



INTERNATIONAL
FOOD POLICY
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IFPRI Discussion Paper 01681

October 2017

Nutrition-Sensitive Agriculture
What Have We Learned and Where Do We Go from Here?

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ABSTRACT

A growing number of governments, donor agencies, and development organizations are committed to supporting nutrition-sensitive agriculture (NSA) to achieve their development goals. Although consensus exists on pathways through which agriculture may influence nutrition-related outcomes, empirical evidence on agriculture's contribution to nutrition and how it can be enhanced is still weak. This paper reviews recent empirical evidence (since 2014), including findings from impact evaluations of a variety of NSA programs using experimental designs as well as observational studies that document linkages between agriculture, women's empowerment, and nutrition. It summarizes existing knowledge regarding not only impacts but also pathways, mechanisms, and contextual factors that affect where and how agriculture may improve nutrition outcomes. The paper concludes with reflections on implications for agricultural programs, policies, and investments, and highlights future research priorities.

KEY HIGHLIGHTS

- Nutrition-sensitive agriculture (NSA) programs improve a variety of diet and nutrition outcomes in both mothers and children, especially when they include nutrition and health behavior change communication and carefully designed interventions to empower women.
- Greater benefits for child nutrition are achieved when programs incorporate actions to improve health, water, sanitation, and hygiene practices and provide micronutrient-fortified products.
- NSA programs should focus on improving access to and consumption of high-quality diets for all household members rather than on reducing childhood stunting (which they have not yet achieved even with well-designed and -implemented programs).
- A variety of contextual, cultural, economic, and food environment factors modify the impacts of agriculture on nutrition outcomes, with markets and women's empowerment being among the most important.
- Although a rich body of evidence is emerging from recent studies on the nutrition impacts of NSA programs and other agricultural investments, there are still important gaps in knowledge that need to be filled. Examples of research priorities include documenting the sustainability, scale-up opportunities and challenges, and cost-effectiveness of NSA programs, and understanding their role in, contributions to, and interactions with markets, the food environment, and local and national food systems.

Keywords: Agriculture, diets, impact evaluation, nutrition, nutrition-sensitive programs, women's empowerment

ACKNOWLEDGMENTS

We are grateful for the significant contributions to the design and focus of the paper from Nancy Johnson, previously senior research fellow at the International Food Policy Research Institute (IFPRI), now senior agricultural officer (CGIAR) at the UN Food and Agriculture Organization, Rome. This work was undertaken as part of the CGIAR Research Program on Agriculture for Nutrition and Health (A4NH). This paper has not gone through the standard peer-review procedure of A4NH's Lead Center, IFPRI. The opinions expressed here belong to the authors, and do not necessarily reflect those of A4NH or CGIAR.

ACRONYMS

BCC	behavior change communication
BMI	body mass index
CRCT	cluster-randomized controlled trial
DHS	Demographic and Health Surveys
EHFP	enhanced homestead food production
HAZ	height-for-age z-score
Hb	hemoglobin
HKI	Helen Keller International
ICDS	Integrated Child Development Services (India)
IMMANA	Innovative Methods and Metrics for Agriculture and Nutrition Actions
IYCF	infant and young child feeding
MNFY	micronutrient-fortified yogurt
MNP	micronutrient powder
NDVI	normalized difference vegetation index
NGO	nongovernmental organization
NSA	nutrition-sensitive agriculture
OSP	orange-fleshed sweet potato
ppt	percentage point
RAIN	Realigning Agriculture to Improve Nutrition
SMG	solar market garden
VMF	village model farm
WASH	water, sanitation, and hygiene
WAZ	weight-for-age z-score
WEAI	Women's Empowerment in Agriculture Index
WHZ	weight-for-height z-score

1. INTRODUCTION

A growing number of governments, donor agencies, and development organizations are committed to supporting nutrition-sensitive agriculture (NSA) to achieve their development goals. Nevertheless, nutrition-specific interventions alone, even if implemented at scale, will not meet global targets for improving nutrition (Bhutta et al. 2013; WHO 2014). Other sectors need to contribute as well, and agriculture has strong potential due to the many ways in which it can influence the underlying determinants of nutrition outcomes (Black et al. 2013), including through improving global food availability and access and through enhancing household food security, dietary quality, income, and women's empowerment. Globally, the need for agriculture to support better nutrition and health has been recognized and was reflected in the discussions leading up to the United Nations' 2030 Agenda for Sustainable Development, and regionally, it is reflected in the growing number of initiatives to support countries in integrating nutrition interventions into their agricultural investment plans, as illustrated by the Comprehensive Africa Agriculture Development Programme investment plans, from design through implementation.

Making agriculture more nutrition sensitive, however, requires a new way of thinking, planning, implementing, and partnering, as well as the active engagement of a variety of stakeholders from multiple sectors. Some of the initial steps undertaken to bring the relevant stakeholders and sectors together include designing and agreeing on conceptual frameworks that identify the multiple pathways by which agriculture can impact nutrition. This topic has been the subject of an extensive body of work including the development of several conceptual frameworks that highlight the dynamic and multifaceted linkages between agriculture, health, and nutrition (Headey, Chiu, and Kadiyala 2012; Herforth and Harris 2014; IFPRI 2011; Kadiyala et al. 2014; Pinstруп-Andersen 2012; World Bank 2007). Drawing on this literature, Ruel and Alderman (2013) identified six pathways through which agricultural interventions can impact nutrition: (1) *food access* from own-production; (2) *income* from the sale of commodities produced; (3) *food prices* from changes in supply and demand; (4) *women's social status and*

empowerment through increased access to and control over resources; (5) *women's time* through participation in agriculture, which can be either positive or negative for their own nutrition and that of their children; and (6) *women's health and nutrition* through engagement in agriculture, which also can have either positive or negative impacts, depending on exposure to toxic agents and the balance between energy intake and expenditure. The characterization of the pathways by which agriculture and nutrition are linked and of the unequivocal mediating role of women's status and empowerment in these linkages has been instrumental in stimulating the development of new initiatives and investments to leverage agriculture to improve nutrition.

Although conceptual frameworks and hypothesized impact pathways are a critically important first step, efforts to support agriculture so that it delivers on nutrition need to be grounded in evidence. A number of reviews of evidence have been published in the past two decades (see, for example, Berti, Krasevec, and FitzGerald 2004; DFID 2014; Fiorella et al. 2016; Leroy et al. 2008; Masset et al. 2012; Pandey, Mahendra Dev, and Jayachandran 2016; Randolph et al. 2007; Ruel 2001; Webb and Kennedy 2014; and Webb-Girard et al. 2012), and all of them agree that evidence on what and how agriculture can contribute to nutrition is extremely scant. The reviews cover a range of agricultural programs including homestead food production systems; home vegetable gardens; biofortified crops; small animals; livestock; fisheries; dairy; and irrigation projects. In spite of differences in the sets of studies reviewed and the methods and nutrition indicators used in the original studies, the findings from these reviews are surprisingly consistent. Overall, they find evidence that agricultural development programs that promote production diversity, micronutrient-rich crops (including biofortified crops), dairy, or small animal rearing can improve the production and consumption of targeted commodities, and some evidence that such improvement leads to increases in dietary diversity at the household and sometimes the maternal and child level. The reviews report a few cases, especially with biofortified vitamin A-rich sweet potatoes, in which increased production and consumption led to improvements in vitamin A status and health in young children, but little evidence overall of impacts on child stunting, underweight, or wasting; in addition, very few studies have looked at impacts on maternal nutritional status. The inclusion of a strong

behavior change communication (BCC) intervention to promote optimal diets and child feeding practices, and a focus on improving women's status and empowerment through agriculture, are consistently reported as key to enhancing the potential impacts of agriculture on diets and other nutrition outcomes. Another main conclusion of the reviews is that most studies so far have had serious methodological limitations that may hamper their ability to demonstrate impacts, especially on anthropometric outcomes. The most common weaknesses include poor evaluation designs, inadequate sample sizes, short duration, and the wrong age group targeted and analyzed for achieving and demonstrating impacts on child anthropometry (Leroy, Olney, and Ruel 2016).

The proliferation of reviews and global reports focused on the linkages between agriculture, food systems, and nutrition in recent years testifies to renewed interest in the topic and calls for investments in closing the evidence gap and moving toward more gender- and nutrition-sensitive agriculture and food systems (FAO 2013; Global Panel on Agriculture and Food Systems for Nutrition 2014, 2016; Pinstrup-Andersen 2010). Indeed, a 2012 inventory of agriculture-nutrition research identified 151 planned or ongoing projects being undertaken by 49 institutions throughout the world (Hawkes, Turner, and Waage 2012).

This paper takes a look at findings from new empirical research published since 2014 that may fill some of the knowledge gaps identified in previous reviews regarding agriculture's contribution to nutrition. It reviews impact findings from new studies that have used experimental or quasi-experimental approaches to evaluate NSA programs in areas where such studies are available, including biofortification, homestead food production systems, livestock transfer programs, value chains for nutritious foods, and irrigation studies. The paper also summarizes findings from observational studies that document associations between agricultural practices and nutrition outcomes, which may shed light on key design elements for the success of future NSA programs. For both impact evaluations and observational studies, we review information available regarding pathways, mechanisms, and contextual factors that affect where and how agriculture may improve nutrition outcomes. The paper does not review the literature on the topic of complex food systems and nutrition, which, although critically important, is

beyond the scope of this more focused review. The paper also addresses issues of maternal and child undernutrition but does not cover the emerging nutrition transition and related problems of overweight, obesity, and noncommunicable diseases. Other excellent reviews and conceptual papers cover these important topics (see, for example FAO 2013; Gillespie and van den Bold 2017; Global Panel on Agriculture and Food Systems for Nutrition 2016; Gómez et al. 2013; IFPRI 2016; Pinstруп-Andersen 2010, 2011; and Popkin 2014). The paper concludes with reflections on implications for agricultural programs and investments, and suggests priorities for future research.

2. METHODS

This paper updates key reviews of the nutrition impacts of agricultural programs with new empirical evidence published since 2014. We started with the review from Ruel and Alderman (2013), which summarized evidence reviews conducted prior to 2013 (see their paper’s online supplementary appendix *Table 3*) and consulted new evidence reviews published since then (DFID 2014; Domènech 2015; Fiorella et al. 2016; Pandey, Mahendra Dev, and Jayachandran 2016; Webb and Kennedy 2014). These reviews helped formulate the search strategy. Table 2.1 lists the search terms utilized to find new literature on NSA programs. Minor changes were made for each database, as needed. We searched for each type of activity or program, along with terms for nutrition outcomes.

Table 2.1 Search topics and terms used in the review of nutrition-sensitive agriculture programs

Topic	Search terms
Nutrition	“nutrition* outcome,” “nutrition* status,” “diet* diversity,” “diet* diversification,” “micronutrient*,” OR “anthropom*”
Biofortification	“biofortif*,” “bio-fortif*,” “harvestplus,” OR “harvest plus”
Homestead production	“homestead production,” “homestead food production,” “home garden,” “homestead garden,” OR “home gardening”
Livestock and dairy	“livestock* programs,” “livestock* production,” “livestock* ownership,” “dairy* production,” OR “dairy* program”
Agricultural extension	“agricultur* extension”
Irrigation	“irrigation” AND “impact”
Aquaculture	“aquaculture,” “fisheries,” OR “fishpond”
Value chains	(“value chain” OR “value-chain”) AND (“nutrition” OR “diet”)
Nutrition-sensitive agriculture	(“nutrition-sensitive” OR “nutrition sensitive”) AND “agriculture”

Source: Authors.

The following databases were used: Scopus, Web of Science (formerly Web of Knowledge), PubMed, and IFPRI Ebrary. The search was restricted to articles and papers published in English since the Ruel and Alderman (2013) review and limited to published material, including journal articles and publicly available discussion or working papers. Table 2.2 reports the number of publications identified in the first stage, by topic and database (including duplicates).

Table 2.2 Number of articles identified, by topic and database

Database	Biofortification	Home food production	Irrigation	Agricultural extension	Livestock and dairy	Aquaculture	Value chains	Nutrition-sensitive agriculture
Scopus	1,624	189	1,284	84	678	2,437	206	223
PubMed	216	7	11	21	34	274	13	26
Web of Science	353	27	129	11	101	71	36	47
IFPRI Ebrary	15	10	5	3	6	2	2	21

Source: Authors.

The total number of published papers found in this round of the search was **8,166**. Using reference management software (EndNote), we removed **1,502** duplicates and screened the remaining **6,664** papers via their titles and abstracts using the inclusion/exclusion criteria listed in Table 2.3, resulting in **43** published papers. Using our own knowledge and that of key agriculture, nutrition, and health experts whom we contacted, we added **9** articles. We then screened the full text of the resulting **52** articles and removed **6** because they did not meet the eligibility criteria (for example, they were either descriptive studies, feasibility studies, or reviews); thus, **45** were included in this review.

Table 2.3 Inclusion and exclusion criteria used for review of nutrition-sensitive agriculture programs

Criterion	Include	Exclude
Publication type	Peer-reviewed and published working papers	Abstracts, reports, and briefs
Publication years	2014–	
Language	English	
Study type	Any quantitative, qualitative, or mixed-methods design	<ul style="list-style-type: none"> - Literature reviews - Feasibility studies
Agriculture	<ul style="list-style-type: none"> - Biofortification - Homestead production / home gardening - Irrigation - Value chains - Livestock - Agricultural extension 	<ul style="list-style-type: none"> - Food systems - Food safety
Nutrition	<ul style="list-style-type: none"> - Anthropometry (for example, WHZ, HAZ, WAZ, stunting, wasting, underweight, MUAC, weight, height, birth weight) - Infant and young child feeding knowledge and practices (for example, breastfeeding; complementary feeding, including minimum meal frequency, minimum dietary diversity, and minimum adequate diet) - Anemia/hemoglobin - Diet / dietary diversity - Macronutrient intake (protein, fats, carbohydrates) - Micronutrient intake (for example, vitamin A, iodine, iron, folic acid) 	<ul style="list-style-type: none"> - Health outcomes not directly related to nutrition (such as delivery complications) - Nutrition information/awareness - Food security
Location	Low- and middle-income countries	High-income countries
Other		Animal/plant outcomes

Source: Authors.

Note: HAZ = height-for-age z-score; MUAC = mid-upper arm circumference; WAZ = weight-for-age z-score; WHZ = weight-for-height z-score.

3. RESULTS

Tables 3.1 and 3.2 present the list and key characteristics of the studies included in this review, by type of agricultural intervention or study. The first set of studies reviewed were impact evaluations that used mostly experimental or quasi-experimental designs to document the impacts of agricultural interventions on nutrition outcomes and, where available, information on impact pathways and mechanisms through which impact was achieved (see Table 3.1 for the main characteristics of studies in this set). The second set of studies reviewed aimed to document associations between different types of agricultural systems or practices and nutrition outcomes (see Table 3.2 for the characteristics of studies in this set). Although we could have included studies covering agricultural investments in a broader range of activities related to technological or institutional innovation, either on-farm or postharvest, or those related to input or output markets, we did not find any evaluations of such investments that looked at their impacts on nutrition or described attempts to make them nutrition sensitive.

Evidence from Impact Evaluations

This section reviews new evidence from rigorous impact evaluations focused on NSA interventions and programs, using the definition from Ruel and Alderman (2013), which states that programs and interventions are nutrition-sensitive if they (1) have a clearly stated objective of improving nutrition and (2) incorporate specific nutrition interventions to achieve this goal. The types of programs identified through our search were categorized into biofortification, homestead food production and home gardening, livestock, nutrition-sensitive value chains, and irrigation. All of these programs focused on promoting production diversity and increasing access to nutritious foods such as biofortified staple crops, nutrient-rich vegetables or fruits, and animal-source foods.

Table 3.1 Summary of impact evaluation studies included in our review of nutrition-sensitive agriculture programs

Author(s), year, study location ^a	Evaluation design	Intervention	Outcomes measured	Findings	Conclusions
Biofortification					
de Brauw, Eozenou, and Moursi 2015, Mozambique	<ul style="list-style-type: none"> - Longitudinal CRCT - Sample of 36 village-level farmer groups randomly assigned to control and 2 treatment arms, the latter receiving nutrition and extension training for 1 year and 3 years, respectively 	<p><i>Nutrition:</i> Trainings on vitamin A and OSP</p> <p><i>Agriculture:</i> Distribution and sale of vines with optional participation in extension meetings (differing intensities of participation)</p> <p><i>Marketing:</i> Actions to increase visibility of and demand for OSP among traders</p>	<p>Children 0–3 years old at baseline:</p> <ul style="list-style-type: none"> - Vitamin A intake - MMDA - DD measured using 24-hour recall 	<ul style="list-style-type: none"> - Significant impact of program on child vitamin A intake, MMDA, and DD - Effect on vitamin A and DD significantly higher for HHs receiving extension services and participating in nutrition training, compared with those receiving only vines 	<p>More intense participation in an integrated biofortification program led to larger impacts on child vitamin A intake and DD.</p>
de Brauw et al. 2015, Mozambique and Uganda	<ul style="list-style-type: none"> - Longitudinal RCT - Mozambique sample: as above - Uganda sample: 84 farmer groups randomly assigned to a control and 2 treatment arms, the latter receiving nutrition and extension training for 1 year and 2 years, respectively 	As above	<p><i>Mozambique:</i></p> <ul style="list-style-type: none"> - Vitamin A intake of children 0–3 years old at baseline - Adoption of OSP (keeping vines for following season) <p><i>Uganda:</i></p> <ul style="list-style-type: none"> - Children’s vitamin A intake - Serum retinol - Adoption of OSP (growing OSP at endline) <p><i>Both:</i></p> <ul style="list-style-type: none"> - Maternal knowledge of vitamin A and OSP - Share of OSP in cultivation 	<ul style="list-style-type: none"> - Impacts in both countries on knowledge of vitamin A, adoption of OSP, and vitamin A intake in treatment HHs; no significant difference between treatment groups with different intensities (duration) of treatment - Average treatment effect larger in Uganda than in Mozambique - Causal mediation analysis shows maternal nutrition knowledge had a small effect on adoption and on vitamin A intake in Uganda only 	<p>Integrated biofortification program had an impact on OSP adoption rates and Vitamin A intake in both countries; less intense programs worked just as well as the more intense program.</p>

Table 3.1 Continued

Author(s), year, study location^a	Evaluation design	Intervention	Outcomes measured	Findings	Conclusions
Jones and de Brauw 2015, Mozambique	As above (Mozambique)	As above	Incidence and duration of diarrhea and other health conditions in last 14 days for children less than 5 years old	<ul style="list-style-type: none"> - Prevalence of diarrhea reduced in treatment villages - Duration of diarrhea less in children eating OSP - Effect higher for children with educated mothers 	Providing OSP reduced the incidence and duration of diarrhea among children.
Homestead food production and other integrated agriculture and nutrition programs					
Olney et al. 2015, Burkina Faso	<ul style="list-style-type: none"> - CRCT - 55 villages randomly assigned to a control and 2 treatment groups, the latter receiving EHFP interventions plus BCC (1) delivered by OWL, (2) delivered by HCM - Children 3–12 months old at baseline (control: <i>n</i> = 577; group 1: <i>n</i> = 443; group 2: <i>n</i> = 432) - Surveys 2 years apart 	<i>Nutrition:</i> BCC training on ENAs by either an OWL or an HCM <i>Agriculture:</i> distribution of inputs (seeds, saplings, chicks, small gardening tools) and training <i>Gender:</i> Direct transfer of agricultural inputs to women; formation of women-led VMFs and women's groups	Children's <ul style="list-style-type: none"> - Anthropometry - Hb/anemia - Diarrhea prevalence - HDD - Maternal IYCF knowledge and practices 	<ul style="list-style-type: none"> - Significant impact in group receiving BCC from HCM on <ul style="list-style-type: none"> • diarrhea • wasting, anemia, Hb (marginally significant) - No impacts on stunting or underweight - Plausibility supported by greater improvements in women's agricultural production and maternal IYCF knowledge and practices in both study arms 	HKI's EHFP and BCC program significantly reduced child wasting, diarrhea, and anemia, and increased Hb over two years. The impacts were achieved through improvements in women's agricultural production and improved maternal IYCF knowledge and practices.
Olney, Bliznashka, et al. 2016, Burkina Faso	As above <ul style="list-style-type: none"> - Women (control: <i>n</i> = 510; intervention: <i>n</i> = 787); OWL and HCM groups were combined 	As above	<ul style="list-style-type: none"> - Mother's dietary intake and DD - Mother's BMI, prevalence of underweight - Women's empowerment 	<ul style="list-style-type: none"> - Significant increase in fruit intake and marginal increase in meat intake and DD - Significant reduction in underweight prevalence; no impact on BMI - Improvements in empowerment score 	In addition to improving child nutrition outcomes, HKI's two-year EHFP and BCC program significantly improved maternal diets, nutritional status, and empowerment.

Table 3.1 Continued

Author(s), year, study location^a	Evaluation design	Intervention	Outcomes measured	Findings	Conclusions
van den Bold et al. 2015, Burkina Faso	As above - Complemented by two rounds of qualitative research	As above	- Intra-HH asset distribution - Women's bargaining power	- Increase in number and relative value of women-owned agricultural assets - No impact on women's control of assets - Larger impact on small ruminant ownership for men and no impact on large livestock ownership - Changes in communities' perceptions about women's ownership and control of assets	HKI's two-year EHFP and BCC program increased women's control over and ownership of assets, and changed gender norms around these issues in rural Burkina Faso.
Osei et al. 2017, Nepal	- RCT with 8 clusters pair-matched and randomly assigned to control or EHFP (the latter with BCC and gender activities) - Cross-sectional surveys at baseline and endline (2.5 years later) with sample of 1,051–1,307 mother/children pairs per group (children 12–48 months old)	<i>Nutrition:</i> BCC training on ENAs <i>Agriculture:</i> distribution of inputs (seeds, saplings, chicks, small gardening tools) and training <i>Gender:</i> Women trained to host VMFs and train other women	Measured in mothers and children: - Weight, height/length - Hb and anemia	- Impact on anemia reduction in children (OR: 0.76) and mothers (OR: 0.62) - Reductions in maternal underweight (OR: 0.61) - No impacts on child anthropometry	The EHFP program had positive impacts on maternal and child anemia and maternal underweight. The program also improved several outcomes along the impact pathways, including production of nutrient-rich foods (eggs, vegetables), improved HH food security and IYCF, and other ENA practices.

Table 3.1 Continued

Author(s), year, study location ^a	Evaluation design	Intervention	Outcomes measured	Findings	Conclusions
Osei et al. 2015, Nepal	<ul style="list-style-type: none"> - RCT with 41 clusters randomly assigned to (1) EHFP (as above), (2) EHFP + MNP supplement, (3) control - Each group included approximately 110 children 6–9 months old at baseline - Measured at baseline and 11 months later 	<p><i>EHFP intervention:</i> As above</p> <p><i>MNP intervention:</i> 60 MNP sachets containing 15 micronutrients distributed at baseline and 6 months later for a total of 11 months of supplementation</p>	<ul style="list-style-type: none"> - Child Hb and anemia - Child anthropometry 	<ul style="list-style-type: none"> - Hb increased significantly in all groups between baseline and endline, with no differential increases in EHFP groups - Marginally significant impacts on anemia in both EHFP and EHFP + MNP groups - No impacts on child growth 	<ul style="list-style-type: none"> - Adding MNP component to EHFP had a marginal effect on anemia but no effect on child growth. - Study confirmed feasibility of using EHFP platform to deliver MNPs for young children.
Kumar et al. 2017, Zambia	<ul style="list-style-type: none"> - CRCT with a control and two treatment groups: (1) agriculture intervention only, (2) integrated agricultural and nutrition interventions - Approximately 1,000 HHs per arm - 2 cross-sectional surveys 4 years apart (2011 and 2015) 	<p><i>Nutrition:</i> IYCF BCC through women’s groups, community health volunteers, and social marketing</p> <p><i>Agriculture:</i> Home gardening; inputs included nutrient-rich vegetable, legume, and tuber seeds; tools and training; and goats and chickens and related training</p> <p><i>Gender:</i> Promotion of gender equality and women’s empowerment</p>	<p>Children 0–59 months old:</p> <ul style="list-style-type: none"> - Anthropometry <p>Mothers:</p> <ul style="list-style-type: none"> - IYCF knowledge and practices - Empowerment 	<ul style="list-style-type: none"> - Decline in stunting in all groups (larger in control group), so treatment had no impacts on stunting - Positive impacts on child WHZ and reduced morbidity (cold/cough, diarrhea) - Low participation in program - Impacts on social capital, access to and control over assets, financial and agricultural decision-making empowerment - Impacts on maternal knowledge of some breastfeeding practices and timing of introduction of complementary foods - Negative impact on women’s time spent on childcare, domestic activities, leisure 	<ul style="list-style-type: none"> - Project had impacts on several outcomes along the agriculture-nutrition pathways, such as agricultural production, women’s empowerment and nutrition knowledge, and child WHZ and infections, but no impact on stunting. - Low participation and general improvements in child stunting and feeding practices in the country during the study may be responsible for the lack of impact on stunting. - Agriculture programs should include measures

Author(s), year, study location ^a	Evaluation design	Intervention	Outcomes measured	Findings	Conclusions
					to protect women's time.
Schreinemachers et al. 2016, Bangladesh	<ul style="list-style-type: none"> - Quasi-experimental design with control and treatment groups - Baseline in 2013 (control: 252 HHs; treatment: 425 HHs); endline in 2014 (control: 238 HHs; treatment: 408 HHs) - cost-effective component - <i>Note that study did not use randomization or matching of comparison and intervention groups, but did discuss selection bias</i> 	<p><i>Nutrition:</i> Training on nutrition focusing on vegetables</p> <p><i>Agriculture:</i> Women's training in home gardening and distribution of inputs to grow nutrient-rich vegetables</p>	Per capita production and consumption (quantity and diversity) of vegetables	<p>Comparison between treatment and control groups showed</p> <ul style="list-style-type: none"> - no differences in area under production - greater production and consumption of vegetables in treatment group 	<ul style="list-style-type: none"> - Training women in home gardening was associated^b with greater HH supply and consumption of vegetables. - Authors reported that cost calculations showed the approach to be cost-effective in addressing micronutrient deficiencies.
Schreinemachers et al. 2014, Bangladesh	<ul style="list-style-type: none"> - Cross-sectional data from 2013 (103 in intervention group since 2012; 479 in control to get intervention in 2013 after survey) - <i>Note that study did not have baseline information and did not use randomization or matching of comparison and intervention groups</i> 	As above	As above	<p>Intervention, compared with control group, had</p> <ul style="list-style-type: none"> - greater area of home garden, production of leafy vegetables, and overall per capita vegetable production - greater diversity of vegetable consumption - greater women's control over the home garden and income-generating activities 	Training women in home gardening was associated ^b with nutrition security through the supply and consumption of diverse vegetables in rural HHs.

Table 3.1 Continued

Author(s), year, study location ^a	Evaluation design	Intervention	Outcomes measured	Findings	Conclusions
Murty, Rao, and Bamji 2016, India	<ul style="list-style-type: none"> - Before-and-after design (baseline and 3 years later) with no comparison group - Sample: All pregnant women and all mothers with children 6–24 months old registered at 11 ICDS centers (total sample size not specified) - Substudy on KAP: 142 mothers with 6- to 24-month-old children 	<p><i>Nutrition:</i> Health and nutrition education, cooking demonstrations, and videos, focused on vegetables</p> <p><i>Agriculture:</i> Homestead gardens (focused on vegetables) and backyard poultry with high-egg-yielding birds</p>	<ul style="list-style-type: none"> - KAP on child feeding - Vegetable garden area - Vegetable and egg consumption 	<p>Comparisons between baseline and endline showed</p> <ul style="list-style-type: none"> - increases in area cultivated and percentage of HHs with vegetable gardens (from 30 percent to 70 percent) - increases in weekly mean frequency of green leafy vegetables cooked, from 1.9 to 2.4, and in percentage of HHs cooking them, from 21 percent to 45 percent - increases in weekly frequency of egg consumption; more than doubling of quantity of eggs consumed - marked increases in knowledge of components of a balanced diet, including animal-source foods - decline in number of children with low WAZs (according to ICDS centers' records) 	<ul style="list-style-type: none"> - Intervention was associated^b with increases in adoption of vegetable gardens and consumption of green leafy vegetables and eggs. - Intervention was associated with reductions in underweight children (although this outcome cannot be attributed to the program because of the data source).

Table 3.1 Continued

Author(s), year, study location ^a	Evaluation design	Intervention	Outcomes measured	Findings	Conclusions
Livestock-oriented programs					
Miller et al. 2014, Nepal	<ul style="list-style-type: none"> - Longitudinal pair-matched RCT - Communities randomly assigned to receive intervention at baseline or after 1 year (staggered) - Sample of about 200 families per group (total of 607 children 6–59 months old) 	<p><i>Agriculture, community development, women's empowerment:</i></p> <p>Training on community development, empowerment, and livestock management activities through women's self-help groups; transfer of goats at the end of first year</p>	<ul style="list-style-type: none"> - Anthropometry of children 6–59 months old - Children's morbidity (diarrhea, fever, cough/cold) 	<ul style="list-style-type: none"> - Positive effects (only in Terai [lowland] area) on child weight, height, and number of days sick - Increased income and ownership of animals (also only in Terai) 	<ul style="list-style-type: none"> - Heifer International's interventions improved HH income and ownership of animals and child anthropometry (only in Terai). - In all districts, longer participation in the program led to greater improvements in HAZ.
Darrouzet-Nardi et al. 2016, Nepal	Two-year analysis of same intervention and sample as above	As above	Child DD (overall score, animal-source food consumption, minimum DD)	Children living in the hills (poorer, more remote, but more suitable for livestock production) exposed for two years (compared with those exposed for one year) were more likely to have consumed one more food group, to have consumed food from animal sources, and to have achieved minimum DD	<ul style="list-style-type: none"> - Heifer International's interventions improved DD and consumption of animal-source foods in children 6–59 months old. - The authors concluded that community-level development programs should be carefully tailored to the unique contextual and seasonal constraints faced in different agroecological zones.

Table 3.1 Continued

Author(s), year, study location^a	Evaluation design	Intervention	Outcomes measured	Findings	Conclusions
Rawlins et al. 2014, Rwanda	<ul style="list-style-type: none"> - Cross-sectional survey of 406 HHs divided into “qualified” (beneficiary or prospective beneficiary HHs) and “nevers” (HHs not eligible to receive intervention) - Econometric modeling used to test associations 	<p><i>Agriculture:</i> Donation of either dairy cows (to eligible HHs with landownership but no ownership of high-producing dairy cows) or meat goats to poor HHs</p>	<ul style="list-style-type: none"> - HH and individual dietary intake and DD - Children’s anthropometry 	<p>“Qualified” HHs, compared with “nevers,” had</p> <ul style="list-style-type: none"> - greater individual DD (through greater dairy consumption by beneficiaries receiving dairy cows) - Higher HH dairy (for cow beneficiaries) and meat (for goat beneficiaries) consumption - Marginally significantly greater child WAZs (for cow beneficiaries) and WHZs (for goat beneficiaries) 	<p>Livestock donations were positively associated^b with HH dairy and/or meat consumption and marginally associated with children’s weight indicators.</p>
Nutrition-sensitive value chains					
Le Port et al. 2017, Senegal	<ul style="list-style-type: none"> - RCT with groups of dairy farmers assigned to receive (1) MNFY + BCC (<i>n</i> = 204 children) or (2) only BCC (<i>n</i> = 245 children) - Children were 24–59 months old at baseline - Baseline and endline were 1 year apart - All dairy farmers who supplied milk to the local company also received payment for the milk 	<p><i>Agriculture:</i> Producers established contracts with firm that paid for milk supplied.</p> <p><i>MNFY:</i> Farmers in group 1 who met contract requirements received 1 sachet of MNFY per day for each child 24–59 months old for 7 days.</p> <p><i>BCC:</i> Messages on ENAs (group sessions, home visits, community meetings, radio spots)</p>	<ul style="list-style-type: none"> - Child Hb and anemia 	<ul style="list-style-type: none"> - Anemia prevalence dropped from 80 percent to 60 percent during 1-year study (no difference between groups) - Statistically significantly greater increase in Hb (+0.55 g/dL) in MNFY + BCC versus BCC-only group; larger in boys (+0.72) than in girls (+0.38, not significant) 	<ul style="list-style-type: none"> - First RCT to show proof of concept that a nutrition-sensitive value chain can improve child nutrition outcomes - Large impacts on Hb in remote area of northern Senegal, where anemia is excessively high

Table 3.1 Continued

Irrigation studies					
Author(s), year, study location^a	Evaluation design	Intervention	Outcomes measured	Findings	Conclusions
Alaofè et al. 2016, Benin	Two treatment villages receiving solar-powered drip irrigation for one year were pair-matched with two control villages	<i>Agriculture:</i> Treatment villages received solar market gardens; control group grew vegetables in hand-watered plots. Project targeted women's groups.	<ul style="list-style-type: none"> - Production of fruits and vegetables - Consumption of fruits and vegetables - DD - Income 	<ul style="list-style-type: none"> - Increases in the variety of fruits and vegetables produced and consumed - Increases in income from sale of produce - Increases in DD from purchase of other nutrient-rich foods 	Introduction of solar-powered drip irrigation technology improved diets through direct consumption and increased income.

Source: Authors.

Note: ^a Studies are ordered by their appearance in the text. ^b Authors claimed impact, but study design does not allow us to infer causality of the associations found; we therefore use the term *association* instead of *impact* in this review. BCC = behavior change communication; BMI = body mass index; CRCT = cluster-randomized controlled trial; DD = dietary diversity; EHFP = enhanced homestead food production; ENA = essential nutrition action; HAZ = height-for-age z-score; Hb = hemoglobin; HCM = health committee member; HDD = household dietary diversity; HH = household; HKI = Helen Keller International; ICDS = Integrated Child Development Services (India); IYCF = infant and young child feeding; KAP = knowledge, attitudes, and practices; MMDA = mean micronutrient density adequacy; MNFY = micronutrient-fortified yogurt; MNP = micronutrient powder; OR = odds ratio; OSP = orange-fleshed sweet potato; OWL = older woman leader; RCT = randomized controlled trial; VMF = village model farm; WAZ = weight-for-age z-score; WHZ = weight-for-height z-score.

Biofortification

Biofortification, the breeding of staple crops that are richer in essential micronutrients than traditional varieties, has been shown to be a feasible and cost-effective approach to addressing deficiencies in vitamin A, iron, and zinc (Bouis and Saltzman 2017). Efficacy trials (conducted under controlled conditions) have shown that staple crops biofortified with vitamin A, iron, or zinc improved populations' respective micronutrient status. Vitamin A–biofortified maize has also been shown to improve vitamin A stores and visual functioning in marginally deficient children (Palmer et al. 2016). Additional efficacy studies are planned for zinc-biofortified wheat and rice using newly developed, more sensitive zinc biomarkers (Bouis and Saltzman 2017).

Evidence of the effectiveness of biofortification (assessed, for example, in the context of agricultural programs) has so far been published only for orange-fleshed sweet potato (OSP) in Mozambique and Uganda. The findings have been reported in previous reviews and are briefly summarized here. In both countries, vine distribution was combined with agricultural extension services and BCC and mass media interventions to promote OSP consumption and optimal infant and young child feeding (IYCF) practices. Farmer adoption was high, and studies documented impacts on vitamin A intake among mothers and young children in both countries and on child vitamin A status in Uganda (Hotz, Loechl, de Brauw, et al. 2012; Hotz, Loechl, Lubowa et al. 2012). More recent analyses of the Mozambique data added specificity to these results, showing that the magnitude of impacts on children's vitamin A intake and dietary diversity increased with the level of farmers' participation in the program (de Brauw et al. 2015). Causal mediation analysis also showed that maternal knowledge of the nutrition messages communicated by the program had a small effect on adoption of biofortified OSP in both Mozambique and Uganda, and on vitamin A intake in Uganda (de Brauw, Eozenou, and Moursi 2015). Additional analyses also documented that the program had large impacts on reducing the prevalence and duration of diarrhea in children younger than five years, with reductions of 11.4 percentage points (ppts) among children younger than five years and 18.9 ppts among children younger than three years (Jones

and de Brauw 2015). These results support the well-known role of vitamin A in protecting immunity. Effectiveness studies of other biofortified crops with other micronutrients are underway, including iron-biofortified beans in Guatemala, iron-biofortified pearl millet in India, and zinc-biofortified wheat in Pakistan (HarvestPlus 2017).

Homestead Food Production and Other Integrated Agriculture and Nutrition Programs

Results from the first cluster-randomized controlled trial (CRCT) that assessed the impact of a carefully designed enhanced homestead food production (EHFP) program with a strong gender component in Burkina Faso were published in 2015 (Olney et al. 2015). The program, implemented by Helen Keller International (HKI), an experienced nongovernmental organization (NGO), targeted households with women and children in the first 1,000 days of life (pregnant women and children up to 2 years of age) through integrated agriculture production interventions with a strong nutrition and health BCC strategy plus women's empowerment activities, with the explicit goal of improving children's nutrition outcomes. Implemented in Gourma Province in Burkina Faso, the program worked with mothers to establish homestead gardens, providing inputs and trainings in gardening, irrigation, and small livestock rearing. Beneficiary women were also trained in essential nutrition actions focused on women and young children through home visits twice a month provided by either an older woman leader or a health committee member. During these sessions, women learned about optimal IYCF practices and discussed successes and challenges related to adopting these practices. The evaluation found that, compared with a control (no intervention) group, the group that received the two-year integrated program with BCC delivered by a health committee member significantly improved in several child outcomes, including increases in hemoglobin (Hb) (+0.7 g/dL) and reductions in anemia (-14.6 pts) in children 3.0–5.9 months of age at baseline; and reductions in diarrhea (-16.0 pts) and wasting (-8.8 pts, marginally significant [$p = 0.8$]) among children 3.0–12.9 months at baseline. Positive impacts were also found on several maternal outcomes, including increased intake of nutritious foods (fruit, meat, and poultry), greater dietary diversity, improvements in several dimensions of women's empowerment, and reductions in maternal

underweight (-8.7 ppts) (Olney, Bliznashka, et al. 2016). Supporting these positive maternal and child impacts, the study documented statistically significant improvements on several outcomes along the impact pathway, including increases in agricultural production, household access to and consumption of nutrient-rich foods, and dietary diversity. Preliminary results from causal mediation analysis also confirmed that impacts on child Hb were mediated by both production of fruits and vegetables and improved maternal knowledge, with production playing a greater role in areas where access to markets was limited (Kennedy et al. 2017).

The program also increased the value of agricultural assets of women in intervention compared with control villages (van den Bold et al. 2015), whereas the value of men's agricultural assets in intervention villages decreased. Although the project had no impact on the area of land cultivated by either men or women, qualitative work indicated that gender norms became more favorable toward women's landownership in treatment compared with control areas. Although HKI did not explicitly seek to influence norms, the project recognized that empowering women is crucial to achieving nutrition objectives. In addition to distributing inputs and providing training to women beneficiaries, the project negotiated with the community for land on which women could establish a village model farm (VMF). Departing from the practice in past HKI projects in other countries, where VMFs were often run by male farmer leaders, this project worked with communal farms run by women. The process of establishing the communal farms raised the project's visibility and engaged the broader community in it. Some of those who reported changing their opinion about women's owning land attributed the change to the project and to what they had observed in the VMF (van den Bold et al. 2015).

Preliminary findings from a second phase of the Burkina Faso study carried out between 2012 and 2014 suggested similar positive impacts of the EHFP program on child anemia, but larger impacts when a water, sanitation, and hygiene (WASH) intervention was added to the program's package of interventions, and even larger impacts when both WASH and a small-quantity lipid-based nutrient supplement for young children were integrated into the program (Olney et al. 2017). These results confirm that improving nutrition requires more than just increasing household access to food. It requires

multisectoral approaches that simultaneously address the multiple determinants of undernutrition, including improving access to health and WASH services and providing specially formulated nutrient-rich foods or products to fill the nutrient gap in mothers and children during the first 1,000 days.

In Nepal, an evaluation of the same HKI EHFP model with a poultry component documented impacts similar to those in Burkina Faso on child anemia and maternal underweight (Osei et al. 2017). The Nepal CRCT with two repeated cross-sectional surveys (baseline and endline) showed impacts on anemia in EHFP program beneficiaries compared with a control group. The program mitigated the rise in both maternal and child anemia that was observed in the study areas over the course of the project (2.5 years). Although the age range of children in the Nepal and Burkina Faso studies was different (and therefore anemia levels were not entirely comparable), overall, childhood anemia was much higher (almost universal) in Burkina Faso, with more than 77 percent of children 24–40 months of age being anemic at endline, compared with one-third of children 12–48 months of age in the Nepal sample (31 percent in the treatment compared with 42 percent in the control group) at endline. Regardless of these differences, EHFP was effective at reducing anemia in both contexts. Also, as was found in Burkina Faso, the Nepal evaluation showed significant impacts on various household and maternal intermediary outcomes along the hypothesized program impact pathway, strengthening the plausibility of the results. More specifically, the EHFP program in Nepal significantly improved household food security and production of eggs and vegetables; several maternal breastfeeding, complementary feeding, and hygiene practices; and the use of preventive health services during pregnancy and the first few years of the child's life.

Also in Nepal, HKI tested the addition of a micronutrient powder (MNP) to its EHFP and poultry program using a CRCT with three comparison groups: (1) EHFP + MNP, (2) EHFP, and (3) control (Osei et al. 2015). The EHFP platform was used to deliver the MNP (60 sachets containing 10 micronutrients) to children ages 6–9 months at baseline and 6 months later. Anemia decreased in all three groups (and Hb increased) over the one-year duration of the project (as expected as children age), but the change was only marginally larger in the two EHFP groups combined, and no differences were found between the two

intervention groups (EHFP + MNP compared with EHFP only). As the authors noted, one of the potential reasons for the lack of statistical significance between intervention and control groups in spite of the large anemia reductions achieved (-12 ppts and -9 ppts in EHFP + MNP and EHFP, respectively) may have been the study's low statistical power due to its small sample size (about 100 children per group). Small sample sizes and short study duration may also explain the lack of impacts on child anthropometry. Overall, however, the experiment showed that EHFP could be a useful platform to deliver MNP and related BCC to reduce anemia, given the very high delivery rate (91 percent) and compliance (97 percent) achieved. It would be interesting to test a similar approach with an adequate sample size and in areas where childhood anemia is more prevalent. As reported above, preliminary findings from a similar study in Burkina Faso, which used the HKI EHFP platform to deliver a lipid-based nutrient supplement and promote improved WASH practices, showed promising impacts on child anemia in a context where it is almost universal (Olney et al. 2017).

A similar homestead food production project implemented by Concern Worldwide, the RAIN (Realigning Agriculture to Improve Nutrition) project in Zambia, also targeted children younger than two years with an integrated package of agriculture, nutrition, and community-based gender sensitization interventions (Kumar et al. 2017). A CRCT design was used to compare three groups that received (1) agriculture, gender, and women's empowerment interventions; (2) the same package of interventions plus nutrition BCC; and (3) the standard government services. The agriculture component, which aimed to increase year-round availability of and access to nutrient-rich foods, included the same types of inputs as those in the HKI projects (distribution of seeds, chickens and goats, agricultural tools, and training). In areas that received a nutrition and health intervention, the project staff trained existing community health volunteers to lead nutrition BCC sessions with beneficiary women. In addition, some communitywide gender sensitization and information activities were undertaken in both intervention arms. The RAIN project had positive impacts on several outcomes along the pathways from agriculture to nutrition, including agricultural production, several aspects of women's empowerment (social capital, access to and control over assets, and financial and agricultural decision-making power), and maternal knowledge of

breastfeeding practices and optimal timing of introduction of nutritious foods in a child's diet. The project also had a small impact on children's weight-for-height *z*-scores (WHZs) and on reducing the prevalence of infections (cold/cough and diarrhea) in children younger than five years. The project, however, did not have any impacts on IYCF practices or on child stunting. The lack of impact on stunting appears to be due, at least in part, to the strong positive trends in stunting reduction already occurring in the country, which resulted in all three comparison groups experiencing dramatic stunting reductions between baseline and endline (as high as 13–18 ppts, with the largest reductions in the control group). Positive trends in maternal IYCF knowledge and practices were also observed in all three groups over the study period, possibly contributing to reductions in stunting. There was some evidence, however, that engagement in the project's agriculture intervention constrained women's time—women in the RAIN areas spent more time on agricultural work and less time on childcare, domestic activities, and leisure than women in the control group. Overall, the project benefited women in some aspects of empowerment and in improving their access to nutritious foods and their nutrition knowledge, but as cautioned by many (Johnston et al. 2015), agricultural projects should more explicitly include measures to protect women's time in order to prevent unintended negative effects.

Schreinemachers, Patalagsa, and Uddin (2016) examined the impact and cost-effectiveness of training poor rural women in Bangladesh in home gardening and nutrition. The study used a difference-in-differences estimation approach (comparing changes between baseline and endline between intervention and control households), but the intervention was not randomized and no attempts were made to match the comparison and control groups on key observable characteristics.¹ The study found that the intervention was associated with greater vegetable production, diversity, and consumption, and with a higher household supply of micronutrients from the garden. The estimated average increase in household

¹ The authors claimed that selection bias was minimized by applying the same eligibility criteria on the control group that were used to select the intervention group, and because the project was able to control who did and did not receive the intervention (that is, households could not ask to receive the intervention from the project). However, the assumption that these measures eliminated all sources of selection bias was not tested.

vegetable supply was relatively small, however: 31 kg per year (or 16.5 g per capita per day), contributing 8.2 percent of the recommended daily intake of vegetables.

An earlier study by the same team (Schreinemachers et al. 2014) used cross-sectional data to examine dietary diversity collected using a 30-day food frequency recall approach. Again, the study was not randomized and did not include baseline information. The authors estimated that intervention households had greater production of leafy vegetables and of micronutrients from their garden than nonintervention households, and more diverse intake of vegetables. However, because the dietary recall module focused only on vegetables, it did not allow measurement of potential substitution among other sources of nutrients associated with increased intake of vegetables, and therefore does not inform us about the program's contribution to total nutrient intake.

A study in Andhra Pradesh, India, also assessed the effects of introducing a homestead garden and backyard poultry intervention linked to the Integrated Child Development Services (ICDS) program in eight villages (Murty, Rao, and Bamji 2016). The goal was to improve maternal and child micronutrient intake during pregnancy and the first 24 months of the child's life by increasing access through agricultural production and using BCC to improve knowledge and practices. The study assessed program effects using a three-year before-and-after design without comparison groups and showed positive changes in a variety of outcomes, including high rates of adoption of a homestead garden (an increase from 30 percent at baseline to 70 percent after three years); better knowledge, attitudes, and practices regarding food taboos during pregnancy and IYCF practice; regular preparation and intake of green leafy vegetables; and increased frequency and quantity of egg consumption. The authors also reported a gradual decline in the percentage of children 6–24 months of age who suffered from moderate to severe malnutrition (using weight-for-age information; cut-off not defined), but these results were generated from the growth charts maintained at the ICDS centers for all children and therefore changes cannot be attributed to the program.

Livestock-Oriented Programs

Livestock-oriented programs, many of which involve livestock transfers, have been implemented primarily as interventions to reduce poverty and improve livelihoods, and secondarily to increase farm households' production and consumption of animal-source foods. Because of their primary focus on poverty reduction, they traditionally have not included specific nutrition interventions even though they may have had nutrition goals, such as increasing consumption of animal-source foods or improving household dietary diversity and, in some cases, child nutritional status. Three recent impact evaluations of Heifer International's livestock transfer programs reported on such studies.

Miller and colleagues (2014) conducted a 2-year longitudinal evaluation of a community development program in 6 communities in the Terai and hill regions of Nepal, pair-matched and randomly assigned to receive Heifer community development activities at baseline (intervention) or 1 year later (control). The participatory community development activities included the distribution of livestock and training to rural women, working through women's groups, with a focus on income generation, women's empowerment, social mobilization, group savings and microlending, and enterprise development. A pair of goats was given to each beneficiary family after 1 year of participation in the program. Child anthropometric outcomes were assessed at baseline and every 6 months over the course of the 2-year study, although program activities did not focus specifically on child nutrition or health. Findings from the 12-month evaluation (prior to livestock distribution), showed that in the Terai areas, where program implementation was stronger, the intervention group had increased income and ownership of animals and land, improved sanitation practices, better child anthropometric outcomes (weight and height), and reduced reported sick days, compared with control. In all districts, longer participation in Heifer activities was associated with larger improvements in child height-for-age z-scores (HAZs).

A follow-up analysis of child dietary diversity using data from the same study, but with measurements after 2 years of program exposure, showed that benefits associated with the program differed depending on agroecological region and season (Darrouzet-Nardi et al. 2016). Children living in the hills (poorer, but more suitable region for livestock production) who had been exposed to the program

for 2 years were 2.20 times more likely to have consumed food from an additional food group in the day prior to the interview, 1.38 times more likely to have consumed animal-source foods, and 1.27 times more likely to have achieved minimum dietary diversity, compared with those who had been exposed to the program for 1 year. Similarly, greater effects were achieved during the hungry season compared with the harvest season. These dose-response effects were not observed in lowland areas (the Terai, an agroecology more appropriate for crop cultivation) or during the harvest season. The authors concluded that to deliver expected impacts, community-level development programs should be carefully tailored to address the unique contextual and seasonal constraints faced in the targeted agroecological zones.

The nutrition impacts of dairy cow and meat goat transfer programs were also assessed in Rwanda (Rawlins et al. 2014). The study was based on a cross-sectional survey conducted in 2011 in two regions and relied on Heifer's selection criteria for its livestock recipients to classify the sample into "beneficiaries" (those who had already received livestock), "potentials" (qualified applicants who had not yet received livestock), and "nevers" (applicants who were rejected by program staff). Regression models and matching methods were used for the analysis, and although they do not allow us to infer causality, they showed an association between beneficiary status and milk consumption for cow beneficiaries and a marginally statistically significant association with meat consumption for goat beneficiaries. The study documented some associations with child anthropometry, but these results were only marginally significant, possibly due in part to small sample sizes.

Nutrition-Sensitive Value Chain Interventions

Although several initiatives in recent years have focused on developing conceptual models, tools, and approaches to making value chains more nutrition sensitive, only one study so far has published results from a CRCT impact evaluation. The study, conducted among pastoralists in a remote area of northern Senegal, assessed the impact of a nutrition-sensitive dairy value chain on child nutrition (Le Port et al. 2017). The purpose of the study was to test whether a dairy value chain could be leveraged to distribute a micronutrient-fortified yogurt (MNFY) to improve Hb and reduce anemia among preschool children from

participating dairy farmer households. The MNFY was produced by a local dairy firm that established a contractual arrangement with dairy farmers and used the MNFY as an incentive to increase milk supply from farmers, especially during the dry season. Farmers who supplied a predetermined minimum amount of milk 5 days per week were eligible to receive the MNFY and were instructed to give it to their 24- to 59-month-old children to address the severe problem of anemia in the region. The project targeted women and therefore distributed the MNFY at the milk collection points, where women usually took care of the transactions. The project also included a BCC strategy focused on the promotion of optimal IYCF practices, including use of micronutrient-fortified foods or products for young children. Compared with a control group that received only BCC, children exposed to the BCC + MNFY intervention had statistically significantly greater increases in Hb over the 1-year study period (+0.55 g/dL), with larger impacts in boys (+0.72 g/dL) than in girls (+0.38 g/dL; not statistically significant). Anemia prevalence was extremely high in this population (80 percent at baseline) and dropped to close to 60 percent over 1 year, but differences between the groups were not statistically significant. To our knowledge, the study is the first proof-of-concept study that has used an experimental evaluation design to document the effectiveness of a nutrition-sensitive dairy value chain at improving nutrition among preschool children living in a remote pastoralist population. Examples of other ongoing experimental studies testing the nutrition impact of nutrition-sensitive value chains include a study of [chicken value chains](#) including a nutrition and WASH intervention in Burkina Faso and a study of [dairy value chains](#) in Kenya.

Irrigation Studies

Irrigation interventions have the potential to impact nutrition and health through several pathways. In her review of the linkages between irrigation, food security, and nutrition, Domènech (2015) described five pathways through which irrigation can affect nutrition. On the positive side, irrigation programs can improve agricultural productivity and diversification (pathway 1), income (pathway 2), and women's empowerment (if gender-sensitive; pathway 5), all of which can improve household food availability and access, as well as consumption of nutritious diets and adoption of optimal IYCF practices. Irrigation can

also provide multiple water services (pathway 3), including water for animal rearing or aquaculture to further improve access to nutrient-rich foods. Greater access to water can also support household and personal consumption (depending on water quality), and promote domestic use of water for hygiene and sanitation, which can reduce contamination and improve the health of family members. On the negative side, if poorly managed, irrigation can serve as a new vector-breeding habitat, increasing the risk of diseases, and can be a source of water pollution from agrochemicals (pathway 4). In her review, Domènech (2015) analyzed the literature that provides evidence on the impacts of irrigation on food security, health, and nutrition along these five hypothesized pathways. The key message from the review is that irrigation does appear to contribute to improving food security, but that, in general, studies have not examined its impacts on nutrition. Thus, the current lack of evidence that irrigation interventions impact nutrition is not due to evidence of a lack of impact, but rather to the lack of studies that have actually sought to document nutrition impacts. The author noted that most of the irrigation programs evaluated did not have any explicit nutrition goals or nutrition interventions. The review offered some guidance on how irrigation investments could be made more nutrition sensitive, including, as a start, by incorporating nutrition, health, and gender considerations into the design, planning, and implementation of irrigation programs and policies.

A recent study examined the impact of solar-powered drip irrigation using solar market gardens (SMGs) on crop production diversity and dietary diversity in Benin (Alaofè et al. 2016). The intervention specifically aimed to enhance food and nutrition security by installing SMGs in two villages, working in conjunction with women's agricultural groups engaged in horticulture. The two treatment villages were pair-matched with control villages based on location, administrative status, and size. Women's agricultural groups in control villages grew vegetables on hand-watered plots, as did those in treatment villages prior to the SMG intervention. The intervention led to increases in the variety of fruits and vegetables produced and consumed between baseline and endline (one year later) in treatment compared with control villages. The majority of SMG women's group households also reported using the additional income from the sale of produce to purchase food items that further improved the diversity of family

diets, including beans and fish. The study showed that introduction of the solar-powered drip irrigation technology could improve diets through direct consumption and increased income. As the authors noted, greater impacts on micronutrient intakes (a critical nutrition problem in the country) could probably be achieved by incorporating a BCC intervention into the program or by coordinating with other approaches to improve micronutrient status.

Evidence from Observational Studies

Observational studies have been used extensively to examine associations between different agricultural practices and nutrition outcomes. Such studies do not allow researchers to derive the same level of causal inference as do well-designed and -implemented experimental trials, but they are useful in unveiling or confirming linkages and associations between hypothesized drivers and outcomes, and for generating new hypotheses about potential impact pathways. For example, early evidence regarding the role of women's empowerment in childcare practices and nutrition outcomes was generated from studies that documented associations between women's social status and indicators of child feeding and care practices or nutritional status (for example, Smith et al. 2003). Similarly, the mediating role of women's empowerment in linkages between agriculture and nutrition was uncovered mostly by association studies (Malapit et al. 2015; Sraboni et al. 2014). For these reasons, we include in this review a summary of key findings from papers published since 2014 that help build evidence on the linkages between agriculture and nutrition using observational (association) studies.

Table 3.2 presents a summary of the 29 observational studies identified in the search process. Of these, 2 papers used nationally representative datasets to examine relationships between agricultural livelihoods, diet, and child nutrition; 11 focused on the relationship between crop production diversity and nutrition outcomes; 10 looked at livestock keeping, sanitation, and nutrition and health outcomes; and 2 looked at associations between climatic variability and nutrition outcomes. Finally, 5 studies (including 1 that also contributed to the work on production diversity) looked at how women's empowerment in agriculture mediates and in some cases mitigates agriculture-nutrition linkages.

Table 3.2 Summary of observational studies reviewed on linkages between agriculture, women’s empowerment, and nutrition

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Income growth, household livelihoods, diets, and child nutrition outcomes						
Bhagowalia, Headey, and Kadiyala 2012, India	Test association between (1) HH income and child anthropometry (2) HH agricultural production and DD	2004/2005 India Human Development Survey, a nationally representative, multi-topic survey of 41,554 HHs in 1,503 villages and 971 urban neighborhoods across India	OLS regressions	<ul style="list-style-type: none"> - HAZ, WHZ - HDD (unweighted sum of number of foods) - share of expenditure on cereals and noncereals 	<ul style="list-style-type: none"> - Income quintiles weakly associated with child anthropometry - Factors associated with child anthropometry: female secondary education, access to safe water and sanitation facilities, antenatal checkups, and child immunization - Agricultural production conditions (such as irrigation, livestock ownership) associated with HDD 	<ul style="list-style-type: none"> - Income growth alone is likely to have modest impacts on child nutrition unless accompanied by improved health and education. - Important entry points for improving nutrition through agriculture include irrigation, crop diversification, and livestock ownership.
Headey 2014, Ethiopia	Examine patterns and trends in, and identify main predictors of child nutrition outcomes and IYCF practices	2000 and 2011 Ethiopia DHS (children 0–60 months old)	Nonparametric methods, OLS, linear probability regressions, Poisson models, Blinder-Oaxaca decompositions of changes in stunting over time	<ul style="list-style-type: none"> - HAZ, stunting, self-reported low birth weight - Child DD (24-hour recall, WHO 7 food groups), child dairy consumption (24-hour recall) 	<ul style="list-style-type: none"> - Predictors of child undernutrition: HH assets, parental education, antenatal care, and birth interval - Predictors of child DD: HH assets, parental education, cow ownership, antenatal care exposure, maternal age 	Income growth and improved food security are likely to have been the main forces driving nutritional change in Ethiopia in recent decades.

Table 3.2 Continued

Crop production diversity, market access, dietary diversity, and child nutrition						
Author(s), year, location^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Abay and Hirvonen 2016, Ethiopia	Test association between market access, seasonality, and child anthropometry	<ul style="list-style-type: none"> - 7 rounds of HH panel data over 24 months (2012–2014) in East Tigray, Ethiopia - 1,656–1,837 children (0–60 months old) in 2,387 HHs 	Linear regression with and without village fixed effects	<ul style="list-style-type: none"> - WAZ, WHZ - HH-level child DD score (7-day recall, 15 food items) 	<ul style="list-style-type: none"> - Lean season associated with lower WHZs and WAZs - No effect of market access on relationship between seasonality and child anthropometry - Better market access associated with greater DD in all seasons 	<ul style="list-style-type: none"> - Seasonality is associated with fluctuations in WHZs and WAZs. - Market access improves DD but does not mitigate seasonal fluctuations in WAZs and WHZs.
Carletto, Corral, and Guelfi 2016, Malawi, Tanzania, and Uganda	Test association between agricultural commercialization (measured by CCI) and child anthropometry, and effect modification of gender and crop mix on this association	Nationally representative panel data of farming HHs from LSMS-ISA: <ul style="list-style-type: none"> - Malawi: 2,222 HHs - Tanzania: 1,744 HHs - Uganda: 1,788 HHs 	Pooled sample with different specifications for commercialization using individual-fixed-effects linear model on z-scores and random effects logit model on probability of being malnourished	<ul style="list-style-type: none"> - HAZ, WAZ, WHZ, stunting, wasting, underweight - HH per capita food expenditure - HH per capita calorie consumption 	<ul style="list-style-type: none"> - No association between CCI or HH expenditure and child anthropometry - Significant and negative effect of commercialization by women on child wasting - Increase in expenditure negatively associated with probability of being stunted and underweight 	There is little evidence of a relationship between increased commercialization and improved nutritional status.
Hirvonen and Hoddinott 2014, Ethiopia	Test association between HH production diversity and child DD	Cross-sectional survey (2013) in 5 regions of Ethiopia: Amhara, Oromia, SNNPR, Somali, and Tigray (7,011 HHs in 252 villages in 84 <i>woredas</i> , including 4,214 children 6–71 months old)	GMM IV model for OLS; nonlinear IV technique for Poisson model based on GMM framework	Child DD: Number of food groups consumed (24-hour recall, 7 food groups)	<ul style="list-style-type: none"> - Increasing HH production increases child DD by 0.57–0.73 (controlling for confounding factors) - Significant interaction between production diversity and market access: market proximity mitigates negative effect of low production diversity on child DD 	HH production choices are strongly associated with children’s diets where HHs have limited access to food markets; this relationship does not hold for HHs with good access to markets to buy and sell food.

Table 3.2 Continued

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Jones 2014, Bolivia	Test association between (1) agriculture and IYCF practices, and (2) IYCF practices, child HAZs, and adequacy of child diets	Cross-sectional survey (2009) of 251 HHs with children 6–23 months old in Bolivian highlands	Multiple regression	<ul style="list-style-type: none"> - IYCF practices, summarized into an index, the ICFI - HAZ - Energy intake, MMDA score (24-hour recall) 	<ul style="list-style-type: none"> - Amount of land cultivated negatively associated with ICFI - Mother's education, livestock ownership, crop diversity positively associated with ICFI - Stronger associations between crop diversity and ICFI at higher elevations - ICFI positively associated with child HAZ, energy intake, and MMDA 	Nutrition-sensitive investments in agriculture that aim to diversify subsistence agricultural production could plausibly benefit the adequacy of child diets.
Jones, Shrinivas, and Bezner-Kerr 2014, Malawi	Test association between production diversity and HDD	2010/2011 Malawi IHS3, nationally representative (6,623 agricultural HHs)	Multiple linear regression	<ul style="list-style-type: none"> - Modified HDD score (7-day recall, 12 food groups) - FCS (7-day recall) - Number of foods consumed and food group frequency (days consumed in past 7 days) 	<ul style="list-style-type: none"> - Production diversity positively associated with HDD; FCS; and consumption of legumes, vegetables, and fruits - Effect of production diversity significantly greater in women-headed and wealthier HHs 	More diverse production systems may contribute to more diverse HH diets, but the relationship is influenced by gender, wealth, control of HH decisions, markets, and the specific nature of farm diversity.
Jones 2017, Malawi	Test association between agricultural biodiversity (measured as CSR) and HDD / diet quality	2013 Malawi IHPS and 2010/2011 Malawi IHS3 (nationally representative longitudinal data for 3,000 HHs)	GEE analysis modeling	<ul style="list-style-type: none"> - HDD score - Daily intake of energy and protein, iron, vitamin A, and zinc per adult equivalent (7-day recall) 	<ul style="list-style-type: none"> - CSR significantly and positively associated with HDD and daily intake of energy, protein, iron, vitamin A, and zinc - No effect of proportion of harvest sold or distance to nearest population center on relationship between CSR and diets 	Promoting on-farm CSR may support enhanced diet quality and diversity, and create opportunities for smallholder farmers to engage with markets in subsistence agriculture contexts.

Table 3.2 Continued

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Koppmair, Kassie, and Qaim 2017, Malawi	Test association between production diversity, market access, agricultural technology, and DD	Cross-sectional survey (2014) of 16 districts and 165 villages in central and southern Malawi (408 farm HHs with children 0–60 months old)	Poisson regression models	<ul style="list-style-type: none"> - HDD score (24-hour recall, 12 food groups) - Mother and child DD score (24-hour recall, 12 food groups) 	<ul style="list-style-type: none"> - Farm production diversity positively and significantly associated with HDD and individual DD (small coefficients) - Stronger association of access to markets and use of chemical fertilizer with DD 	<ul style="list-style-type: none"> - Improving market access is more promising for improving diets than is production diversification. - Diversification should not obstruct market integration and commercialization.
Kumar, Harris, and Rawat 2015, Zambia	Test association between production diversity and DD (children 6–23 months old) and anthropometry (children 6–59 months old)	Baseline survey data from RAIN project in Central Province, Zambia (3,340 HHs with children 24–59 months old)	<ul style="list-style-type: none"> - Ordered logit models (with DD as ordered variable) - Marginal probit (for DD and anthropometry as indicator variables) - OLS regressions (for anthropometry as continuous variable) 	<ul style="list-style-type: none"> - HDD score (24-hour recall, 12 food groups) - Child DD: DD score (24-hour recall, 7 food groups); minimum DD (24-hour recall; ≥ 4 food groups) - HAZ, WHZ, stunting, and wasting 	<ul style="list-style-type: none"> - Positive association between production diversity and DD (children 6–23 months old) - Production diversity also associated with higher HAZ and lower stunting (children 24–59 months old) 	Production diversity can have a significant impact on DD in young children in subsistence HHs and subsequently on nutritional status as these children age.

Table 3.2 Continued

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Malapit et al. 2015, Nepal	Test association between production diversity and nutrition outcomes, and whether this association is modified by women's empowerment in agriculture (measured by WEAI)	Baseline cross-sectional survey (2012) from the Suaahara project (3,332 rural HHs with children 0–60 months old in 3 agroecological zones)	OLS regressions	<ul style="list-style-type: none"> - WAZ, HAZ, WHZ, and adult BMI - Child DD (24-hour recall, 7 food groups) and maternal DD (24-hour recall, 9 food groups) 	<ul style="list-style-type: none"> - Production diversity positively associated with child DD (small coefficient) and WHZ - Women's empowerment mediates association - Group membership, control over income, reduced workload, and WEAI score positively associated with maternal BMI - Control over income positively associated with HAZ - Lower gender parity gap associated with child DD and HAZ 	<ul style="list-style-type: none"> - Positive associations of production diversity with maternal and child DD and anthropometry suggest that policies to promote diversification can improve nutrition. - Women's empowerment mitigates the negative effect of low production diversity on maternal and child DD and HAZ.

Table 3.2 Continued

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Shively and Sununtnasuk 2015, Nepal	Test association between production diversity, market participation, and child anthropometry	2010/2011 NLSS, a nationally representative survey (1,769 children 0–59 months old in 1,289 farm HHs)	Multiple linear regressions for HAZ and binary logistic regression for probability of stunting	HAZ, stunting (younger children: < 24 months old; older children: ≥ 24 months old)	<ul style="list-style-type: none"> - Increases in yield associated (small coefficients) with HAZs and lower stunting in older children - Own-consumption significantly associated with lower HAZs and higher stunting in older children - Small but significant positive association between agricultural commercialization and HAZs for younger children - No significant association between production diversity and child nutrition 	<ul style="list-style-type: none"> - Efforts to strengthen agricultural diversification and overall performance could benefit child nutrition. - Increased income from agricultural sales more than offsets possible adverse impacts associated with less food available for own-consumption.
Sibhatu, Krishna, and Qaim 2015, Indonesia, Kenya, Ethiopia, and Malawi	Test association between production diversity and DD	Cross-sectional HH surveys: (1) 2010/2011 Ethiopia Socioeconomic Survey (nationally representative, 2,045 HHs) (2) 2010/2011 Malawi IHS3 (nationally representative, 5,114 HHs) (3) 2012 survey of 674 HHs in Jambi Province, Indonesia (4) 2012 survey of 397 HHs in	Multiple regression models estimated separately for each country and with pooled data from all four countries	HDD score (7-day recall, 12 food groups)	<ul style="list-style-type: none"> - Significant and positive association between production diversity and HDD (small coefficients) in pooled sample - No association between production diversity and HDD in Kenya and Ethiopia - Negative association (small coefficient) between distance to market and HDD in pooled sample and Malawi model only 	<ul style="list-style-type: none"> - When production diversity is not beyond optimal levels, it is positively associated with DD. - Increasing on-farm diversity is not always the most effective way to improve HDD in smallholder HHs because greater market access tends to reduce the role of farm diversity for HH nutrition.

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
		Kiambu County, central Kenya				
Livestock, animal-source food consumption, and nutrition and health linkages						
Bageant, Liu, and Diao 2016, Nepal	Test the association between livestock ownership, milk consumption, and child anthropometry in the context of conflict	<ul style="list-style-type: none"> - 3 rounds of nationally representative panel HH data (NLSS) (959 HHs from 1996 and 2003; 2,800 children 0–60 months old from 2011; HH variables from all rounds) - Conflict data from other datasets 	<ul style="list-style-type: none"> - Linear regression for child anthropometry - Fixed-effects and correlated random-effects Tobit model for panel data 	<ul style="list-style-type: none"> - Child HAZ and WAZ - HH milk consumption 	<ul style="list-style-type: none"> - Livestock ownership positively associated with HH milk consumption - HH milk consumption positively associated with HAZ but not WAZ - Conflict had greater negative association with HH milk consumption in HHs with fewer livestock 	<ul style="list-style-type: none"> - Livestock ownership positively affects HH milk consumption, which in turn is associated with greater child HAZ. - Conflict affects the dairy production-consumption linkage, and the effects are felt more strongly among HHs with fewer cattle.
Flores-Martinez et al. 2016, Afghanistan	Test association between agricultural asset ownership and HH mutton consumption and anemia in women	<p>Cross-sectional HH data, nationally representative:</p> <ul style="list-style-type: none"> - 2010/2011 Afghanistan Multiple Indicator Cluster Survey, 9,199 adult women - 2011/2012 National Risk and Vulnerability Assessment, 20,828 HHs 	<ul style="list-style-type: none"> - Logistic regression and quantile regressions on anemia status - Logit models and Poisson count models for mutton consumption 	<ul style="list-style-type: none"> - Mutton consumption: days in a week and quantity per capita - Anemia (women 15–49 years old) 	<ul style="list-style-type: none"> - Sheep ownership associated with likelihood and quantity of mutton consumption - Sheep ownership associated with lower prevalence of anemia in women - Other agricultural assets had weak or no association with anemia 	Linkage between sheep ownership and anemia in women is at least partly due to mutton consumption arising from own-production in the presence of market incompleteness.

Table 3.2 Continued

Author(s), year, location^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Hoddinott, Headey, and Dereje 2015, Ethiopia	Test association between cow ownership and child dietary intake and anthropometry	Baseline data for evaluation of the government of Ethiopia's Agricultural Growth Program; 7,930 HHs in Amhara, Oromia, SNNP, and Tigray regions	Probit and OLS regressions	<ul style="list-style-type: none"> - Child (6–59 months old) anthropometry: HAZ, WHZ, stunting - Dairy intake (7-day recall in children 6–24 months old) 	<ul style="list-style-type: none"> - Cow ownership associated with greater dairy intake, higher HAZ, and lower stunting (children 12–18 months old), but not with WHZ - No association between cow ownership and HAZ in villages with functioning markets 	Although cow ownership improves child milk intake and nutritional status, it is less important where there is market access, suggesting that market development can substitute for HH cow ownership.
Iannotti and Lesarogol 2014, Kenya	Test determinants of micronutrient intake in pastoralist communities undergoing livelihood transitions	3 rounds of panel HH data (2000, 2005, 2010) with 200 HHs from 2 communities in Samburu County, Kenya	OLS regressions in each round and panel regression by generalized least squares with random effects for longitudinal modeling	<ul style="list-style-type: none"> - Individual DD (24-hour recall, 9 food groups) - Probability of adequate intake of vitamins A, B₁₂, and C; folate; zinc; and iron (24-hour recall) 	<ul style="list-style-type: none"> - Livestock ownership associated with nutrient adequacy for vitamin A, vitamin B₁₂, and zinc - DD associated with livestock and poultry ownership and other HH factors (income, HH head's education), as well as bean and rice consumption 	<ul style="list-style-type: none"> - Micronutrient inadequacies in vitamins A, B₁₂, and C were found among pastoralist communities. - Policies promoting livestock production with an appropriate mix of cropping and off-farm poverty alleviation strategies are needed.
Kabunga 2014, Uganda	Assess association between adoption of improved dairy cows, milk consumption, and child anthropometry	Cross-sectional, 2009/2010 Uganda National Panel Survey (907 HHs that own cows, with 715 children 0–60 months old)	Propensity score matching	<ul style="list-style-type: none"> - HAZ, WHZ, WAZ - Per capita annual milk consumption 	<ul style="list-style-type: none"> - Improved dairy cow adoption associated with milk consumption and HAZ but not with WAZ and WHZ - Stratified sample shows association with HAZ only for large farms 	Large farmers, instead of smallholders, will more likely achieve higher child nutritional benefits from adopting improved dairy cows.

Table 3.2 Continued

Author(s), year, location^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Kidoido and Korir 2015, Tanzania	Test association between improved dairy production, HH income, and child anthropometry	Panel HH data, 2008/2009 and 2010/2011 Tanzania LSMS-ISA	2SLS	HAZ, WAZ, WHZ (children 0–60 months old)	<ul style="list-style-type: none"> - Dairy income associated with food expenditure among low-income HHs - Dairy consumption positively associated with HAZ, WAZ, and WHZ in low-income HHs - In high-income HHs, dairy consumption associated with WHZ for boys only 	<ul style="list-style-type: none"> - Dairy is an important pathway to improving nutrition in low-income HHs . - Pro-poor dairy interventions should be integrated with increasing market access and use of gender-aware strategies to deliver equitable intra-HH benefits.
Headey and Hirvonen 2016, Ethiopia	Test association between poultry ownership, exposure of children to poultry, and child anthropometry	Cross-sectional HH survey (2015) in rural areas of 5 regions (Amhara, Oromia, Somali, SNNP, and Tigray), including 2,704 HHs and 3,494 children 0–60 months old	Various regression model specifications	HAZ	<ul style="list-style-type: none"> - Poultry ownership positively associated with HAZ - Corraling of poultry in HH dwelling overnight negatively associated with HAZ - Corraling of other livestock not associated with HAZ 	Although poultry ownership can improve HAZ, overly close exposure to poultry poses a concurrent risk factor for undernutrition, most likely because of increased risk of infection.
Headey et al. 2016, Bangladesh, Ethiopia, and Viet Nam	Test association between presence of animal feces in compound and child anthropometry	Baseline (2010) and endline (2014) data from Alive & Thrive project (2,214, 1,750, and 2,104 mother-child [6–23 months old] dyads in Bangladesh, Viet Nam, and Ethiopia, respectively)	Multivariate logit models with individual and pooled datasets	HAZ and WHZ	Presence of animal feces significantly and negatively associated with HAZ in the pooled sample and in Ethiopia and Bangladesh, but not in Viet Nam	Although open defecation remains a major health concern, exposure to animal feces is probably more common, and potentially hazardous for child nutrition.

Table 3.2 Continued

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Mosites et al. 2015, Ethiopia, Kenya, and Uganda	Test association between livestock ownership and child stunting	Cross-sectional DHS, rural children (0–60 months old): <ul style="list-style-type: none"> - Ethiopia (2011), <i>n</i> = 8,079 - Kenya (2008/2009), <i>n</i> = 3,903 - Uganda (2010), <i>n</i> = 1,645 	GEE	Stunting	<ul style="list-style-type: none"> - Livestock ownership significantly associated (small coefficient) with lower stunting in Ethiopia and Uganda but not Kenya - Effect did not vary by wealth, diarrheal disease, or animal-source food intake - Weak association when weighted measure of livestock ownership used 	<ul style="list-style-type: none"> - A small association exists between livestock ownership and child stunting. - The small effect size is likely due to data limitations or the complex relationship between nutrition and livestock, including exposure to animal feces, livestock health, and productivity.
Mosites et al. 2016, Kenya	Test association of livestock ownership, livestock disease, or both with child anthropometry	Cohort data on HHs with children < 5 years old (925 children in 755 HHs in 10 villages): <ul style="list-style-type: none"> - Livestock ownership data collected quarterly (2013/2014) - Child anthropometry data collected monthly (2014/2015) - Livestock disease data collected throughout study 	Cohort study using linear mixed regressions	HAZ, WHZ, annualized child growth rate (cm/year), and mean monthly growth rate	<ul style="list-style-type: none"> - Livestock ownership not associated with HAZ, WHZ, or growth rates - Livestock disease associated with growth rates only in some months (June–November) and among children 0–23 months old 	The study did not find an association between livestock ownership and child growth, but it did find that livestock disease episodes may be related to a lower child growth rate in some groups.

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Environmental and climatic factors affecting agriculture						
Mulmi et al. 2016, Nepal	Test association of agroclimatic conditions at different periods of gestation, birth, and infancy with child anthropometry, and test whether market access and sanitation mediate this association	<ul style="list-style-type: none"> - Nepal DHS 2006 (5,327 children 0–60 months old) and 2011 (2,335 children 0–60 months old) - NASA satellite observations of variation in NDVI 	Two-stage difference-in-differences design, which exploits random exposure to varying agroclimatic factors in relation to birth month	HAZ (children 12–59 months old)	<ul style="list-style-type: none"> - Agroclimatic conditions associated with HAZ; for boys, the effect is greatest in second trimester of pregnancy; for girls, in first three months after birth - Toilets in HHs and greater market access reduce negative effect of agroclimatic conditions on HAZ (large coefficient) 	<ul style="list-style-type: none"> - Findings are consistent with biomedical studies of sex-specific fetal development and socioeconomic studies of gender bias in childcare. - Both kinds of vulnerability are eliminated in HHs with toilets and greatly reduced in districts that have more active use of food markets.
Shively, Sununtnasuk, and Brown 2015, Nepal	Measure the relationship between environmental variability and child anthropometry	<ul style="list-style-type: none"> - 2011 Nepal DHS (2,335 children < 5 years old) - NDVI data from NASA satellites (2002/2012) 	Probit models	Stunting (children 24–60 months old); wasting (children 0–60 months old)	<ul style="list-style-type: none"> - Increases in NDVI in child's first year associated with stunting (small coefficient) - Effect on HAZ smaller in Terai than in mountains - NDVI (in month of survey) weakly associated with wasting 	Stunting and wasting are correlated with fluctuations in environmental conditions that affect agricultural production, but the relationship is heterogeneous across the landscape in Nepal.

Table 3.2 Continued

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Women's empowerment in agriculture						
Cunningham et al. 2015, Nepal	Examine association between women's empowerment (measured by WEAI) and child anthropometry	Baseline cross-sectional survey (2012) of Suaahara nutrition program, including 1,787 rural HHs with children 0–23 months old in 3 agroecological zones	Multivariate OLS regressions	HAZ and WHZ (children 0–23 months old)	Women's empowerment (specifically leisure, access to credit, and autonomy in production) associated with HAZ but not with WHZ	<ul style="list-style-type: none"> - The study highlights the potential role of women's empowerment in improving child nutrition in Nepal. - More evidence is needed on whether interventions to improve women's empowerment improve nutrition.
Malapit and Quisumbing 2015, Ghana	Test association between women's empowerment in agriculture (using WEAI) and child and maternal anthropometry and diets	2012 baseline survey of agricultural HHs representative of Feed the Future's zone of influence in northern Ghana (2,027 women of reproductive age with 1,437 children 0–60 months old)	OLS regressions	<ul style="list-style-type: none"> - HAZ, WHZ, WAZ, maternal BMI - IYCF practices (24-hour recall), including child DD (7 food groups), minimum DD (≥ 4 food groups) - Women's DD (24-hour recall, 9 food groups) 	<ul style="list-style-type: none"> - Strong associations between women's empowerment and IYCF practices for girls, but not for boys - Women's empowerment weakly associated with child anthropometry - WEAI positively associated with women's DD but not with BMI 	The study suggests that the specific domains of women's empowerment that affect nutrition outcomes differ among mothers, boys, and girls.
Malapit et al. 2015, Nepal	See section on crop diversity, market access, dietary diversity, and child nutrition above					

Table 3.2 Continued

Author(s), year, location ^a	Study objectives	Sampling design, characteristics, size	Data analysis methods	Outcomes measured	Key findings	Conclusions
Sraboni et al. 2014, Bangladesh	Test association between women's empowerment in agriculture (measured by WEAI) and energy (calorie) availability, DD, and adult anthropometry	Cross-sectional survey data from Bangladesh Integrated Household Survey 2011/2012, nationally representative (3,213 farm HHs where both women and men were interviewed)	2SLS with empowerment variables instrumented	<ul style="list-style-type: none"> - Per capita calorie availability, HDD score (7-day recall, 12 food groups) - Adult BMI 	<ul style="list-style-type: none"> - Increases in WEAI and narrowing of empowerment gap between men and women positively associated with HH energy availability and DD - Negative relationship of group membership and credit with male BMI 	<ul style="list-style-type: none"> - Although increases in empowerment are positively associated with HDD and energy availability, other factors such as HH wealth are more important determinants of adult BMI. - Negative impacts of some domains of empowerment on male BMI suggest the existence of intra-HH trade-offs.

Source: Authors.

Note: ^a Studies are ordered by alphabetical order, within each category. 2SLS = two-stage least squares; BMI = body mass index; CCI = crop commercialization index; CSR = crop species richness; DD = dietary diversity; DHS = Demographic and Health Surveys; FCS = food consumption score; GEE = generalized estimating equations; GMM = generalized method of moments; HAZ = height-for-age z-score; HDD = household dietary diversity; HH = household; ICFI = infant and child feeding index; IHPS = Integrated Household Panel Survey; IHS3 = Third Integrated Household Survey (Malawi); IV = instrumental variables; IYCF = infant and young child feeding; NDVI = normalized difference vegetation index; LSMS-ISA = Living Standards Measurement Study–Integrated Surveys on Agriculture; MMDA = mean micronutrient density adequacy; NASA = US National Aeronautics and Space Administration; NLSS: Nepal Living Standards Survey; OLS = ordinary least squares; RAIN = Realigning Agriculture for Improved Nutrition; SNNPR = Southern Nations, Nationalities, and Peoples' Region; WAZ = weight-for-age z-score; WEAI = Women's Empowerment in Agriculture Index; WHO = World Health Organization; WHZ = weight-for-height z-score.

Income Growth, Agricultural Livelihoods, Diets, and Child Nutrition Outcomes

Two papers looked, respectively, at the contributions of household income, livelihoods, and sociodemographic factors in explaining child nutrition outcomes in India (Bhagowalia, Headey, and Kadiyala 2012) and at the drivers of nutrition changes over time in Ethiopia (Headey 2014). Both studies used publicly available, nationally representative datasets and focused on child anthropometry and dietary diversity as their main outcomes. In India, income growth alone was only modestly associated with child anthropometry, whereas stronger associations were found for female secondary education, access to safe water and sanitation facilities, and use of antenatal and child preventive health services (Bhagowalia, Headey, and Kadiyala 2012). The authors concluded that income growth alone would likely have modest impacts on child nutrition unless accompanied by improved education and access to health services. In contrast, the study in Ethiopia identified income growth and improved food security as the main forces driving nutrition change between 2000 and 2011 (Headey 2014). The contrasting results are likely due to vast structural and economic differences between India and Ethiopia, but also the nature of the analyses conducted—in India, the analysis was cross-sectional and looked at determinants of nutrition at one point in time; in Ethiopia, the analysis was prospective and modeled drivers of changes in nutrition outcomes over time. Relative to dietary diversity, both studies identified agriculture as playing an important role. In India, the authors identified irrigation, crop diversification, and livestock ownership as possible entry points for diversifying household diets; in Ethiopia, cow ownership, along with several other factors including household assets, parental education, antenatal care exposure, and maternal age were correlated with children's dietary diversity. Although the dietary diversity measures differed, these studies came to similar conclusions regarding the role of livestock ownership and agricultural production conditions as correlates of dietary diversity. They also both made the point that income growth or agriculture alone is not sufficient to improve dietary diversity or child anthropometry.

Crop Production Diversity, Market Access, Dietary Diversity, and Child Nutrition

Outcomes

The number of papers published on the topic of production diversity since 2014 illustrates increased interest in exploring whether production diversity (defined in different ways) is indeed an important driver of better diets and nutrition. Several of the studies explicitly considered the role of markets in the linkages between production and consumption diversity, whether using a measure of the distance to markets or of the degree of commercialization.² The key findings of this body of research are that there is generally a positive association between crop production diversity (or crop species richness, as in Jones 2017) and dietary diversity, but that the extent to which on-farm production diversity matters differs according to context and is more important in more physically isolated locations (Jones 2014) or those with imperfect market infrastructure (Zambia in Kumar et al. 2015; Nepal in Shively and Sununtnasuk 2015), compared with those located closer to well-functioning markets. Indeed, studies from settings as diverse as Ethiopia (Hirvonen and Hoddinott 2014; Sibhatu, Krishna, and Qaim 2015); Indonesia, Kenya, and Malawi (Sibhatu, Krishna, and Qaim 2015); and Nepal (Malapit et al. 2015) have suggested a positive association of farm production with dietary diversity in some, but not all, contexts. In contexts where farm production diversity is already high, the dietary diversity relationship may not be significant or may even turn negative, owing to the forgone income resulting from farm diversification beyond optimal levels (Sibhatu, Krishna, and Qaim 2015).

Market access, typically measured as distance to the nearest market and availability of off-farm income sources, comes up in many studies as a key factor that modifies the relationship between production and dietary diversity. In Ethiopia (Abay and Hirvonen 2016; Hirvonen and Hoddinott 2014) and Malawi (Koppmair, Kassie, and Qaim 2017), for example, market access was found to mitigate the potentially negative effect of low crop production diversity on dietary diversity. In Malawi, access to markets for buying food and chemical fertilizers and selling produce was found to be more important for

² Livestock ownership is discussed separately below.

dietary diversity than diversity in farm production (Koppmair, Kassie, and Qaim 2017). Similarly, a pooled analysis of data from Ethiopia, Malawi, Kenya, and Indonesia showed that market access had stronger effects on dietary diversity than did production diversity (Sibhatu, Krishna, and Qaim 2015). The study documented that reducing distance to market by 10 km had the same effect as increasing farm productivity by 1 additional crop or livestock species; producing 1 added crop, on the other hand, resulted in a small 0.9 percent increase in the number of food groups consumed, although effect sizes varied by country. Overall, market participation in the four countries studied had a greater effect than production diversity, and it reduced the role of production diversity on dietary diversity (Sibhatu, Krishna, and Qaim 2015). Women's empowerment was also identified as an effect modifier of the association between production and consumption diversity in Nepal (Malapit et al. 2015). In that study, higher women's empowerment helped mitigate the negative effects of low production diversity on maternal and child dietary diversity. Similarly, in Malawi, the association between production diversity and household dietary diversity was modified by gender, wealth, control of household decisions, market access, and the specific nature of farm diversity (Jones, Shrinivas, and Bezner-Kerr 2014).

Although the relationship between crop diversity and dietary quality appears robust, linkages between crop diversity and nutritional status are generally weaker, and some studies have found that it varies by child age. In Zambia, Kumar, Harris, and Rawat (2015) found strong associations between production diversity and dietary diversity among younger children, ages 6–23 months, but significant associations between production diversity and HAZs and stunting only among older children, ages 24–59 months. This finding is not entirely surprising, given that stunting is a cumulative process that reflects chronic undernutrition over time. A lagged effect between improvements in dietary diversity (say, when children are 6–23 months of age) and their effect on children's linear growth (detectable at an older age) is entirely plausible. In Ethiopia, Abay and Hirvonen (2016) found that children living closer to markets had more diverse diets and higher mean WHZs and weight-for-age z-scores (WAZs). They also showed, however, that market access did not mitigate seasonal fluctuations in children's weights. In Nepal, Shively and Sununtnasuk (2015) found higher shares of roots and production of animal products, as well

as increased market orientation, to be associated with reductions in the probability of stunting and improvement in HAZs (Shively, Sununtnasuk, and Brown 2015).

Commercialization is different from market access and is usually measured using the proportion of crop production that is sold (although some studies use a binary dummy variable for whether *any* part of the produce is sold). A three-country analysis of nationally representative panel surveys from Malawi, Tanzania, and Uganda found little evidence of a relationship between increased commercialization and child nutritional status (Carletto, Corral, and Guelfi 2017). In fact, the study found a weak negative relationship between nutrition indicators and women's share of the portion of household output that is sold, possibly indicating negative effects of greater female market participation on time allocated to childcare and domestic responsibilities.

Livestock, Animal-Source Food Consumption, and Nutrition and Health Outcomes

Livestock ownership provides households with a rich source of high-quality protein and bioavailable micronutrients, a potential source of income (through sales of livestock products), and productive assets. Since 2014, 10 published papers have examined livestock production-consumption (and in some cases, nutrition) linkages, of which 4 specifically focused on dairy cows and milk consumption, and 3 on the potential health and sanitation implications of exposure to livestock feces (2 papers) and diseases (1 paper).

Milk has long been recognized as an important food for young children, especially for its stimulating effect on linear growth (De Beer 2012), thought to be due to its rich content of high-quality proteins, minerals, and insulin-like growth factor-I (Mølgaard et al. 2011). Four of the studies reviewed focused on dairy cows and confirmed dairy production's association with increased milk consumption and lower prevalence of childhood stunting (or higher HAZs) in Ethiopia (Hoddinott, Headey, and Dereje 2015), Uganda (Kabunga 2014), Tanzania (where milk consumption was also associated with higher WAZs and WHZs) (Kidoido and Korir 2015), and Nepal (Bageant, Liu, and Diao 2016). The magnitude of these associations varied by context; in Ethiopia, the association between cow ownership and linear

growth was found only among households that had limited access to markets (Hoddinott, Headey, and Dereje 2015); in Uganda, it was found only among households with large farms (Kabunga 2014); and in Tanzania, it held only among poorer households (Kidoido and Korir 2015). In Nepal, the association was affected by conflict, with reductions in milk consumption during conflict felt more strongly among households with fewer cattle (Bageant, Liu, and Diao 2016).

A three-country analysis of Demographic and Health Survey (DHS) data looked at the association between livestock ownership and stunting, but without documenting the potential intermediary effect of livestock on milk consumption. The results showed that a tenfold increase in livestock ownership was associated with a small reduction in the prevalence of child stunting in Ethiopia and Uganda, but not in Kenya (Mosites et al. 2015). The authors attributed the relatively small effect to the complex relationships between livestock ownership and the potential health risks associated with increased exposure to animal feces, as well as livestock health and productivity constraints. A study in Afghanistan documented an association between sheep ownership, mutton consumption, and decreased anemia among women of reproductive age, with the authors noting that the results were driven by own-consumption in a situation with imperfect market access (Flores-Martinez et al. 2016). A study of pastoralist households in Kenya (Iannotti and Lesorogol 2014) found cattle and chicken ownership to be a positive determinant of dietary diversity, and livestock ownership in general a predictor of the adequacy of key vitamins and minerals including vitamin A, vitamin B₁₂, and zinc.

Benefits from owning livestock must be weighed against the possibly negative effects animals may have on human health. Recent studies have looked at livestock ownership and child nutrition and health outcomes taking into consideration the risk of increased exposure to animal feces. Headey and Hirvonen (2016) found that although poultry ownership was positively associated with child HAZs in Ethiopia, the practice of corralling poultry (but not other livestock species) in the household dwelling overnight was negatively associated with HAZs, probably because it increased children's exposure to chicken feces. An analysis of data from Bangladesh, Ethiopia, and Viet Nam also found the presence of animal feces in the compound to be significantly and negatively correlated with child HAZs in

Bangladesh and Ethiopia, but not in Viet Nam, where baseline nutritional status was better and handwashing with soap was commonly practiced (Headey et al. 2016). Mosites et al. (2016), tracking a cohort of young children in western Kenya, found no association between livestock ownership and child growth, and attributed this finding to the potentially high disease burden among children in these households. Whether this burden is due to actual transmission of disease between livestock and humans or because livestock diseases result in lower household wealth cannot be convincingly disentangled in this study.

Environmental and Climatic Factors Affecting Agriculture and Child Nutrition Outcomes

A small subset of the literature examined the influence of environmental and climatic factors affecting agriculture and child nutrition. Shively, Sununtnasuk, and Brown (2015) estimated the probability that a child was stunted or wasted using data from the 2011 Nepal DHS as a function of the Normalized Digitized Vegetation Index (NDVI), a proxy for growing conditions and food supply, as well as geographic indicators to control for topographic and climate variation and household, mother, and child characteristics. They found stunting and wasting to be correlated with fluctuations in environmental conditions, with HAZ effects less strong in the Terai, however, owing to better agricultural, market, and health infrastructure than in the hills and mountains. Interestingly, positive deviations from the NDVI when the child was in utero or during the first year of life were associated with a higher probability of stunting, possibly owing to higher agricultural workloads for women in years of higher agricultural output. In contrast, positive deviations in the NDVI in the same period of the child's life were associated with a lower probability of wasting, suggesting that better growing conditions were associated with better access to food in the short term, which in turn helped prevent or reduce wasting.

Also in Nepal, Mulmi and others (2016) correlated data on child anthropometry from the 2006 and 2011 Nepal DHS with satellite observations of variations in the NDVI. They found that boys were more vulnerable to variations in the NDVI during their second trimester of gestation and girls in their first three months after birth. Both kinds of vulnerability were eliminated in households with toilets and

greatly reduced in districts that had more active food markets, consistent with the studies on market access. In other words, the authors found that climate affected child growth only in districts where households' food consumption was primarily from own-production.

Women's Empowerment in Agriculture and Diet and Nutrition Outcomes

The recent availability of a standardized measure of women's empowerment in agriculture, the Women's Empowerment in Agriculture Index (WEAI) (Alkire et al. 2013), has greatly increased the use of women's empowerment measures in surveys and in the analytical work looking at the mediating or mitigating role of women's empowerment in agriculture for nutrition outcomes at the household and individual levels. Sraboni and colleagues (2014), using nationally representative data from Bangladesh, found increases in women's empowerment in agriculture to be positively associated with energy availability and dietary diversity at the household level. In Nepal, a study found that women's overall empowerment in agriculture and in 3 specific domains of empowerment—satisfaction with leisure time, access to and decisions regarding credit, and autonomy in production—was positively associated with length-for-age z-scores among children less than 2 years of age (Cunningham et al. 2015). Using a different sample that included all children 0–5 years of age and only women who participated in agriculture, Malapit and colleagues (2015) found that the domains of women's empowerment in agriculture associated with maternal versus child nutrition outcomes did not always overlap. In their sample from Nepal, overall empowerment, women's group membership, control over income, and reduced workload were positively associated with greater maternal dietary diversity and body mass index (BMI), whereas control over income was associated with higher child HAZs, and a lower gender parity gap was associated with both higher HAZs and greater dietary diversity in children younger than 5 (Malapit et al. 2015).

Associations between nutrition and women's empowerment in agriculture also vary across cultures due to the context specificity of gender norms and differences in levels of empowerment, both overall and by domain. In northern Ghana, women's empowerment was found to be strongly associated

with the quality of IYCF practices but only weakly associated with child nutritional status, and associations of empowerment indicators with child outcomes varied by the sex of the child. Similar to the findings in Nepal, domains of empowerment that were associated with women's nutrition outcomes were different from those associated with children's diet and nutrition outcomes (Malapit and Quisumbing 2015).

Agriculture may also affect nutrition through changes in women's time allocation. Several studies in our review highlighted that agricultural programs and interventions put constraints on women's time, which in turn may have negative consequences on nutrition and health by reducing time for childcare, healthcare seeking, food preparation, and leisure (Carletto, Corral, and Guelfi 2017; Cunningham et al. 2015; Jones et al. 2012; Kumar et al. 2017; Shively and Sununtnasuk 2015). However, a systematic review of time use in agriculture and nutrition concludes that existing studies do not provide clear-cut evidence on the nutrition implications of agricultural interventions, even when these interventions increase time spent in agriculture, because households tend to use adaptive measures to adjust for changes in time allocation (Johnston et al. 2015). For example, with increased income from the sale of commodities, households may be able to purchase prepared foods instead of engaging in time-consuming food preparation, or they may be able to shift the time allocation of different household members to help with household chores or childcare and thereby offset the potentially negative impacts of agriculture on women's time and on maternal and child nutrition.

4. DISCUSSION

Our review of recent evidence on NSA unveiled a rich set of studies published over a short three-year time span (since 2014). The body of evidence on how agriculture can contribute to nutrition has rapidly expanded, with the publication of 17 peer-reviewed papers analyzing impact evaluations of different types of NSA, livestock, value chain, and irrigation programs, and 28 papers using survey data to explore the linkages between agriculture, women's empowerment, diets, and nutrition. We focus our discussion on what we have learned from this new body of evidence, the remaining research gaps in knowledge, and priorities for research.

What Have We Learned?

Intervention Studies

The most consistent finding from our review of NSA programs, which all aimed to increase household access to nutrient-rich foods, is their impact on household and child dietary diversity (where studied) and on the consumption of animal-source foods or fruits and vegetables (when targeted). Impacts on micronutrient intakes were also found in studies that measured dietary intake through a 24-hour recall (Hotz, Loechl, de Brauw, et al. 2012; Hotz, Loechl, Lubowa, et al. 2012). These results were achieved in diverse settings and through a variety of program models including biofortified vitamin A-rich OSP, gender-sensitive EHFP, livestock and dairy value chain programs, and a fruit and vegetable SMG irrigation program. Overall, these programs were highly successful at meeting their production and consumption goals and, more specifically, at achieving their main objective of improving household and individual access to nutrient-rich foods.

The new set of studies also generated evidence of the impacts of EHFP (with chickens) on child Hb and anemia in Burkina Faso (Olney et al. 2015) and Nepal (Osei et al. 2017), where it was assessed. These studies add to previous evidence of impacts on micronutrient status (vitamin A) provided by the evaluation of biofortified vitamin A-rich OSP in Uganda (Hotz, Loechl, Lubowa, et al. 2012). The studies

that used an EHFP or a dairy value chain platform to distribute micronutrient-fortified sprinkles or yogurt targeted to young children also documented impacts on anemia (Osei et al. 2015) and Hb (Le Port et al. 2017), concluding that agricultural programs could be effective platforms to deliver micronutrient-fortified products targeted to young children. Of the six studies that measured child anthropometry, however, none found an impact on stunting (with the exception of a livestock study that found impacts in one of the two geographic areas studied (Miller et al. 2014)) and impacts on WHZ or wasting were small or marginally significant (Olney et al. 2015; Kumar et al. 2017; Miller et al. in one region only; Rawlins et al. 2014). Three studies documented reductions in diarrhea prevalence or days sick in young children (Jones and de Brauw 2015; Olney et al. 2015; Miller et al. 2014), and two showed reductions in the prevalence of maternal anemia and underweight (Olney, Bliznashka, et al. 2016; Osei et al. 2017).

Overall, the new studies have expanded the breadth of agricultural programs studied (from traditional home gardens to EHFP systems with small animals, livestock programs, dairy value chains, and irrigation) and the set of nutrition outcomes measured in children (from anthropometry and diets to micronutrient status and morbidity). New studies also started to document some of the untapped potential of agriculture to improve women's nutritional status, especially in countries such as Burkina Faso, Nepal, and Zambia, where maternal undernutrition is a critical nutrition problem. The studies also used more consistent indicators of household, women's, or children's dietary diversity, allowing for comparability across contexts. The range of effects on production and consumption varied between studies, but in general, impacts on maternal and child dietary diversity, food intake, micronutrient status, and weight-specific nutritional status indicators were modest. For stunting, the lack of impacts may be explained at least in part by the relatively short duration of most programs (1.0–2.5 years) and the wide age range targeted by many, often well beyond the first 2 years of life, when the greatest benefits on child growth from nutrition interventions can be expected (Black et al. 2013; Leroy, Olney, and Ruel 2016). As documented before, studies also may have been underpowered to detect effects on stunting (Herforth and Ballard 2016). Finally, several new studies specifically documented impacts along the project-specific hypothesized pathways, strengthening the plausibility of impacts on maternal and child diets and

nutritional status outcomes. For example, results from the evaluation of EHFP in Burkina Faso and Zambia showed impacts on specific dimensions of women's empowerment such as social capital, ownership of and control over assets, and decision making in selected domains, and a number of studies documented impacts on maternal IYCF knowledge, practices, or both (Kumar et al. 2017; Miller et al. 2014; Murty, Rao, and Bamji 2016; van den Bold et al. 2015). These findings confirm the hypothesized mediating (and in some case modifying) role of women's empowerment and improved knowledge and practices in fostering nutrition impacts from agriculture (SPRING 2014).

Our review also found marked improvements in recent studies both in program design and in the quality and rigor of impact evaluations. In contrast with the studies included in previous reviews, most of the agriculture and nutrition programs reviewed here were truly nutrition sensitive (except for some of the livestock studies and the irrigation study) in that they had both explicit nutrition goals and carefully designed nutrition interventions. Nutrition, health, and hygiene training and BCC were the most common nutrition interventions, but a few studies also delivered micronutrient-fortified products, recognizing that in some contexts, increasing household access to nutritious foods may not be sufficient to meet the high micronutrient requirements of children in their first two years of life. Several of the programs also had a strong focus on gender equity and women's empowerment, which included not only targeting women but also engaging women, men, and communities through trainings and social mobilization and carefully designed promotional activities. The purpose of these gender-focused activities was not only to improve the quality and productivity of women's lives but also to ensure that resources would be used more efficiently to support children's nutrition, health, and well-being. Only two studies specifically documented impacts on women's empowerment outcomes, however.

In addition to having improved program designs, the new studies have tended to pay more attention than before to implementation quality, and a few of them documented working with researchers to design a program impact pathway framework (Rawat et al. 2013) and to measure, through process evaluations, implementation fidelity, quality of service delivery, use of the program, and the perceptions of program implementers and users (Olney, Bliznashka, et al. 2016, 2015; Osei et al. 2017). Finally, the

quality of impact evaluation designs and analyses also improved in the newly published studies, with some using CRCTs or quasi-experimental approaches. More studies than before used baseline and endline surveys and valid comparison groups (through either randomization or matching) to document impacts, although weaknesses remained in some studies, including the lack of a valid control group or of baseline information.

In sum, the set of new studies reviewed generally had stronger and more nutrition-sensitive program designs, clearer and better-tailored target groups for the nutrition objectives they had set, more rigorous evaluation designs and better-defined sample size calculations, more appropriate data analysis approaches (for example, use of double differences, control for potentially confounding factors, and so on), and more standardized nutrition outcomes. Some evaluations also included careful analysis of hypothesized program impact pathways. Additionally, most new programs evaluated were genuinely designed to be nutrition sensitive, and in several cases also gender sensitive. The emerging evidence from these higher-quality nutrition- and gender-sensitive program designs, which pay careful attention to both implementation quality and pathways of impact, and use careful and rigorous evaluation methods, is generally positive, although effect sizes are modest for maternal and child diet and weight-specific anthropometric indicators and, so far, no impacts have been documented on stunting.

Observational Studies

An exceptionally large number of observational studies on the linkages between agriculture and nutrition have been published in the past three years, many focusing on the importance of production diversity for household, maternal, and child diets. The main takeaway from this literature is that production diversity and livestock ownership are consistently associated with household and dietary diversity and, when measured, with increased intake of essential micronutrients. Livestock ownership is also specifically associated with greater animal-source food intake (especially milk in young children). Evidence of associations with health and nutritional status outcomes is still limited, but milk intake (in households that own livestock) is positively associated with child linear growth, confirming the well-documented

contribution of milk to linear growth (De Beer 2012). A second key takeaway from this literature is that although production-consumption diversity linkages were found in all studies, the associations were modified by contextual factors, the most important one being market access. Indeed, studies that included some measure of market access highlighted its strong role as an effect modifier of the association between production diversity or livestock ownership and household or child dietary diversity, and in some cases between production diversity or livestock ownership and child nutritional status (Hoddinott, Headey, and Dereje 2015; Mulmi et al. 2016). Other contextual, socioeconomic, and food environment factors were also identified as important effect modifiers of the associations between production, consumption, and nutritional status.

As found for the evaluation literature, the quality of the association studies varied but was generally better than that of earlier studies, with greater attention paid to using appropriate statistical modeling tools, controlling for potentially confounding factors, using robustness checks as needed, and focusing on appropriate age groups for nutritional status indicators. The choice of indicators of consumption diversity and child nutritional status was generally consistent, but significant variation arose in the selection of production diversity and market access indicators, making comparison between studies difficult.

With the availability of a new indicator to measure women's empowerment in agriculture (the WEAI), overall and for different dimensions of empowerment, some of the new studies confirmed the hypothesized association between women's empowerment, food security, and women's and children's nutrition outcomes, including child HAZs. The studies also revealed complex relationships between different domains of women's empowerment and how they affect women's and children's (and boys' and girls') outcomes differently, as well as the context sensitivity of these relationships.

Overall, the main conclusions from the association literature are that production diversity or livestock ownership is important to consumption diversity and possibly nutritional status, but mostly for households that live in remote areas and have limited access to markets, which usually are the poorest of the poor. Women's empowerment is also an important mediator and in some cases an effect modifier of

these relationships. The main implications of these findings are that increasing production diversity should not be considered a main goal in itself in all contexts (Sibhatu, Krishna, and Qaim 2015) and that market interventions should be leveraged and combined with women's empowerment and BCC interventions to further improve availability of, access to, affordability of, and demand for nutritious foods.

What Are the Remaining Gaps in Knowledge and Priorities for Research?

Although encouraging progress has been achieved in documenting agriculture, gender, and nutrition linkages in the context of community-based programs and through analyses of existing data, much remains to be learned about what, how, and at what cost agriculture can contribute to improving nutrition. Evidence will continue to grow over the next 5 to 10 years, with innovative ongoing studies on nutrition-sensitive value chains (for example, value chains for biofortified staple crops, dairy products, and chickens); experimentation with new platforms such as livelihoods-focused self-help groups, government extension services, and agriculture-targeted financial services for women in South Asia; and research that incorporates targeted WASH interventions to address the potential harm of homestead agriculture involving small animal rearing (Gelli et al. 2017), to name a few. The Innovative Methods and Metrics for Agriculture and Nutrition Actions (IMMANA) portfolio of research on agriculture, nutrition, and health metrics should also generate a set of innovative tools, methods, and indicators for analyzing multisectoral programs and standardizing approaches and measurement in this area. Large knowledge gaps remain, however, on the potential nutrition contributions of traditional community-level agricultural programs and value chains such as those included in the present review, but also on the more holistic national and global agriculture and food systems and their effects on all forms of malnutrition. We focus our discussion on research gaps mostly regarding the former and refer the reader to other recent reviews on agriculture and food systems for the latter (Gillespie and van den Bold 2017; Global Panel on Agriculture and Food Systems for Nutrition 2016; Pingali and Sunder 2017).

To further enhance our understanding of the value and contribution of household- and community-focused agricultural programs to women's empowerment and to maternal, adolescent, and child nutrition, we provide examples of some key research gaps that need to be filled in the short to medium term:

- **Long-term impacts and sustainability:** Given the impacts of nutrition- and gender-sensitive agricultural programs on several outcomes along the impact pathways, and especially impacts on women's empowerment, knowledge, and practices, we can assume that these programs could have long-lasting impacts on women's social, health, and nutritional status, which in turn could have impacts on their families and future children. So far, no information exists on the long-term impacts—or the sustainability of any impacts—of nutrition- and gender-sensitive programs, nor on the sustainability beyond these programs' specific funding cycles of the practices adopted or assets built by participants. A preliminary analysis of the Burkina Faso EHFP suggested some spillover effects of the program on maternal and child weight indicators, but no sustained impacts on household assets, livestock ownership, food security, or dietary diversity (Bliznashka et al. 2016). Research on the long-term impacts and sustainability of nutrition- and gender-sensitive agricultural programs should be prioritized.
- **Scaling up and operating at scale:** The types of NSA development projects reviewed were implemented at a relatively small scale and often for short periods of time delineated by funding cycles. None of the programs included in this review were implemented at scale, and data, information, and evidence from efforts to scale up NSA development programs are extremely slim (Gillespie, Menon, and Kennedy 2015; Linn 2012). Research is needed on how and where to scale up or implement NSA programs, the key factors for success, and the cost of scaling up and achieving impacts at scale. Research should also characterize how agricultural development programs can fit within—and complement—the scale-up of larger agricultural and food systems investments.
- **Cost and cost-effectiveness:** The complexity of collecting and interpreting cost data for multisectoral programs has prevented many researchers from doing so. Moreover, cost-effectiveness assessments, which focus on one outcome (for example, stunting), cannot capture the multiple benefits of programs that generate impacts on a series of outcomes (for example, women's empowerment, knowledge, diets, nutritional status) (Bill & Melinda Gates Foundation and DFID 2017). Cost-effectiveness assessments of such programs also cannot factor in the benefits the programs may have on several of the underlying determinants of stunting, which in turn may have long-term cumulative impacts on either the targeted children, their younger siblings, or the next generation. Cross-disciplinary research is urgently needed to develop methodologies to assess cost-effectiveness for programs that are designed to have impacts on a suite of outcomes.
- **Which target groups, which nutrition outcomes?** With the recent focus on the first 1,000 days and the call for action on reducing stunting, many agricultural development programs switched from an earlier focus on improving household production, food security, and dietary quality to a goal of reducing childhood stunting. As a result, several programs shifted their targeting mechanism from the community level (based on poverty and food insecurity) to poor households with pregnant women and children in their first 1,000 days. This shift was appropriate if the main nutrition goal of the program was to reduce stunting, but current evidence suggests that agriculture may in fact be more beneficial for improving household

access to nutritious food and diverse diets than for reducing stunting, and for household members other than young children, who have particularly high nutrient needs. Research should therefore continue to assess which nutrition indicators (for example, diets or micronutrient intake and status) are most likely to respond to agriculture interventions, and which household members are most likely to benefit. So far, the few studies that have assessed impacts on women's nutritional status have found significant impacts on diets, weight and BMI, and micronutrient status. It is likely that other household members, including adolescent boys and girls, who are also nutritionally vulnerable, may benefit more from agriculture interventions than young children. Research should therefore be undertaken to redefine which nutrition outcomes and which age groups agriculture should aim to support in different contexts.

- **Using agriculture programs as delivery platforms for tailored nutrition interventions:** An alternative to completely reverting the targeting of community-level agricultural programs to households based on poverty and food insecurity would be to develop and adopt different models, based on household demographic characteristics or other factors. There could, for example, be a model specifically designed to meet the needs of households with pregnant women and children in their first 1,000 days. Similarly, some models could be tailored to address the needs of adolescent boys and girls or the elderly, or could explore targeting some resources (including BCC) to specific individuals within the household and others to the household as a whole. Such a strategy would require careful targeting, monitoring, and community tracking to identify households with the preestablished eligibility criteria for the specialized intervention packages and may therefore be operationally too complex, at least in most contexts. Research could assess the operational feasibility and effectiveness of some variations of these approaches. Different implementation modalities could also be assessed, including comparing existing government delivery systems; NGO programs; and innovative approaches that link government, private, and NGO delivery systems.
- **BCC in the context of agricultural programs:** Effective nutrition, health, and hygiene BCC requires carefully designed, locally adapted materials and tools, and well-trained and dedicated staff to deliver it. It is generally resource intensive and requires time and active engagement from both staff and beneficiaries. In the area of breastfeeding, for example, evidence shows that more intensive and better-targeted BCC and the use of multiple approaches including combinations of home visits, community-based or service-based sessions, and mass media tend to deliver greater impacts on knowledge and practices than single approaches (Nguyen et al. 2016; Rollins et al. 2016; Sinha et al. 2015). Process evaluations of agricultural programs have identified BCC as a common bottleneck in implementation (Olney, Aminuzzaman, et al. 2009; Olney, Dillon, et al. 2016), and although most programs have shown some impacts on knowledge and practices, there is room for much more improvement than what is usually achieved. Research is needed to identify best practices in designing and implementing effective yet affordable BCC strategies in the context of agricultural programs and how to make them attractive and useful for beneficiaries without adding too much burden on their time. BCC topics also need to be broadened, from the traditional focus on optimal IYCF practices to the promotion of healthy and nutritious diets, meal planning and budgeting, and hygiene, and health service utilization for all household members. Achieving greater operational efficacy, impact, and cost-effectiveness from BCC strategies is not specific to agriculture, so research in this area should join broader efforts to strengthen BCC in all aspects of development and food systems improvement.
- **Dimensions of women's empowerment that affect maternal and child nutrition:** Although there is some evidence that women's empowerment positively affects maternal and child nutrition, a lack of clarity remains on which specific dimensions of empowerment affect

which nutrition outcomes. Existing research using the WEAI suggests that different aspects of empowerment matter for different outcomes, and that these also differ according to social and cultural context. One criticism of the WEAI is that its focus on agriculture may miss out on other aspects of empowerment that may be more directly related to nutrition, such as control of nonagricultural income or decision making on nutrition and health inputs. The [Gender, Agriculture, and Assets Project](#), Phase 2, is developing a measure of women's empowerment that agriculture projects can use to track project impact, with specific attention to which dimensions of empowerment matter for nutrition. Research will be needed to test the tool in different contexts and generate evidence on which dimensions of women's empowerment need to be strengthened to improve maternal and child nutrition.

- **Context, food environment, and gender roles:** Another takeaway from the review is the importance of broad contextual and food environment factors that shape the agriculture and nutrition equation. There are useful frameworks to characterize—and indicators to measure—food environments (Global Panel on Agriculture and Food Systems for Nutrition 2016; National Cancer Institute 2017), and researchers need to use them and if possible create typologies of food environment contexts that would require or could accommodate different types of NSA interventions. Similarly, gender roles are culture and context specific, making it difficult to generalize the possible impacts of women's empowerment interventions, because they will vary depending on existing gender norms. As more evidence is accumulated from evaluations in different contexts, it may be possible to create typologies of how gender roles interact with NSA interventions.
- **The role of markets and nutrition-sensitive market interventions:** The association literature showed the consistent and large modifying effect of market access on agriculture's impact on nutrition outcomes, especially access to and consumption of diverse diets. This finding has clear implications for continued work on market development, which in and of itself would likely improve diets among poor households living in remote areas. Another implication is that markets could be leveraged to become more nutrition sensitive and provide a source of information about nutrient-rich foods, healthy diets, and meal planning, further impacting diets and nutrition. This approach, which has been used at a small scale for traditional value chains (Hawkes and Ruel 2011), would need to identify and involve all market actors and institutions to work toward the common goal of improving access to, affordability of, information about, and demand for nutritious and diverse diets. More research on how different types of markets can support improvements in diets and nutrition is needed. Research is also needed to test effective interventions to support increased production diversity and nutrition knowledge (through targeted BCC) in communities where access to markets continues to be limited.
- **Unintended negative impacts of agriculture programs on nutrition:** The two main types of potentially negative consequences of agriculture documented in the set of studies reviewed include impacts on women's time for child feeding and care, and the health and nutrition risks associated with exposure to livestock and chicken feces, especially for young children. More research is needed to document the importance, nature, and consequences of these risks, and to design and test effective measures to mitigate them. The development of time- and labor-saving tools and machinery to reduce drudgery, particularly for women, has been proposed to address constraints on women's time, but research is needed to assess the extent to which such tools actually benefit women, rather than deprive them of income-earning opportunities in situations in which they are unable to control the use of these tools (Johnson et al. 2016).

5. CONCLUDING REMARKS

New evidence from rigorous impact evaluations confirms that NSA programs improve a variety of nutrition outcomes in both mothers and children, especially when these programs include nutrition and health BCC and carefully designed interventions to empower women. Greater benefits for child nutrition outcomes (for example, dietary diversity, nutrient intakes, Hb/anemia, diarrhea, and WHZs) are achieved when programs also incorporate actions to improve health and WASH practices and to provide specially formulated fortified products to address children's high nutrient requirements in areas where access to nutrient-rich foods is limited. Impacts on stunting, however, have not yet been documented, in spite of renewed efforts to strengthen NSA programs' design, scope, implementation, and evaluation. We conclude that loading NSA programs with multiple interventions that address a large number of direct and underlying determinants of child nutrition (for example, income; food availability and access; micronutrient adequacy; gender equity; and nutrition, health, and hygiene knowledge, practices, and use of services) is effective in improving several nutrition outcomes, but is insufficient to achieve stunting impacts in the usual two- to four-year time frame used for impact assessments. We question whether a high quality of operations, implementation, and monitoring can be maintained for such complex, multisectoral programs, and whether successful scale-up is achievable. Given these constraints, we join the emerging consensus on the need for agriculture to focus on supporting access to and consumption of high-quality diets rather than on directly reducing childhood stunting. Improving diets for all household members is a much more logical, reasonable, and achievable goal for agriculture than addressing childhood stunting, and it is equally important for global development (Global Panel on Agriculture and Food Systems for Nutrition 2016; Herforth and Ballard 2016). Our review shows that NSA programs consistently improve household access to nutritious foods and the quality of mothers' and young children's diets. Although this has not yet been tested, it is likely that NSA programs can convey similar benefits to other household members, including the nutritionally vulnerable adolescents and elderly. The main implication of this recommendation for NSA programs is that they should continue to be designed

carefully, taking into account the specific context in which they are to be implemented and using formative research to identify the main constraints that limit household and individual access to healthy diets, women's empowerment, and optimal nutrition.

Previous reviews have discussed the issues of complexity and potential overload in relation to NSA programs and other multisectoral, nutrition-sensitive programs, raising the question of “integration” versus “co-location” of interventions (Ruel and Alderman 2013). This question relates to whether it is necessary to *integrate* multiple interventions from different sectors into programs, at the risk of making them overly complex and difficult to implement and scale up with quality, or whether the same impacts could be achieved by *co-locating* or targeting sectoral interventions to the same individuals, households, or communities. A recommendation to “think multisectorally, and act sectorally” (World Bank 2013, 33) suggests stimulating dialogue across sectors at the planning, monitoring, and review stages, while ensuring that each sector uses its unique expertise to implement (sectorally) with quality and efficiency. This approach should be rigorously tested and compared with integrated programs offering the same set of interventions, using implementation and impact research tools to assess efficiency, effectiveness, and cost-effectiveness.

Another main takeaway from the review is the importance of context in determining how, to what extent, and under what conditions agriculture impacts nutrition. The literature looking at associations between agriculture and nutrition outcomes was particularly useful in highlighting how markets modify production-consumption diversity linkages. In general, production diversity was found to be important for dietary diversity mostly, if not only, among households that have limited access to markets. This led Sibhatu, Krishna, and Qaim (2015) to comment that recommendations to diversify production everywhere are misguided and that supporting commercialization of smallholder farms may be a far more effective strategy to improve nutrition. Several other contextual factors, including women's social status and empowerment; social norms; and socioeconomic, environmental, political, cultural, and food environment factors were identified as key aspects that affect both associations between agriculture and nutrition outcomes and the uptake of, response to, and nutrition impacts of agriculture programs (Fiorella et al.

2016; Herforth and Ballard 2016). The importance of context makes the tailoring of programs and interventions all the more important but greatly complicates the interpretation and generalizability of findings across studies. This complexity, however, needs to be addressed, and it is possible that some typologies of contexts and related decision-making tools could be designed in the future when results from a larger body of evidence are available.

A lot has happened in the area of agriculture and nutrition over the past decade, and the body of evidence—and its quality—have increased exponentially. It will be particularly important in the near future to expand this work to look at issues of sustainability, scale-up, and cost-effectiveness, and to explore how the new body of evidence can help inform broader agriculture policy and investment decisions. With the rich set of ongoing studies, a greater understanding of what agriculture can and cannot do to contribute to nutrition improvements, and a solid commitment to achieving the Sustainable Development Goals, the next 10 years promise to bring new evidence, action, and successes in improving nutrition through agriculture.

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