase the value of foods, and that these inputs interacted with each other. These included (1) farmer organization and training and access to inputs and credit, (2) post-harvest technology transfer and facility set up, (3) local procurement, market information and access to the markets, (4) innovative marketing of high value foods, (5) targeted messaging about the value of food products for women and children, (6) integrating local foods into complementary, supplementary and therapeutic feeding programs and (7) utilizing nutrition education across all steps and increasing women's access to resources. Their review of a study in Indonesia also reinforced the concept that foods that are locally valued are best targeted; in this case they were chili peppers, shallots, mangoes, and shrimp. Value chains for smallholders in LMICs enable them to get their products to domestic and global consumers. Although numerous studies are available on how to get smallholders more engaged in value chains, most do not consider how to improve the nutritional status of the farming households (Traoré, 2009). Nor have these studies considered the nutritional impact of value-chain investments on consumers. Campbell (2013) provides a full examination of the evidence on value chain investments as it relates to the Feed the Future Learning Agenda. This review reported that only a few projects have actually addressed nutrition outcomes. Similarly, the extensive search by Hawkes and Ruel (2011) found only eight relevant case studies, and even those provided only limited evidence of impact—when nutrition was measured it was usually because the agricultural projects also included a nutrition education component. A full examination of value chains is beyond the scope of this review; however, the following examples provide insight on factors that need to be considered to increase income and purchasing power for farmers and improve the nutritional status of consumers. Although few of the value-chain projects reviewed here have examined the entire pathway from production to a biological effect, they confirm some of the reasons why the value-chain approach can be useful for achieving nutritional goals. They also reveal how value-chain approaches could be used in ways that are relevant to improving nutrition and increasing the supply and demand of nutritious foods by the poor.

There are some potential limitations to applying value-chain concepts to achieve nutrition goals. Value chains so far have been focused on adding value in the chain, often in ways that make products more expensive for consumers. In addition, they focus on single food commodities, whereas a healthy and high-quality diet consists of a combination of different foods. Finally, value-chain approaches focus on private competitive markets and may not necessarily be well-adapted to reach the most vulnerable; this aspect requires further research. Finally, they have given little explicit attention to making nutritious foods available in institutional settings like food aid distribution points or schools, though if such institutions express their demand in the marketplace, a well-functioning value chain should be able to meet that demand.

Increasing farm income with value chain approach

Organizing to meet growing urban demand. The increase in local demand for high-value fruit and vegetables due to urbanization and the spread of supermarkets in urban areas provides a potential opportunity for smallholders (Narrod et al., 2009; Mergenthaler, Weinberger, & Qaim, 2009; Rao, Brümmer, & Qaim, 2012). Even when farmers are marginalized from export markets and when local markets are controlled by a few, smallholders can become valuable contract suppliers for larger growers (Maertens, Colen, & Swinnen, 2011). In order to remain competitive in modern value chains, however, smallholders will eventually need to create strong cooperatives with capacity to manage larger-scale marketing operations (Mergenthaler et al., 2009).

A program that promoted agricultural cooperatives in Ethiopia demonstrated positive results (Humphrey & Navas-Alemán, 2010; ACDI/VOCA, 2005; Dorsey & Assefa, 2005). It supported the establishment of connections between the cooperatives and traders and processors inside and outside of Ethiopia. Although no detailed quantitative information regarding diets or nutrition was collected, cooperative members had higher incomes compared with non-members, which they presumably used in part to improve their diets.

Improving quality of supply for processed nutrition products. There are more than 4.5 billion people in the world who are chronically exposed to mycotoxins, dangerous metabolites produced by some fungal organisms on food products. Exposure to aflatoxin, the most common mycotoxin, is a major risk factor for cancer and liver damage and is associated with stunting and being underweight. Aflatoxin exposure negatively affects protein synthesis and micronutrient metabolism which significantly decreases immune status. Nutrients needed for antibody synthesis are either not available or transported from the liver (e.g., protein, zinc and vitamin A) or they are used in fighting oxidative damage (e.g., selenium). Decreases in the immune response associated with aflatoxin exposure are associated with an increased risk for diarrheal, respiratory, and malaria infections. Liver damage due to aflatoxin may also be the tipping point that leads to kwashiorkor as a clinical outcome of severe protein-energy malnutrition (Williams et al., 2004).

Currently there are inconsistent regulatory standards for the amount of aflatoxin that is considered safe based on the risk for hepatocellular carcinoma (liver cancer). The amount of aflatoxin that is currently allowed between countries varies from 4 to 20 nanograms per gram for maize and peanuts (Wu, Stacy, & Kensler, 2013). The elimination of aflatoxin and other mycotoxins from foods prior to harvesting, during harvesting, or in the post-harvest storage period can provide an important method for increasing the value of many product such as peanuts, corn, cassava, cottonseed oil, and animal feeds that contaminate milk (Gnonlonfin et al., 2012).

An analysis of several cost-effective methods for decreasing aflatoxin exposure has shown that there are several possible strategies (Khlangwiset & Wu, 2013). It is possible to create resistant in-bred and genetically engineered maize lines and groundnut cultivars that directly decrease aflatoxin growth or insects infestations that promote fungal growth. Post-harvest methods include sorting out infected product to prevent further contamination, controlling moisture and temperature, and preventing insects/pests. One of the more simple ways to decrease exposure is to replace the consumption of aflatoxin contaminated foods with foods that have less contamination such as sorghum and pearl millet. It is also possible to bind up aflatoxin using various dietary approaches such as adding calcium montomorilonite (NovaSil) to the diet, and consuming green tea polyphenols and plants with chlorophyllin.

Aflasafe is one commercial product that has taken a biological control method to decrease aflatoxin in peanuts and can be used in prior to harvesting to prevent aflatoxin (Alakonya & Monda, 2013). Hilina, a food-processing company in Ethiopia, worked with local producers to eliminate aflatoxin contamination in peanuts, thereby enabling the smallholders to supply ingredients for the production of ready-to-use therapeutic foods (RUTFs - fortified processed food used to treat severe acute malnutrition). The ultimate objective was to enable the local production and supply of RUTFs at a reduced cost (Jones, 2011). Within 4 years, Hilina eliminated aflatoxin contamination from the nuts supplied from farmer groups, while at the same time quadrupling farmer incomes from groundnuts. During the intervention period, farmers spent at least 40 percent of their income on food, implying increased and higher-quality consumption. Work and school attendance in the community had also increased, suggesting lower morbidity rates. These results suggest that market-driven interventions that increase income are a sustainable approach to improving livelihoods and nutrition.

Obtaining nutritional benefit with value chain approach

Value chain approach for introducing new foods. Biofortification of staple foods to create nutrient-dense varieties has already been discussed as a technique for integrating agriculture and nutrition in Section III.1 above. The properties of food that appeal to the senses (taste, texture, smell, appearance) are important determinants for consumer acceptance and are thus important for developing and scaling up value chains for biofortified foods. A common finding from a variety of studies is that consumer acceptance and willingness to buy biofortified foods, even at a greater price than traditional foods, increases when nutrition education is added to a marketing campaign, as was evident for orange corn in Zambia and OFSP in Uganda (Meenakasi et al., 2012; Chowdhury et al., 2011). These studies also suggested that the channel used to provide the nutrition messages was less important than the content of the information.

An Integrated Nutrition Framework developed and implemented by the Government of Kenya provided training and linked producers to input suppliers in order to enhance capacity and productivity. It also improved quality control and value addition by enhancing the efficacy of the market information system and improving local business conditions. An OFSP project implemented within this framework helped to increase consumption of nutritious foods (Henson et al., 2012; Fintrac, 2011).

Providing nutrition information can also improve the acceptance of new technologies for food preparation, as was shown with under-milled rice in the Philippines (Sudha et al., 2013). However, de Brauw et al. (2013) suggested from large studies conducted in Mozambique and Uganda that the provision of OSFP vines to farmers was more important for the acceptance and consumption of OSFP than nutrition training. This finding was based on results from a randomized, controlled effectiveness study of a large-scale intervention conducted in Mozambique and Uganda to promote household-level production and consumption of OFSP. The intervention integrated three major components: OFSP vine distribution, training on improved production practices, and conservation of OFSP vines between planting periods (Low et al., 2007; Arimond et al., 2011; Coote et al., 2011; Westby, Coote, & Tomlins, 2011). After 2 years, the project led to OFSP adoption rates of 61to 68 percent among project households and nearly doubled the average dietary intake of vitamin A (de Brauw et al., 2013). Country differences suggested that this was dependent on how well farmers were able to preserve and share vines among themselves.

A value chain approach was taken in Bihar, India, to increase the production and consumption of makhana, an aquatic crop. The focus of this project was to increase the branding of the product in markets by packaging and labeling the product. The final product increased the income for the urban retailer and those involved with packaging the product. However, it did not increase the income of the producers (Minten, Singh, & Sutradhar, 2012). This study suggests that branding alone is not sufficient to improve the income of smallholders.

Integrated rice-vegetable production and marketing system. In Sierra Leone, an operational research project entitled REACH (Renewed Efforts against Child Hunger partnership) experimented with scaling up the demand for nutritious foods by purchasing locally from smallholder farmers using a value-chain approach. The objective was to identify food-based interventions that could increase the incomes of smallholder farmers and improve the nutritional status of family members, particularly mothers and children under 2 years of age (Torgerson, Rhodes, Wiegers, van Dorp, & Ljungqvist, 2011). REACH focused on value-chain development for rice and a small-scale commercial vegetable production initiative. In spite of the potential of both interventions to improve nutrition, REACH found little evidence of positive changes in the nutrient intake and status among smallholders involved in rice and vegetable production. This initiative is an example that improved production and income may not translate into improved nutrient intake and nutritional status (de Hoogh et al., 2011). This could be explained partly by the fact that nutritional considerations were not an integral part of these interventions or because there was no nutrition education targeting behavior change of communities along the value chain.

Milk production and consumption. In conjunction with Land O'Lakes International Development, a market-based, value-chain approach was initiated with smallholders in Zambia to reduce household food insecurity through increased incomes from the sale of milk and other dairy products. The project also sought to increase the demand for dairy products among producers and consumers (Swanson, 2009; Grant & Russell, 2011). The project was able to bring vulnerable households out of poverty successfully and sustainably, reducing their food insecurity, improving their income, diversifying their sources of income, and improving the quality and diversity of their diets. Income increased by about 52 percent for the small producers among the more than 22,000 beneficiaries (Hawkes & Ruel, 2011). The number of months households were food secure increased by 36 percent, while household dietary diversity scores were 33 percent greater among project-supported beneficiaries than among non-beneficiaries. Project beneficiaries also consumed greater quantities of animal-source foods, even beyond dairy, compared with non-supported groups. Finally, all households with a milking cow reported improved nutrient intake, particularly among children.

A Dairy Value-Chain Action Plan Development that focused on enhancing dairy productivity was implemented in Kenya. This was done through better animal husbandry, improved milk quality, the integration of producers into commercially viable value chains, and the development of markets for milk and dairy products. Beneficiaries increased sales of milk to rural consumers directly and through their cooperative self-help groups. Milk and milk products were distributed to lower-income urban consumers, through traders, hawkers, milk bars, etc., and to higher-income urban consumers through large, medium, and small processors and retailers. No specific indicators that might capture their nutritional impacts through increased consumption of milk and other dairy products were monitored, however (Henson et al., 2012; Land O'Lakes, Inc., 2009).

Bean production and consumption. A project in Uganda integrated information on agronomic, postharvest, nutritional, and market factors regarding bean production and consumption. It built a strong program of academic training and engagement. With the ultimate goal of improving sustainable livelihoods in rural communities, the immediate objectives were to improve harvested-bean yield and quality; enhance the nutritional value of, and demand for, beans through appropriate handling and processing practices and technologies; and identify solutions for overcoming constraints to increased market access and consumption. Actions included research into increasing yields, improving nutrient quality after harvest, understanding consumers' preferences and demand, increasing consumer awareness of the nutritional and health benefits of beans, and promoting bean consumption (Mazur, Nakimbugwe, Ugen, & Kizito Musoke, 2011). Better nutrition was achieved by increasing both supply and demand through focusing on the nutritional value of the bean for consumers and on the economic value to producers. Nutritional outcomes were not measured, as rural and urban consumers increased their consumption of beans through new value-added products that also contained other ingredients.

Mishili et al. (2009) also worked in three West African countries (Nigeria, Ghana, and Mali) to determine what factors were associated with the value of cowpeas for smallholders and could be modified so local farmers could increase their portion of the domestic urban markets. They were able to show that improving production and handling practices could increase the value of their cowpeas, and that larger peas resulted in higher prices. The impact on skin and eye color of the peas and even the texture was more site-specific, however. Interestingly, the amount of damage due to the cowpea bruchid (*Callosobruchus maculatus)* holes was not significant. However, the range of damage that was assessed is not known.

<u>Non-agricultural value chains with nutrition benefits</u>. Although not directly related to agriculture, a successful project funded by the Inter-American Development Bank provided funds to support the entry of micro-producers in Central America into the global market for handicrafts (Humphrey & Navas-Alemán, 2010; Guaipatin, 2005). The objective of the project was to increase the incomes of micro-enterprises by supporting a buyer-driven approach to value chain development. The project evaluation compared baseline and endline data, but did not include a control group. In addition to increasing income, it was reported that project participants had improved their diets.

<u>Food fortification</u>. There are many types of food processing procedures that affect the nutritional values of food products. Food fortification is a nutrition-focused approach that is closely aligned to food production. Most programs have focused on fortifying foods with iodine, vitamin D, iron, folate, niacin, thiamin, and vitamin A when trying to combat micronutrient deficiencies. Staples are one of the primary vehicles to fortify as they are universally consumed and remain a reliable source of food when families are faced with economic shortfalls (Timotijevic, Timmer & Oguunlade, 2013; Balarajan, Ramakrishnan, Özaltin, Shankar, & Subramanian, 2011). Food fortification can be applied across various arrays, including (1) mass or targeted programs, (2) voluntary or mandated programs, and (3) nationally and centralized programs or locally implemented programs. Additionally, there are in-home fortification programs using centrally-produced products such as Sprinkles or locally produced products for home use such as Ying Yang Bao in China (Chen, Wang, He, Chang, & Preedy, 2013). In all these cases, there is a need to have local infrastructure and trained personnel and this program requirement can generate additional income-earning opportunities for smallholders (Miller & Welch, 2013).

The advantage of focusing on local food fortification is that many of the staples that are being fortified are often imported and local fortification may help fill a gap in a small farmer's income by creating a product that can be brought to the market with added value (Mackerras, Thomas, March, & Hazelton, 2013; Timotijevic et al., 2013). Local production can also help reach the most vulnerable populations which mass fortification programs are not able to adequately target and cover (Burchi et al., 2011). Local food production may also be able to expand the range of fortified products that are locally acceptable. For example, studies have shown that Ultra Rice® as a vehicle for iron fortification is as effective as iron drops for young children (Beinner, Velasquez-Meléndez, Pessoa, M.C., & Greiner, 2010).

The Global Alliance for Improved Nutrition (GAIN) has developed a model to determine how to best match fortification programs with need as a function of public-sector financing vs. private-sector sustainability and the relative importance of focusing on the general public and specific high-risk groups. Small scale local fortification is less reliant on market-based factors and therefore less sustainable through the general market. However, it is able to target more vulnerable populations who are also less able to pay for the added value and thus these programs often need more public funding (Moench-Pfanner & Van Ameringen 2013). However, other models along the food chain have shown that with the right knowledge and motivation, consumers are willing to pay a greater price for more nutrient rich foods (Meenakashi et al., 2012; Chowdhury et al., 2011; de Brauw et al., 2013). Furthermore, the cost efficiency and cost effectiveness of fortification programs can now be more easily compared with other interventions as potentially use the newly created Omega value for comparative outcome studies which provide a value to compare nutrient intake per dollar spent (Ryckembusch et al., 2013).

Evidence gaps

Given the limited number of studies on the value chain and nutritional status, there are many gaps in knowledge on how value chain investments can lead to improved consumption of diverse diets. It is not known at what points on the value chain it would be most cost-effective to intervene to increase the income of producers and the consumption of diverse diets of both producers and consumers. It should be possible to conduct additional studies to determine which changes in the value chain affect consumption patterns using pathway analysis without having to conduct costly and impractical randomized clinical trials (Pinstrup-Anderson, 2013). These studies can focus on how policies affect income, prices, women's time use, and diet (Pinstrup-Anderson, 2013). Other research priorities include investigating how farming systems can give higher priority to producing a greater variety of nutrient-dense foods rather than simply increasing production of calorie-dense foods and, at the other end of the value chain, whether increasing the nutrient content of diverse foods can occur without significant increases in prices so consumers can reap the benefits from new products. Similarly, research on local food fortification has focused on consumers and there is limited information on if and how local farmers can benefit from community-oriented fortification programs. Much of the information that is lacking in these areas is due to lack of strong evaluation designs.

Additional research is needed on the role that contract farming has on the income of smallholders and their ability to purchase high-value foods. Theoretically, working directly with large market actors can get smallholders better access to inputs, but performance with externally-funded projects in Asia has been mixed (Asian Development Bank, 2012). Experience in this sector has shown that even with contract farming, smallholders still need access to credit, business skills, roads, and information services, and they need to organize to have strength in numbers.

The short- and long-term risks associated with dual cropping of biofuel and food crops are not known. It is also necessary to determine the demand elasticity of the products that result from various value chains to know if consumers will purchase new, more diverse and nutritious foods under various economic conditions. One of the global factors that may affect crop production is the growth in demand for biofuels (Ewing & Msangi, 2009). It is possible that in LMICs, a balanced approach for smallholders to increase the value of their crops is to produce crops that can be used for both consumption and bioenergy at a local level. This may cushion farmers against fluctuating food prices, increase employment opportunities, and improve women's time use as women spend less time gathering biomass for home energy use. Data is needed to determine whether or not this is so, and if yes, what would be the required financial and technical investments for this conversion.

Another line of studies related to dual-cropping is to determine the right balance between production of food crops for income and consumption and for feeding of large animals. With this form of dual cropping, crop residues from food crops are used for feed, and animal manure is used for farming. Potentially, this allows farmers to produce more food on less land and decrease the environmental impact of farming and provide for a more diverse diet without having to increase inputs (Herrero et al., 2010), but the economic feasibility for smallholders is not known.

There is a need to understand how to enhance the capability of smallholders to adhere to food safety regulations and certifications, as this is likely to increase their ability to gain entry into larger domestic and export markets. It is known that they need access to credit and know-how to meet defined standards (Herzfeld, Drescher, & Grebitus, 2011), but research is needed on whether this will be sufficient.

Food safety and quality regulations target characteristics of food that increase their value, such as nutrient content, hygienic standards, labor practices, and environmental sustainability practices. These regulations have health benefits for consumers (including the smallholders themselves), but they have a cost that must be paid initially by the farmer and that ultimately is reflected in the price of the end products. Most smallholders are net food buyers and there is a trade-off for them between obtaining more secure market access for their crops and maintaining low prices for the food they buy (Gómez et al., 2011). Research is needed to determine how smallholders are likely to weigh this trade-off and what will give them more benefit: focusing on adding value to foods that will be affordable by the poor or adding more value to food to target wealthier consumers. Additional information is also needed from studies such as those being carried out by GAIN in Ghana, which is collaborating with the cocoa industry to integrate health and nutrition as part of cocoa certification programs. The collaboration focuses on food production by cocoa farmers, strengthening the role of women in society, and providing nutrition education on the value of micronutrients. Another area where additional research is needed concerns determining the best technologies and methods to decrease postharvest losses. Farmers may be losing a third of their value in fruit and vegetable production between harvest and consumption (Kitinoja, Saran, Roy, & Kader, 2011). Decreasing this loss can increase food availability and income without the need to increase production by the same amount. Investments in this area will also improve employment and income for those who are employed in this growth sector (Weinberger & Lumpkin, 2007). Research can focus on the causes and magnitude of postharvest losses and what is the return on investment for various postharvest technologies including cooling practices, packaging, transportation, treatments to decrease spoilage and pest infestations, and other food safety technologies (Kitinoja et al., 2011). However, research funds in this area are very limited. For example, only about 5 percent of total funds being spent on horticultural research at this time is going toward reduction of postharvest losses.

3. Impact of Agriculture Technology Interventions on Diet and Nutrition

Which agriculture technology interventions have improved diets and nutrition outcomes?

Evidence

Introduction

Several agricultural technologies have been developed, tested, implemented, and evaluated with regards to crop production, but these are rarely tied to nutritional outcomes for producers. The major efforts have focused on soil and plant health, including technologies such as irrigation, fertilizer, and pesticides. There has also been a growing interest in how to use modern communication systems to provide information and skills to rural farmers. Other technologies that potentially improve dietary diversity and nutrition outcomes for farmers have included biofortification; decreasing postharvest loss; food processing (grinding, milling, drying, etc.); and biotechnology to improve animal production. Only a few reports on these technologies provide information about how they have improved diet and nutrition outcomes. This review focuses on irrigation, pesticides, and fertilizers, as they are major costs for smallholders and are more directly related to food production. We also examine the role of communications as a way to bring together agriculture and nutrition information systems. All the studies reviewed below cite evidence that shows how agricultural technologies that are important for increasing productivity can also have positive impacts on nutrition, if certain conditions are met.

Irrigation

Irrigation shows promise for breaking the cycle of low productivity that characterizes the persistent poverty found in rural agricultural communities in LMICs. By enabling year-round cultivation of high-value crops, irrigation can improve incomes and food security, and alleviate both chronic and seasonal malnutrition that is prevalent in food insecure areas (Dillon, 2008; Oni, Maliwichi, & Obadire, 2011; Bhagowalia et al., 2012; Fanadzo, 2012). Some smallholder irrigation systems are used mostly to grow vegetables in the dry season for home consumption and sale. Irrigation systems can also contribute to improving the intake of staples and animal-source foods as a result of higher incomes and improved livestock productivity (Aseyehegn, Yirga, & Rajan, 2012). People who have access to irrigated land can stabilize their food supplies more easily by having a more secure source of product for consumption and sale, though this benefit is likely to be more significant for large farming operations than for smallholders. In some instances, small-scale irrigation systems also provide more water for domestic use that can improve health status through better hygiene (Manos, Papathanasiou, Bournaris, Paparrizou, & Arabatzis, 2009; Schaible & Aillery, 2012; van der Hoek, Feenstra, & Konradsen, 2002; Keiser et al., 2005).

The impact of irrigation interventions on poverty alleviation has been extensively covered in the literature (Lipton, Litchfield, & Faurès, 2003; Aseyehegn et al., 2012; Burney & Naylor, 2012), but the potential of irrigation to improve nutrition and health has been less documented. The literature is also inundated with case studies of irrigation projects that have ultimately failed, often due to energy access issues, technical failure, or lack of training in horticultural methods (Belder, Rohrbach, Twomlow, & Senzanje, 2007; Sasson, 2012).

Introduction of treadle pumps for smallholders in Malawi enhanced food security resulting from introduction of horticulture and increased income (Mangisoni, 2008). Burney, Woltering, Burke, Naylor,

& Pasternak (2010) also reported positive impacts of irrigation on food security among users of solar-powered drip irrigation systems in Benin. The consumption of vegetables during the dry season increased, and irrigators were 17 percent less likely to identify themselves as being chronically food insecure. In Ethiopia, farmers using small-scale irrigation systems increased their agricultural production through diversification and intensification of crops grown (Aseyehegn et al., 2012). Cropping pattern changes were also reported in India after the installation of micro-irrigation technologies, with adopters producing more diverse crops, including high-value and water-intensive crops (Namara, Upadhyay, & Nagar, 2005).

In The Gambia, the links between production, income, consumption, and nutrition were assessed in rice irrigation projects (von Braun, Puetz, & Webb, 1989). The cultivation of rice increased the income of farmers by 13 percent; moreover, with each 10 percent increase in annual income there was a corresponding 9.4 percent increase in food expenditure and a 4.8 percent increase in calorie consumption. In Ghana, farmers using riverine seasonal shallow wells for irrigation had the greatest household dietary diversity scores and these scores were associated with improved birth weights, child anthropometric status, and improved hemoglobin concentrations (Hoddinott & Yohannes, 2002; Namara et al., 2011). The results from Ghana also found that income gains from livestock were14 percent greater among irrigation users compared with non-users.

Very few studies have analyzed the linkage between irrigation and health (Domenech & Ringler, 2013). Studies that have been done focus on use of irrigation for producing dark green leafy vegetables since they contain high levels of β-carotene and iron and therefore are useful in fighting vitamin A deficiency and anemia (Nawiri, Nyambaka, & Murungi, 2013). These studies found that the effect on dietary diversity depended on several factors, such as the epidemiologic setting, the ecology of the area, and the socioeconomic status of the population (Wielgosz, Mangheni, Tsegai, & Ringler, 2012).

Although most studies report that irrigation interventions can have many positive effects on nutrition and health, their negative impacts and limitations are also important to note and consider when implementing new irrigation programs. This includes an increased dependency on mono-cropping (Hossain, Naher, & Shahabuddin, 2005). Also, irrigation systems may affect water-related diseases by changing vector-breeding habitats (Ijumba & Lindsay, 2001; Keiser et al., 2005). Additionally, toxicity data reflecting how pesticides, arsenic-contaminated water, and wastewater can get incorporated into irrigation systems and affect the health of people exposed to these contaminants is still limited. The impact of an irrigation dam project may also not benefit everyone. For example in Ghana, children continued to be anemic and not meet their energy requirements after a dam project was completed (Steiner-Asiedu, Abu, Setorglo, Asiedu, & Anderson, 2012). The authors suggested that it was necessary to have nutrition education target the incorporation of fish from the dam into young child feeding in these communities.

Fertilizer and pesticide use

Fertilizers increase crop production per unit area, increase the quality and nutritional content of crops, and contribute to the quality of food and its content of essential trace elements. Fertilizers can increase crop resistance to diseases and pests (Spann & Schumann, 2010). Crop production can also become more diverse to help meet the nutritional needs of families (Stewart, van Rooyen, Dickson, Majoro, & de Wet, 2010; Roy, Finck, Blair, & Tandon, 2006; Erisman, Sutton, Galloway, Klimont, & Winiwarter, 2008; Shivay, Kumar, & Prasad, 2008; Bouis & Islam, 2012; Bruulsema, Heffer, Welch, Cakmak, & Moran, 2012). The increased yields and quality can improve the returns from market sale of crops and the health-promoting properties of fruits and vegetables (Jifon et al., 2012). Overall, the use of fertilizer has provided significant economic and social benefits for farmers who have the resources to purchase them, resulting in greater farm incomes, improved food consumption, and the maintenance of national food security (Prasad, 2009; Huang, Sass, Sun, Zhang, & Yu, 2010).

The downside of fertilizers is that some portion inevitably washes into waterways along with eroded sediments. Nitrogen fertilizers that contaminate rivers, lakes, and the ocean can cause eutrophication and dead zones that kill aquatic life. Nitrates and nitrites from fertilizer are also among the most common contaminants in drinking water (Nițuc, Năstase, Mihăilescu, & Chioveanu, 2010; Hord, 2011). Another issue that exacerbates the potential harm from fertilizers is that they are often used inefficiently and in excess and end up in groundwater (Lipton, Sinha, & Blackman, 2006).

Pesticides also increase yields, protect crops, increase the preservation of food, and help prevent vector-borne diseases (Aktar et al., 2009; Sheikh, Nizamani, Jamali, & Kumbhar, 2011). On the other hand, they can have detrimental effects on the environment and human health. Pesticides can cause water pollution when erosion carries the chemicals off farms along with eroded soils after each rainfall. Pesticides are associated with reproductive morbidity, poor fetal growth, and birth defects (Barr et al., 2010; Brender, Felkner, Suarez, Canfield, & Henry, 2010; Dugas et al., 2010; Chevrier et al., 2011). Prenatal pesticide exposure is also associated with measurable deficits in child neurodevelopment from birth to adolescence (Engel et al., 2007; Sagiv et al., 2008; Torres-Sánchez et al., 2009; Harari et al., 2010; Vandenberg, 2012). Pesticides can affect the respiratory system and lead to obstructive and restrictive lung diseases. Childhood asthma has been associated with maternal exposure to organophosphate and organochlorine insecticides, and respiratory tract infections in infants have been linked to maternal exposure to organochlorine insecticides (Sunyer et al., 2005; Sunyer et al., 2006; Hoppin et al., 2008; Hoppin et al., 2009; Hernández, Parrón, & Alarcón, 2011). Studies on pesticide exposure provide strong evidence that pregnant women and children need to minimize their pesticide exposure from all potential sources, including dietary, indoor and outdoor air, water, and farm and domestic use. Investment in the proper use of fertilizers and pesticides remains important and is crucial for LMICs in order for smallholders to meet the growing demand for food and become active members in global value chains (Aktar et al., 2009; Sheikh et al., 2011). Current evidence supports the view that investments in product improvement and training are profitable and contribute simultaneously to improved productivity and safety. However, information on how this translates into impact on nutrition and health outcomes is very limited.

Communications

Using ICT is not new for disseminating agriculture and nutrition information. Radio, television, newspapers, and more personal channels such as village leaders and cooperatives have been used to give out information and conduct social marketing campaigns to improve nutritional status. With the advent of the Internet and mobile technology, there has been a resurgence of interest in how to develop better ICT methods for getting information to rural populations, including farmers with regards to agricultural practices. Mobile phones and computer centers are the most targeted channels to provide not only technical and scientific information on crop production and nutrition, but also to support the marketing of products that can help level the playing field between small producers and traders (Aker, 2011).

Rural information systems have been hampered by low literacy, poverty, lack and unreliability of electricity, and the cost of the ICT infrastructure. Even with these limitations, local telecenters in Tanzania have increased access to information on markets, weather, credit, inputs, and animal and crop management. End users have been able to share limited resources, such as a mobile phone, to create two-way communication systems using text messaging. Mobile phones have even been used to send photos of plants to help diagnose plant diseases as a form of "tele-agriculture" to support yields (Mtega & Ronald, 2013). As ICT programs grow, they need to plan to include women explicitly so that women get equal access to information, including information on healthy ways to diversity diets and apply good nutrition practices.

Evidence gaps

Although irrigation has been shown to increase yield and diversity of foods grown, there is a need to determine what types of irrigation systems smallholders will be willing to implement with an acceptable level of risk in various environmental situations.

More efforts are still needed to address how irrigation impacts nutrition. Studies need to include measures of nutrition and health impacts by collecting indicators of food intake, biomarkers, and functional outcomes of all who are targeted. It is also important to monitor indicators of potential harm with each intervention and determine which irrigation systems are able to limit vector-borne diseases such as dengue and malaria.

What motivates farmers to adopt or not adopt small-scale irrigation technologies is not well understood. Moreover, there is a need to better understand how to design subsidy programs and increase the size of loans available through microcredit programs so as to favor small-scale irrigation technologies with known nutritional benefits.

By controlling risks while maximizing benefits, irrigation programs can become an important input for improving nutrition and health of vulnerable populations. More research is needed on identifying risks and overall impacts that will be critical to the design and implementation of effective irrigation interventions.

Given the important role of fertilizers and pesticides in promoting food and nutrition security, it is important to invest in research aimed at optimizing the benefits associated with their use. Research is needed on how to improve training methods and provide incentives for behaviors that will result in applying the right fertilizers and pesticides at the right rate, at the right time, and in the right place. This will enhance the benefits and minimize the potential negative impacts associated with these chemicals. It is hypothesized that fertilizer use efficiency technologies such as urea deep placement can address both fertilizer inefficiency and water contamination issues if used effectively; however, evidence to support this is still lacking.

Studies on the interaction between pesticides and health need to continue quantifying dietary and other sources of pesticide exposure for smallholders and their families. Most studies have only examined the health effects resulting from high levels of pesticide exposure. More information is needed on the effect of low levels of exposure from both dietary and non-dietary sources (Fenner-Crisp, Keen, Richardson, Richardson, & Rozman, 2010).

Additional research on biological interventions that can be combined with food production is another area of increasing importance. Changing food patterns are thought to have decreased the microbiota of the human gut, putting our species at an increased risk for various infectious and non-infectious diseases (Blaser & Falkow, 2009). At the same time, scattered studies suggest that it is possible to modify the microbial companions of food to increase the microflora population of the gastrointestinal tract as a potential way to increase energy and micronutrient absorption and decrease the impact of pathogenic organisms (Dethlefsen, McFall-Ngai & Relman, 2007). For example, a comparative study of children from Europe and Burkina Faso suggested that diets that enhance the short-chain fatty acids in the gut may provide protection against infectious species of *Shigella* and *Escherichia* (De Filippo et al., 2010). Additional human research in this area is needed, however.

Studies on whether changing plant microbiota could be an alternative to aflatoxin treatments for decreasing the presence of mycotoxins from *Aspergillus*, and on whether changing the rhizosphere (below ground) and phylospshere (above ground) environments of plants could be a method to increase crop production would fill an evidentiary gap on a topic of growing interest. Similarly, research on biological techniques that could modify and improve agricultural use of fertilizers and pesticides and therefore decrease the potential harm from these products and the cost for food production would also be valuable (Berlec, 2012).

Other technologies need to be studied under a variety of environmental and socio-cultural conditions. There is not enough information about how to link new methods of land management (e.g., no-till farming) with nutrition in terms of crop choice, e.g., which crop will generate the most income, which will result in greatest improvement in nutritional status, and which will make the fewest demands on women's time. There is still a lack of knowledge on how to encourage adoption of technologies to reduce postharvest loss. Further development of local food processing methods that can help preserve and add value to foods at the home level is also needed. An example is the current search for a way to improve the local grinding of teff in Ethiopia to decrease labor demands and reduce postharvest loss.

There is a need to communicate information about how different technologies can be combined to maximize dietary diversity and nutrition. Mechanisms need to be put in place so that agronomists, engineers, and nutritionists can work together in ICT programs to develop sustainable local food systems. This would help maximize and sustain nutrition initiatives such as de-worming and iron and vitamin A supplementation campaigns. Finally, behavioral change theories and topics should be incorporated in the design of nutrition education programs for smallholders to facilitate their decision making regarding use of increased agricultural income.

4. Capacity Development for Large-Scale Nutrition Outcomes

What investments in human and institutional capacity development have effectively generated large scale nutrition outcomes?

Evidence

Introduction

Historically there have been relatively few large-scale investments at a national or sub-national level within LMICs that have built human or institutional capacity to target and effect nutrition outcomes. Nevertheless, a few striking examples do exist of successful investment in building capacity at both national and local levels to improve nutritional status. Insights offered by these examples are reported here.

Human capacity concerns the knowledge and skills of individuals (APLGU, 2009). Institutional capacity concerns the function, competence, resources, and structure of institutions (Bhagavan & Virgin, 2004). For the purpose of this review, beneficiaries of human capacity development include: (1) individuals who provide services to target populations so they have the knowledge and skills needed to effect nutritional outcomes, and (2) individuals who receive services that help increase their knowledge and build their skills. Beneficiaries of institutional capacity development include government ministries, health care systems, agricultural extension services, cross-sector and multi-sector coordinating mechanisms, local authorities, and community-based membership groups, amongst others.

Human capacity development

The most common investments to build human capacity for improving nutritional status have involved recruiting and training CHWs. Each successful program has spent significant resources in this area, whether the CHWs are part of the paid health care system or volunteers.

CHWs are mostly incorporated into community-based programs CBPs. Investment in the CHWs usually includes initial training that can last from a few days to several weeks. Training provided to CHWs typically covers (1) how to implement nutrition and health care services for mothers, (2) how to educate communities on good infant and child feeding practices, (3) how to improve the micronutrient status of children, and (4) how to introduce women to best practices for food production, storage, and preparation, with a special focus on providing adequate nutrition for women and children.

Followup training is essential and can be used to expand the skills of the CHWs, especially with regards to behavior-change communication skills (Aker, 2011). As CHWs' skill levels increase, they are better able to interact with community members in areas such as health and nutritional assessments or advocacy (McPherson et al., 2010).

Increasing the number of trained CHWs builds and stabilizes the institutional capacity of the health care system to deliver large-scale programs. The number of CHWs in programs ranges widely. A program in Thailand had one CHW for every 20 children, which resulted in having 1 percent of the total population trained as CHWs. On the other end of the spectrum, the Bangladesh Integrated Nutrition Program had one CHW for every 300 households. It is also common to have one supervisor for every 10 to 30 CHWs (Mason, Sanders, Musgrove, Soekirman, & Galloway, 2006).

Increasing the number of agricultural extension workers and updating their training is another investment that has been used to improve the income and nutrition of smallholders (Meinzen-Dick et al., 2010; Gill & Gill, 2010). Extension programs are able to increase yield, expand and increase the stewardship of land, prevent losses along the value chain, and increase the adoption of biotechnology (Gill & Gill, 2010). New extension approaches have included having programs be more decentralized and farmer-driven, and privatizing and contracting out extension services (Meinzen-Dick et al., 2010). Additionally, investing in incorporation of training and enforcement of various standards and regulations in extension programs has also been suggested as an important method for increasing smallholder incomes by enabling them to supply safe food to markets (Perez-Aleman, 2012).

One of the primary ways that extension workers have supported nutrition is by reaching women farmers. Extension workers can help women learn new techniques for producing greater quantities and more diverse foods for home consumption and increase their ability to obtain income from their agriculture activities and thus enjoy greater purchasing power in the marketplace. However, women farmers are underrepresented when it comes to having access to extension workers (Meinzen-Dick et al., 2010). Extension workers can support the uptake of new technologies by women farmers and potentially decrease the unbalanced access to resources that women farmers have in many LMICs. However, for this to happen, the information that is given to women farmers needs to be the same as that provided to men, which is often not now the case (Peterman et al., 2010).

In building human capital, it is important to increase the human capacity of the poor. Programs need to target either the most vulnerable households by income and/or geographic area, or the most malnourished individuals as measured by anthropometry.

Building institutional capacity

Successful large-scale nutrition programs reflect the presence of well-developed institutional capacity. Where they exist, such programs have typically focused on (1) changing behaviors through education (breastfeeding, timing and food for complementary feeding, and hygiene), (2) micronutrient interventions; and/or (3) supplementary feeding to prevent and treat moderate and severe protein-energy malnutrition. AFROSAI-E (2010) lists five measures of institutional capacity:

- Independence and legal framework;
- Organization and management;
- Human resources;
- Audit standards and methodology; and
- Communication and stakeholder management.

Evidence from the literature suggests two that are particularly important for sustained improvement in nutrition. These are: (1) strong leadership and national commitment, and (2) coordination of efforts across sectors and administrative levels.

Ecker and Nene (2012) argue that the lack of national commitment is one of the main reasons for not reducing undernutrition. According to Gillespie, Haddad, Mannar, Menon, and Nisbett (2013), the most important factor that leads to successful nutrition programming is leadership and a full-out national commitment. If programs that focus on building human capacity for good nutrition outcomes are to be sustained, this commitment must be of a continuing and long-term nature (World Bank, 2006; Heaver, 2005; Nabarro, 2013). Such a commitment can be expressed through adherence to Right to Food principles, as in the case of Brazil, which has incorporated the Right to Food within its constitution (Chmielewska & Souza, 2011). It can also be expressed through participation in global initiatives to tackle hunger and undernutrition. For example, 40 countries have joined the United Nation Standing Committee on Nutrition *Scaling Up Nutrition* (SUN) Movement, and this is viewed as an illustration of their national commitment to decrease undernutrition (Nabarro, 2013).

Factors that indicate a strong national commitment for nutrition-focused programs were described by Ruel (2008) as:

- Strong government action coordinated across central, state, and local levels; and across sectors;
- Leadership at the highest level to ensure attention across branches of government and regions;
- Inclusion of vulnerable groups and their communities in terms of mobilization and information sharing;
- A strong M&E culture that provides a basis for incentives and correction of policy actions in the context of implementation; and
- Significant scaling up of public spending.

Since undernutrition is a complex problem, it requires coordination across government ministries, with various NGOs and the private sector. This, in turn, requires communication, trust, and an understanding and appreciation by all stakeholders (Mwadime, 2011). A unified national and sub-national effort has to establish hunger elimination and poverty reduction as its primary objectives. An important strategy to obtain this is to create a national coordinating body that brings together various public sector entities with different programmatic responsibilities, e.g., food programs; social assistance programs; primary care programs; water and sanitation programs; financing, credit and subsidy programs; education programs; and other sector programs that specific situations require. The committees need to set clear policies and goals, and plan and implement sustained M&E protocols.

All national programs need local support, not only from local officials but also from other community members such as teachers, students, farm leaders, family members, village health workers, health care service providers, and from representatives of local and international NGOs, religious organizations, local community groups, agriculture groups, and women's groups working in the area (Mason et al., 2006). There is often a need to build the institutional capacity of local groups, particularly of women's groups.

Khan et al. (2008) note that strengthening implementation and evaluation processes is an essential aspect of building institutional capacity. This includes getting key stakeholders on steering committees that have the authority and responsibility for directing and managing undernutrition control activities at the community level, and bringing agriculture and nutrition experts together to devise proper cross-sector monitoring and education plans.

Khan et al. (2008) identified the outcome of building institutional capacity for nutrition programs as promoting social mobilization of undernutrition-prevention activities. Effective social mobilization strategies at national and local levels are a key input for building institutional capacity (Tontisirin & Gillespie, 1999). Using CBPR has been shown to be effective in several Asian countries to develop and mobilize community-based nutrition programs (Tontisirin & Bhattacharjee, 2008). In Thailand, this resulted in having government-sponsored facilitators and local mobilizers interface with each other at the community level to provide resources to families. In Laos, it resulted in the development of home gardens, and in Bangladesh it helped disseminate appropriate technologies to smallholders. In Nepal, incorporating female community health volunteers was the key factor for obtaining a high rate of vitamin A distribution to preschool-age children (McPherson et al., 2010). In all these cases, there was a phased implementation in which a few provinces or districts participated initially and then the programs expanded to achieve national scope.

Types of programs involving capacity building that demonstrated positive impact

The most successful targeted nutrition programs that have benefited from human and institutional inputs are CBPs and, more recently, CCT programs. CBPs usually combine a series of inputs at the local level and often use CHWs to help deliver these services (Mason et al., 2006). CCT programs provide financial incentives to families that are linked to specific beneficial and social development behaviors. CCT programs are more effective when they enhance women's responsibility for the behavioral changes that benefit themselves and their children (Lagarde, Haines, & Palmer, 2007).

The interventions that are most commonly part of CBPs have been reviewed for their effectiveness (Bhutta et al., 2008; Bryce et al., 2008). It has been found that implementation of these interventions is able to reduce undernutrition by 25 percent. The most successful nutrition interventions include (1) targeted food and nutrient supplementation such as iodization of salt, centralized fortification programs delivered through clinics, or fortification programs based on local production and home provision, and (2) various education programs including promoting breastfeeding and appropriate complementary feeding practices. Building institutional capacity to deliver these interventions and to conduct growth monitoring is often part of these programs. Experiences from the CBPs that have incorporated these interventions have shown large variations in outcomes and sustainability. Outcomes differ according to the target population (pregnant or lactating women, neonates, infants, or children); the effectiveness of individual interventions to change nutritional status of the target population; and the extent to which conditions needed for developing the required human and institutional capacity are present.

The Poverty Alleviation Plan in Thailand is a CBP that was developed within a primary health care system. It mobilized more than 700,000 CHWs, many of whom served as local facilitators, which helped sustain the program. This program significantly decreased protein-energy malnutrition within 20 years. Anemia was reduced by 50 percent in pregnant and lactating women and vitamin A deficiency is no longer a problem. However, it was more difficult to reduce low birth weight rates, and anemia rates did not decrease for children. Interestingly, due to the nature of iodine deficiency, low urinary iodine levels have remained an issue and iodine deficiency still needs to be targeted (Winichagoon, Kachondham, Attig, & Tontisirin, 1992; Tontisirin, Nantel, & Bhattacharjee, 2002).

In Latin America, CCT programs were first initiated with success in Mexico, where the most extensive evaluations have been conducted (Rivera, Sotres-Alvarez, Habicht, Shamah, & Villalpando, 2004). The CCT program Oportunidades serves more than five million households. Its greatest impact is among the poorest households.

In order for CCT programs to be successful, they need to involve the following sequence of activities: (1) selection of geographic areas that are most at risk; (2) coordination of the various sectors that are involved with the targeted behaviors such as the health and education sectors; (3) targeting of households that will benefit from the program, usually by economic status; (4) recruiting, meeting, and enrolling the targeted beneficiaries of the program; (5) organizing the delivery of the demand transfers; (6) verifying that the beneficiaries carry out the required conditions, whether it be attending clinic sessions or having children attend school; (7) informing the beneficiaries and providing them their appropriate cash transfers in a timely manner; and (8) conducting the necessary M&E protocols

(Glassman, Todd, & Gaarder, 2007). These activities match the institutional capacity needs described by Bhagavan and Virgin (2004).

Heaver (2002) succinctly summarized the kinds of human and institutional capacities and investments that need to be provided to improve nutrition beyond decreasing poverty:

- Strong national commitment and agreement that improving the nutritional status of the poor is important for development;
- Local ownership;
- Coordinated investments in the training of CHWs and agricultural extension workers;
- Empowered local communities that have oversight for the allocation of resources;
- Local contributions to instill self-reliance and increase the chances of sustainability;
- Resources to target the most vulnerable populations;
- A national nutrition investment plan with short- and long-term goals;
- National and local input into the development of programs;
- Technical support for organizations to maintain their commitment to nutrition; and
- Phased implementation (starting small and building up in a manner that optimizes investments.

Evidence gaps

There is considerable evidence regarding capacity-building interventions that work on a small scale. Studies need to be conducted, however, to determine the type and amount of human and institutional capacity required to integrate agriculture and nutrition programs at a scale sufficient to cover large numbers of smallholders and the urban poor. It also is not known how to integrate CBPs and CCT programs with agriculture interventions so that smallholders and urban poor can take advantage of safety nets that provide short-term relief and, at the same time, obtain the long-term benefits of economic development that agriculture can provide. Research is needed on determining who benefits the most in both the short and the long term from CBPs and CCT programs as measured by indicators of nutritional status, health, income, wealth, and happiness, so program elements can become more refined and better targeted.

Given the grouping of interventions within CBPs and CCT programs, it is important to generate evidence on how to combine various components of these programs in new ways with agriculture. For example, could training and education programs on health, nutrition, and consumer economics be usefully integrated with training in good agricultural practices and farm management? Can institutional capacity be built to create value-added programs to support local food production for school feeding programs that encourage school enrollment and improve the nutritional status of children? There is also a need to obtain more qualitative evidence on what increases participation in CBPs and CCT programs.

More information is needed about what skills are best utilized by extension workers and which extension activities give the highest return on investment, e.g., field visits to individual plots, presentations at group meetings, demonstration plots, and farmer field schools. Training methodologies should be evaluated to determine what type of training will best enable extension workers to obtain cultural skills necessary to be effective and to engage women in extension activities. Studies on how to train women as extension workers are also needed.

Finally, the most critical gap is the lack of knowledge on how to get long-term commitments of national and global leadership to sustainable programs for reducing poverty and improving nutritional status on a large scale.

IV. BROADER QUESTIONS FOR THE THEME

As undernutrition is mostly segregated and confined to the poor and rural, there is a need to integrate questions about increasing food availability for the masses with questions about how to direct nutrient-rich food toward those who are most vulnerable. More broadly, is there a way to have multiple small interventions that decrease both hunger and undernutrition at the local level that can eventually have sub-national, national, and global impact? Is it possible to scale up nutrition by linking many small projects into a large net so that each thread is helping a community? In essence, can undernutrition be conquered one village at a time, and what are the ramifications of this approach?

Or do programs always have to be large to generate the maximal production of food, e.g., large dam projects for irrigation, large mono-cropping farms focusing on staples that then use the market and various safety net programs to get food to the poor? This is not to negate the need to produce and transport enough food along a value chain to meet the exponential growth in urbanization. However, it is necessary to find ways that smallholders can get more fruits and vegetables to urban areas where they can be consumed by populations that are at risk for overnutrition and related diseases. The double burden of undernutrition and overweight is of increasing concern and needs to be studied in relationship to agriculture and food security programs. Finally, and most importantly, the question of whether programs are being implemented and evaluated within a human rights approach that acknowledges the right to nutritious and safe food for all should be explicit in all further research.

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