
Introduction

Without availability and access to a variety of foods, populations in the developing world are suffering from deficiencies in iron, zinc, iodine, vitamin A, and other micronutrients in addition to deficiencies in energy and protein. These deficiencies have far-reaching health consequences, imposing an economic burden and reducing quality of life. Supplementation and fortification programs have demonstrated effectiveness, but there is an increasing interest in potentially more sustainable solutions via agricultural interventions.

This report reviews the available evidence to address five questions:

1. Do diversified diets improve nutritional status and other health outcomes?
2. Can agricultural interventions change production and consumption behavior?
3. What are the pathways from changes in production to changes in diet?
4. Are agricultural interventions cost-effective methods to improve nutrition?
5. What are the constraints to dietary diversification?

The studies presented are culled from peer-reviewed and grey literature which was retrieved with a list of search terms including: smallholder, homestead production, agriculture, developing world, dietary diversity, agricultural diversification, anthropometric indicators, nutritional status, micronutrient intake, micronutrient status, animal-source foods (ASF), cost-effectiveness, fortification, supplementation, disability adjusted life years (DALYS), production diversification, horticulture transition, nutrition transition, nutrition education and several combinations thereof. Existing reviews were mined for sources that were not retrieved in the keyword search.

In total, 125 references are included, 92 of which are from peer-reviewed journals. The remainder are conference proceedings and grey literature (such as CGIAR center reports).

1. What is the evidence that diversified diets improve nutritional status and other health outcomes?

There is a growing body of literature suggesting a link between dietary diversity, improved nutritional status, and reduced risk of disease (Kant et al., 1995; Kant, 1996; Ruel, 2002; Onyango, 2002 and similar). In a survey of 154 rural Kenyan children aged 12-36 months, dietary diversity (as measured by unique food items consumed) was strongly and consistently related to anthropometric status (Onyango et al., 1998). A low dietary diversity score (based on number of food groups consumed; items were recalled by respondents and coded into groups by

NOTE: The findings and conclusions contained within this material are those of the authors and do not necessarily reflect positions or policies of the Bill & Melinda Gates Foundation.

researchers) was correlated with underweight status for a sample of 580 non-pregnant women in rural Burkina Faso, even when controlling for socioeconomic and demographic variables (Savy et al., 2005). The authors note that dietary diversity in their sample is significantly associated with dietary quality and is also significantly associated with anthropometric indicators. These findings provide some evidence for a correlation between diet diversity, diet quality, and health outcomes in the developing world.

Dietary diversity (among five food groups) and overall energy intake were strong indicators of nutrient adequacy among Tehranian women (Mirmiran et al., 2006). The number of unique food items consumed and variety of food groups consumed were indicators of nutrient adequacy among adolescents and adults of both sexes in rural Mali; high scores in the dairy, green leaf, and vegetable groups were particularly important (Torheim et al., 2004). Dietary diversity (measured by 7-9 food groups) was also associated with nutrient adequacy among children in Madagascar and South Africa (Moursi et al., 2008; Steyn et al., 2006).

The correlation between variety of food groups consumed and anthropometric status was *not* observed among urban women in Burkina Faso (Savy et al., 2008). The authors suggest that even low-income women have access to a variety of foods in the urban setting; low dietary diversity scores in the urban group were still higher than the average scores in the rural group. The role of urban-rural status is further complicated by evidence that dietary diversity (as measured by unique food items as well as variety of food groups) was associated with a higher risk of stunting among urban children in Mali (Hatloy et al., 2000) but the same relationship was *not* observed among rural children. The authors note that the dietary diversity in urban households with low socioeconomic status was higher than that of rural households with high socioeconomic status. The accuracy of dietary diversity as a proxy for diet quality may therefore vary by setting. This shortcoming may be partially addressed by using a more detailed measure of dietary diversity in urban evaluations; Savy et al. (2008) found that a measure using 22 food groups (as opposed to 9) was correlated with socioeconomic status and diet quality, though there was still no association with anthropometric indicators.

The urban-rural distinction was also observed among Mexican men (Ponce et al., 2006). Dietary diversity (measured by consumption of 24 food groups) and micronutrient adequacy increased with socioeconomic status of urban subjects, and both were significantly higher among urban poor than among rural poor. In this group, dietary diversity was also associated with consumption of saturated fat and cholesterol. This is likely due to the increased availability and consumption of processed foods in the wake of the “nutrition transition” (Maunder et al., 2001; Haddad, 2003). Access to processed foods can increase the number of food items consumed without improving nutritional outcomes.

Belanger and Johns (2008) suggest that health benefits of dietary diversity go beyond those of simple nutrient adequacy. This is likely due in part to the improved bioavailability of micronutrients when consumed in combination. For instance, in developing countries where availability of easily absorbed animal-source iron is low, vitamin C becomes especially important to mediate iron absorption (Seshadri et al., 1985; Tontisirin et al., 2002). In the developing world, plant sources provide most vitamin A (Tontisirin et al., 2002) but bioavailability of vitamin A and other micronutrients from animal-source foods is thought to be higher than that of plant sources (Castenmiller & West, 1998; Murphy & Allen, 2003). Additionally, Golden (1991) found that monotonous diets can exacerbate malnutrition by diminishing appetites already suppressed by physiological nutrient deficiencies.

Reviews of the literature indicate a strong positive association between intake of animal source foods and nutrient adequacy, particularly energy intake, iron, and vitamin A (Allen, 2003). With some exceptions, livestock interventions are associated with increased energy and/or micronutrient intake (Leroy & Frongillo, 2007). Meat

consumption in particular has been linked to increased physical activity and improved anthropometric outcomes among school-age children in Kenya (Neumann et al., 2007).

As with any nutritional variable, the positive impacts of dietary diversity will be mediated by other health-related factors such as infection, parasitic status, access to clean water, and access to health care services. Among young children in India, for example, diarrhoeal episodes were a predictor of nutrition status (Devi & Geervani, 1994) and diarrhoeal and malarial episodes were a predictor of nutritional status among young children in Tanzania (Mbago & Namfua, 1992).

2. Is there evidence that agricultural interventions can change production and consumption behavior?

Though the literature suggests that agricultural interventions can address the access and availability constraints that may limit more diversified diets, it is difficult to draw concrete conclusions about behavioral change. Bonnard (1999) notes that while agricultural interventions have the potential to help achieve desired nutritional outcomes, those outcomes are potentially mediated by other factors such as how food and resources are allocated within the household or access to sanitation services.

Because many agricultural interventions are highly complex, involve both social and physical factors that can be locally specific (such as agroecological zone and farmer knowledge) and have additional objectives such as improved yields, randomized evaluation methods are extremely expensive and have limited external validity. Quasi-experimental methods also suffer from a (1) lack of baseline data; (2) lack of suitable controls; and (3) the inability to determine potentially inherent differences between adopters and non-adopters in cases where non-adopters are used as a control group. Evaluation goals may sometimes conflict with program objectives. For instance, a recent study of orange-fleshed sweet potato (OFSP) adoption actively discouraged dissemination in order to maintain the integrity of controls (HarvestPlus draft, preliminary results).

Despite the obstacles to rigorous evaluation, there is a large and growing body of literature which, taken as a whole, provides clear indications that agricultural interventions can have a strong and positive effect on nutritional status. Unless otherwise noted, the results included in the following section are all significant (at $p < 0.05$) relative to the control group used. In the 42 cited studies reporting primary evaluation data, the most common outcome variable is consumption of the target food or nutrient (26/44 studies, plus an additional 10/44 studies in which consumption is an independent variable). A handful of studies include anthropometric (13/44), clinical (8/44) or production (10/44) variables as well. The distribution of outcome variables is partly reflective of study aims; interventions in the agricultural tradition are more likely to focus on production, while interventions based in nutrition are more likely to analyze clinical, anthropometric, or consumption variables. The most common research design is a cross-sectional sample at a single time point (24/44). For studies collecting data at multiple time points, the evaluation period varies from 1 week to 3 years, with the exception of two long-range studies that use population data rather than an intervention-specific sample (Hop, 2003; Smitasiri & Chotiboriboon, 2003). Sample sizes are indicated for some studies to provide a sense of the scale of these evaluations.

Broad lessons

The interventions with the most robust evidence of success are multi-platform, combining agricultural training and inputs with food preparation and nutrition education (Harris, 1991; Ruel & Levin, 2000; Berti et al., 2004). The addition of a marketing component can support project effectiveness and sustainability if it is sensitive to the community context. Marketing efforts that do not account for local differences in yield, market development, and

market accessibility may be unsuccessful or may cause households to sell the new crop production rather than consuming it (Yorgey, 2008 citing Low, 2007).

Tontisirin et al. (2002; 1999) find that community-based approaches are the most successful in modifying behaviors and diversifying diets. Involving community members in the planning, implementation, monitoring and evaluation processes may improve compliance and nutritional outcomes, particularly if influential community members such as healers are involved (Loevinsohn & Gillespie, 2003; Tontisirin & Gillespie, 2002).

Gender issues are important, particularly because the nutritional status of nursing mothers will have direct effects on the nutritional status of their children. Smallholder-targeted interventions have had varying effects on women in the treatment population. Local norms for a crop production system are an important determinant of the ultimate outcomes for women, particularly in cases where a target crop is traditionally managed by one gender. However, there are documented cases in which income from a formerly “women’s” crop is taken over by men following successful agricultural interventions (Dolan, 2002). In these cases, women may retain the burden of labor and its attendant caloric needs even as their ability to meet those needs through crop income is reduced. The World Bank (2007) presents a case in which program designers in Togo addressed that issue by marketing soy as a legume (traditionally female production) rather than as a cash crop (traditionally male production). The success of that approach can provide useful lessons for future interventions.

An educational component is necessary but not always sufficient

Ruel and Levin (2000) note that early interventions often omitted education and communication components, and nutrition outcomes (self-reported dietary diversity and anthropometric indicators) were generally not improved. More recent programs, particularly in South Asia, have integrated educational and communication strategies with more success (Marsh, 1998; English & Badcock, 1998; Hagenimana et al., 1999, Talukder, 2010). Education alone is most suitable when food sources are available but underutilized; in areas of food scarcity, education interventions are not as likely to succeed without a food-based component (Harris, 1991). For instance, in areas where iron deficiency is prevalent because of food scarcity, encouraging increased vitamin C intake through local foods may not be adequate (Allen & Gillespie, 2001).

In studies that target nutritional outcomes, education-only interventions are focused on nutrition education rather than agricultural training and education. Agricultural education on its own (without accompanying access to inputs or other services) has not been analyzed in terms of nutritional outcomes. However, several nutritionally focused education-only programs have been implemented with apparent success in improving a range of nutrition and behavioral outcomes. In nine published studies reporting primary data evaluating education-only programs, there were no reports of intervention failure. However, the statistical rigor of the evaluations varies greatly, and there is a possibility that evaluations reporting success are more likely to be available in the published literature.

In Indonesia, the percentage of mothers and children consuming at least one egg per week increased from 80% to 92% following a social marketing campaign to promote eggs and dark-green leafy vegetables (de Pee et al., 1998). The increase was independent of SES or chicken ownership, and most of the consumed eggs had been purchased. During the same time frame, the average consumption of vegetables increased by approximately 20%, from 93 to 111 grams per person daily. Serum retinol levels also increased. In Malawi, a dietary diversity education program increased dietary diversity, diet quality, and anthropometric measures among children in intervention groups relative to control groups (Gibson et al., 2003).

Education about the health benefits of animal source foods (ASF) led to increased ASF consumption following interventions in Peru and Thailand (Creed-Kanashiro, 2003; Smitasiri, 2003). Nutrition education programs in Peru reduced stunting in infants (Waters et al., 2006) and increased length and weight gain in infants and toddlers (Penny et al., 2005). Educational programs also increased infant length and weight in China (Gulden et al., 2000, cited in World Bank, 2007), increased child weight in Bangladesh (Roy et al., 2005) and increased the mean energy intake of infants in Bangladesh (Kimmons et al., 2004).

In the Bangladesh program (Roy et al., 2005), a portion of the treatment group also received a food supplement; weight gain was greater in the food-plus-education group than in the education group alone. An 18-month longitudinal study in India found that a food-plus-education group had greater weight and length increases than the education-only group and the control group. The education-only group did demonstrate greater weight gain than did the control group (Bhandari et al., 2001). Allen (2003) interprets these results as an indicator that in food-scarce areas, interventions that provide food along with education are likely to be more effective than those that provide education alone.

The long-term efficacy of these programs is largely unstudied, though a longitudinal study in Bangladesh found that increases in nutritional knowledge remained steady three years after a vitamin-A-focused educational intervention. No increase in the consumption of vitamin-A rich foods was observed (Hussain & Kvale, 1996). Incomes in the study region had decreased in the years following the intervention and the resulting economic constraints may have affected consumption habits, but the lack of a control group hampers interpretation of the results.

Integrated interventions such as Homestead Food Production have been widely successful

Many of the most-cited case studies come from Helen Keller International's homestead food production program (HFP) in Bangladesh, Cambodia, Nepal, and the Philippines (Talukder et al., 2010; Bushamuka et al., 2005). The intervention includes homestead gardening and livestock extension services and inputs, as well as nutrition education through local NGO partnerships. Agents establish Village Model Farms (VMFs) in target communities; VMFs serve as a source for inputs (both plant and animal) and training. The VMF owner also coordinates a women's producer/farmer support group, linking them to services as well as markets.

Talukder et al. (2010) report that households in HFP intervention villages were significantly more likely to have adopted improved gardening practices. Among these households, vegetable production volume and number of varieties increased threefold and fourfold relative to the baseline average, and both were positively correlated with increased vegetable consumption for children in the household. Children in households with traditional gardening practices consumed an average of four types of vegetables, while children in households with developed gardens consumed an average of thirteen vegetable varieties. There were also significant increases in household egg consumption relative to baseline (N=720). Bushamuka et al. (2005) found that improvements in income and production were still observable among formerly participating households three years after the withdrawal of program support, suggesting that the integrated intervention is at least partially sustainable.

Serum hemoglobin data were collected for a subset of the HFP sample. Among children aged 6-59 months, significant decreases in anemia were observed in Bangladesh and the Philippines and non-significant decreases were observed in Cambodia and Nepal. Among non-pregnant mothers of children aged 6-59 months, anemia prevalence decreased significantly in Nepal and Bangladesh but remained constant in Cambodia. Anthropometric data were collected but not reported (Talukder et al., 2010).

Faber et al. (2002) describe a home-gardening and vitamin A education program reaching 126 households in South Africa. The authors observed significantly increased serum retinol in 2-5 year old children at endline (20 months) in the intervention village as compared to baseline (n=110); endline levels were significantly higher than those in the neighboring control village (n=111). Within the intervention village, endline serum retinol was significantly higher for children from households with a project garden than for children from households without a garden; serum retinol in households with no garden was similar to levels in the control village. Maternal knowledge about vitamin A also improved significantly. No change was observed in anthropometric indicators.

In Tanzania, an education and seed distribution program was associated with improved knowledge and practices in the experimental area, as well as increased consumption of vitamin-A rich foods (Kidala et al., 2000). Sixty-five per cent of the children in the experimental area consumed vitamin A-rich foods more than 7 times a week, compared to 37% of children in the control area (n=236). However, lower serum retinol levels were observed in the experimental area than in the control area. The authors suggest that a helminth infestation in the treatment area may have confounded the results; when the analysis controlled for helminth status, there was no significant difference in serum retinol levels between the treatment and control groups. Interpretation of the results is further complicated by a five-year delay between the intervention period and the evaluation. There was unfortunately no published analysis conducted during or immediately following the intervention.

An intervention in India provided inputs, nutrition education, and agricultural training to 1500 households in 30 villages in order to encourage home gardening of vitamin-A rich foods (Chakravarty, 2000). At endline, the percent of households consuming green leafy vegetables three or more times per week had increased substantially; from 15-20% of households at baseline to 40-50% of households at endline. The average daily intake of greens and fruits increased by 15 and 7.5 grams, respectively. The study design did not include control areas or statistical analysis of the results.

An intervention in Bangladesh included a community educational component as well as the provision of seeds. The authors documented increases in vegetable production, vegetable consumption, and nutrition knowledge among mothers in the treatment area (Greiner & Mitra, 1995). Assigning the consumption changes to the intervention is difficult due to two factors: first, a drop in the price of rice during the study period; second, a high likelihood that the neighboring control village had been affected by diffusion of the intervention. Statistical analysis of the intervention's effectiveness was therefore limited.

Another Bangladesh intervention (Bhattacharjee et al., 2007) reached adolescent girls through school-based gardens and nutrition and agriculture education. The project demonstrated improved knowledge among the girls, though their ability to put their knowledge into practice was limited by their low status within the household. Micronutrient intakes and frequency of fruit and vegetable consumption were significantly higher among women, girls, children and infants in project households; since some of that increase may have been due to consumption of produce from the school garden, it is difficult to know how much to attribute to changes in home production and consumption.

Evaluation of HKI's Cambodia program found that households in the intervention group were more likely than control households to earn income from home gardening activities. However, this relationship was also observed at baseline (Olney et al., 2008). In India, 40% of the households participating in an HFP program in India sold 10 to 25% of the produce from their gardens (Chakravarty, 2000); production-for-income was common even though this intervention did not include a market development component.

Livestock interventions have some demonstrated success

It has been suggested that interventions to promote ASF are not appropriate in low-SES settings (Yip, 1997) but existing reviews of the literature support the efficacy of livestock-based interventions (Leroy & Frongillo, 2007; Allen, 2003). A poultry intervention in Bangladesh (Nielsen, 2003) did not result in increased consumption of poultry or eggs, but women and girls in intervention households did report increased consumption of fish (n=70). An early intervention in Egypt was associated with higher protein intakes, ASF intake, and iron consumption among participating households as compared to non-participating households; there was also a drop in anemia prevalence among school-aged children from participating households (Galal et al., 1987).

An early dairy intervention found decreased milk consumption in villages with dairy cooperatives, but increased energy and protein consumption in households owning dairy cows; the author hypothesizes that the change is due to income effects (Alderman, 1987). Adopters of an improved dairy production intervention in Ethiopia consumed more energy, fat, protein, retinol and iron at the household level than did the non-adopters (n=56), and their income was 72% higher (Tangka et al., 2002). Intensive dairy production in Kenya raised household incomes and food expenditures (Mullins et al., 1996).

The VAC program in Vietnam is a longstanding initiative to encourage gardening, aquaculture, and animal husbandry through a variety of direct and indirect approaches. While a causal link to increased consumption cannot be firmly drawn, the program has been credited with increased ASF production (Hop, 2003).

Macro-level factors influencing diversification trends

A framework put forth by the Asian Productivity Association (2004) suggests that there are four factors that can influence the move towards agricultural diversification at the country level: (1) investments in research and development; (2) provision of adequate infrastructure; (3) removal of non-trade barriers and (4) provision of relevant technology and knowledge. Pingali & Rosegrant (1995) put forth a similar framework, suggesting that investment in infrastructure, research and development, land rights, and market liberalization can encourage diversification and alleviate short-term equity and environmental consequences. The focus in this context is diversification for economic growth rather than for nutrition per se.

In the Kurekshetra district of India, increased road density and urbanization at the district level was associated with commercialization; commercialization was associated with farm-level specification and regional diversification (Jha et al., 2009). GIS analysis at the country level yielded similar results; urbanized districts with good road connections to urban centers were the most likely to diversify towards high-value commodities (Rao et al., 2004).

There is little recent work analyzing agricultural diversification in Africa at the macro-level. Delgado (1995) suggests that policies focused on increasing supply-side responsiveness may promote diversification, but there has been little empirical work addressing the question. Diversification for own-consumption has not been well studied at the macro level.

3. What are the pathways from changes in on-farm production to changes in diet?

While there is good evidence for the efficacy of agricultural interventions, there is very little empirical research addressing the mechanisms by which those interventions achieve improved outcomes. The World Bank (2007) describes two direct pathways to impact as (1) production for own consumption; and (2) production for sale and increased income. The report also notes that successful agricultural interventions can have an impact by improving the economic and social status of women, reducing real food prices or improving the overall economic health of a region.

Outside of homestead and livestock interventions, there is a dearth of information about the tradeoff between production for income or for own-consumption. There has been some analysis of the effects of commercialization initiatives on nutrition, but the majority of those studies focused on changes in overall energy intake rather than micronutrient adequacy (DeWalt, 1993; Kennedy et al., 1992; von Braun and Kennedy, 1994; cited in World Bank, 2007). Still, it is useful to note that in the reviewed interventions increased levels of focus crop production were generally associated with increased food expenditures and sometimes increased caloric intake; this correlation provides some evidence for the functionality of the production-for-income pathway. However, the authors of one review also note one case of negative impacts on consumption when subsistence production was not maintained, presumably because of reduced availability of own-produced food staples (DeWalt, 1993).

Production for income

Onyango (2002) suggests thinking of income as an intermediary variable; it is dependent on socioeconomic status but it is also a predictor for nutritional outcomes. There is controversy about the effect of income on diet (Bouis & Haddad, 1992). Improved income in the absence of education will not necessarily lead to improved diets, particularly in areas facing a transition away from traditional diets (Haddad, 2003; Pingali, 2004; Hawkes, 2007). With the increased availability of packaged foods that are apparently diverse but nutritionally similar, there are calls to communicate that apparent diversity may not be nutritional diversity (Maunder, 2001).

HKI's interventions in South Asia (Talukder, 2010) provide some insight into these pathways for home gardeners; compared to control households, intervention households produced higher volumes and more varieties of vegetables. Children in these households saw a corresponding increase in vegetable consumption. In addition, household income increased as a result of sales from production, and the majority of the extra income was used to purchase additional food for the household. Conclusions about pathways are, however, limited—while this intervention demonstrated increases in production, income, and self-reported consumption, it is unclear what portion of the consumption increase resulted from own-production and what portion resulted from purchased food.

It is also important to note that HFP programs often target women. Three-quarters of the gardens in HKI's sample were managed by women (Talukder et al., 2010). In addition, the authors suggest that women were the likely decision-makers regarding income earned from HFP activities. Little information is available about the effects of increased income from horticulture in the absence of female-targeted efforts.

Livestock interventions in Bangladesh and India (Nielsen et al., 2003; Alderman, 1987) resulted in improved animal-source food consumption even without increases in consumption of own-produced food. These findings could support the idea of impact through the production-for-income pathway. Other interventions could also be working through that pathway, but the overlap between types of food produced and reported consumption makes it difficult to assess those relationships.

Own-consumption.

Preliminary results of the HarvestPlus OFSP project in Uganda and Mozambique indicate that the intervention was successful in increasing OFSP production, and that the majority of that production went towards household consumption rather than to the market (HarvestPlus draft, 2010). The authors did not report whether or not the intervention had an effect on the income of the adopting households. The authors found that households producing OFSP do express interest in selling some portion of their crop; they hypothesize that as the demand for

OFSP and the access to markets increases, the risk involved in devoting resources towards OFSP production will be reduced and production-for-income will increase.

Zeza and Tasciotti (2008) use dietary diversity as a proxy for food security in a survey of developing countries in Latin America, South Asia, and Sub-Saharan Africa. Their measure of diversity is based on 14 food groups. They find that participation in urban agriculture is associated with improved dietary diversity in 10 of the 15 countries studied; the authors suggest that the majority (75-85%) of urban agriculturists are producing for own consumption, but they do not directly test any causal hypotheses.

4. Are agricultural interventions cost-effective in comparison to other nutrition interventions?

Cost-benefit analyses in the literature are overwhelmingly targeted towards fortification, bio-fortification, and supplementation programs (Baltussen et al., 2004; World Bank, 1994). Estimates of benefit-cost ratios for supplementation and fortification programs range from 20-70 (Horton, 2008; Bouis, 1999; World Bank, 1994). However, successful supplementation programs depend on access to target populations—no small consideration in many of the poorest regions—as well as a continued investment throughout the life of the program. In addition, there is no potential for the magnification of benefits through the process of dissemination. In contrast, agricultural interventions can in theory sustain themselves, and their impact can be magnified as new crops are propagated and agricultural knowledge spreads throughout communities (Harris, 1991, Bouis, 1999, HarvestPlus draft, 2010).

Ethical and practical considerations have favored cost-effectiveness measures over benefit cost analysis in health interventions. Yet there is very little information about the cost-effectiveness of agricultural interventions from a nutrition standpoint. Bonnard (1999) notes that agricultural interventions are often evaluated in terms of their economic outcomes rather than their health outcomes; it is assumed that increased production will result in increased consumption. While this may be a reasonable assumption in some cases, it is an obstacle to useful comparisons between agricultural interventions and other approaches. There are questions about the validity of a cost-effectiveness measure in assessing the value of an agricultural intervention; it is difficult to accurately capture all of the benefits and costs associated with the changes in income, health, and poverty status that may result from agriculture focused projects (Levin, 2010, personal correspondence). Rouse (2002) points to similar limitations to adequately representing the health and economic contributions of mothers in DALY analyses (Rouse, 2003).

Cost-effectiveness will also vary widely even between similar programs. Fiedler (2007) points out that for vitamin A supplementation programs, the cost of the supplement itself averages only 6% of program costs. Variability in costs of personnel, level of access, environmental factors, and basic structure of a program can therefore have significant effects on even the most straightforward interventions. Local settings will determine whether program components can be added on at marginal cost or whether significant investments in training and infrastructure are required (Horton, 1999).

In a preliminary analysis of the HarvestPlus OFSP program in Uganda and Mozambique (HarvestPlus draft, 2010) the authors estimated a cost of \$15-20 per DALY saved. They note that the effectiveness of the program was not compromised by shortening the duration of the intensive engagement to one year rather than two; they also suggest that diffusion (discouraged during the study period to maintain the integrity of controls) will allow the benefits to accrue across a broader population.

A cost-effectiveness analysis of three vitamin A interventions in Guatemala found the cost per high-risk person achieving adequate vitamin A to be \$0.98 for sugar fortification, \$1.68-1.86 for capsule distribution and \$3.10-4.16 for food production and education interventions (Phillips et al., 1996). One study (Edejer et al., 2005) ranks

fortification as the most cost-effective (\$19 per DALY averted) and supplementary food and nutrition education as the least cost-effective (\$130 per DALY averted; calculated as an addition to other interventions). An analysis of unit costs for nutrition investments in Asia (Horton, 1999) estimates that fortification costs less than \$0.15 per beneficiary per year, supplementation costs up to \$1.70 per beneficiary per year, and gardening and nutrition programs cost \$2.00-\$10.00 per beneficiary per year (costs vary widely by program design). A more recent analysis (Horton et al., 2010) uses the 36 countries with the highest burden of under nutrition as the target population, estimating supplementation costs at \$1.20 per child for vitamin A supplementation; \$1 per child for zinc supplementation; \$3.60 per child for additional micronutrient powders; \$2.00 per pregnancy for iron-folic acid supplementation during pregnancy; \$0.20 per person for iron fortification of staple foods; and \$0.05 per person for salt iodization.

As noted earlier, the most effective agricultural interventions include a nutrition education component. It is difficult to find estimates of the costs and benefits of nutrition education, but a facility-based nutrition education program in Peru reduced stunting in infants at a marginal cost of \$6.12 per child reached, \$55.16 per case of stunting prevented, and an estimated cost of \$1952 per death averted (Waters et al., 2006).

As a comparison, cooking in iron pots has received attention as a strategy to reduce anemia and a potential component of educational efforts. There is evidence that iron pot cooking can increase in blood iron stores (Borigato & Martínez, 1998; Adish et al., 1999). In one study, the cost of providing iron pots was \$5,000 for a population of 10,000 in Ethiopia. This compares to estimated costs of \$8,000-\$12,000 to supplement a similar population (Ruel & Levin, 2000). However, one study found that iron pot cooking is significantly less effective than supplementation in raising serum ferritin levels (Sharieff et al., 2007), and it is therefore difficult to make true comparisons of cost-effectiveness.

Agricultural interventions through indirect pathways are potentially cost-effective as well. Babu (2000) suggests that attempts to identify, document, and encourage the utilization of nutrient-rich indigenous plants could be a cost-effective and sustainable method of improving the nutritional status of local populations. The call for biodiversity initiatives is echoed elsewhere in the literature (Wispelwey & Deckelbaum, 2010; Belanger & Johns, 2008; Johns & Sthapit, 2004).

Finally, there have been estimates of high benefit-cost ratios of bio-fortification research (Bouis, 1999) particularly fortification of crops with an established demand and market structure. Bio-fortification can improve dietary diversity if it introduces rather than replaces food items, and fortified varieties can improve nutritional status within a relatively short timeframe even in the absence of increased dietary diversity (Stein, 2007).

5. What are the constraints to dietary diversification?

Limits to increasing dietary diversity are often attributed to an inadequate consumer understanding of the food-health links, along with limited access to a range of affordable foods or seeds (Gruere et al., 2009 in Bioversity, 2010). In harsh growing conditions, where few crops are reliably supported, the ability to purchase a variety of food is often limited along with the ability to produce it. Even where markets are available, their limited offerings generally reflect local constraints. Rural markets in these areas may be characterized by poor infrastructure, especially access roads and storage options, and they may be stocked by sellers – often local farmers or traders – who supply only the limited seeds and crops known to grow in the region (Lipper et al., 2010). When nutritionally diverse foods are available in rural markets, they may be expensive, their benefits may be unknown, or they may not be adapted for local production conditions.

Anticipated decreases in biodiversity throughout SSA may reduce pathways to dietary diversification; a decline in variety of plant species consumed may increase micronutrient deficiencies among groups formerly dependent on traditional foods (Johns & Eyzaguirre, 2007; Kennedy et al., 2003; Belanger & Johns, 2008). Traditional and small-scale agriculture draws on locally important plant species (Johns & Eyzaguirre, 2007; Grivetti & Ogle, 2000; Belanger & Johns, 2008) as an important source for dietary diversity. Though staple foods are an important part of many traditional food systems, traditional diets have been supplemented with wild-source small animals such as birds and insects (Johns & Sthapit, 2004) and some traditional varieties of rice show higher micronutrient levels than their high-yield counterparts (Kennedy et al., 2003).

Nutritional surveys have a tendency to overlook the contribution of wild and local foods (Grivetti & Ogle, 2000; Kennedy et al., 2005), perhaps because they are sometimes seen as low-status foods within communities (Bonnard, 1999; Gopalan & Tamber, 2003). Those perceptions can be a barrier to cultivation and consumption of nutrient-dense vegetables. However, education efforts can break down the stigma against those foods, potentially changing consumption behavior (Bonnard, 1999; Gopalan & Tamber, 2003). The role of education in this particular type of behavior change has not been well-studied, but Babu (2000) found evidence that an intervention centered around moringa (drumstick) leaves could be successful. Moringa has been traditionally considered a “crisis” food, but after training by extension staff Malawians demonstrated a willingness to cook and eat moringa in place of more expensive alternatives such as pumpkin leaves (Babu & Chale, 1994).

Logistical barriers can be important. In Bangladesh (Bhattacharjee, 2007) school principals who declined to set up a demonstration garden cited a lack of boundary wall, lack of funds, and lack of protection from pests and animals as constraints to participation. Adolescent girls who participated in that program cited lack of decision-making power within the home as a constraint to setting up their own garden or otherwise applying the nutrition information learned at the school. Livestock interventions may face barriers from religious doctrine or inequitable intra-household allocation patterns but these barriers can sometimes be addressed through educational initiatives (Allen, 2003).

In the agriculture-for-nutrition context, there has been very little analysis of treatment effects on women’s time and labor. Leroy et al. (2008) note that changes in women’s time could have important consequences, both for their nutritional needs and the nutritional and caretaking needs of their children.

Other constraints to on-farm production may mirror constraints to technology adoption and on-farm change in general. Market access, drainage, and irrigation are constraints to diversification in South Asia (Joshi et al., 2007). Low market access is hypothesized to increase production for own-consumption as a risk-management and food-security strategy (Biol et al., 2006). Reardon et al. (2010) find that increased market access may be associated with increased dietary diversity, particularly with urbanization and access to supermarkets; the authors note that consumers express a clear preference for supermarket shopping over more traditional markets, choosing supermarkets even when other options are available. They do not speculate on the nutritional effects of these changed shopping patterns. On the production side, lack of income, assets, or credit access can constrain farmers considering a change (Kebede, 1990; Qaim, 2005; Feder, 1993; Lee, 2005). Households with low market and credit access are less likely to adopt new technologies or make a change to cash-cropping (Zeller et al., 1997; Yusef & Kohlin, 2004; Kayizzi-Mugerwa, 2008). Lack of assets or credit access are also closely tied to risk tolerance; households with low credit access are less able to bear high variability. Low credit access also contributes to high present discount rates by reducing a household’s ability to smooth consumption (Yusef & Kohlin, 2004).

Conclusion

There is a strong sentiment that agricultural interventions can improve dietary diversity, and that dietary diversity can improve nutrition and related health outcomes. The programs with demonstrated ability to improve nutrition outcomes are most often cross-cutting interventions, borrowing from the agriculture, nutrition, and public health traditions. While these multi-platform programs can be costly to evaluate and difficult to implement, the evidence supports their potential to create sustainable quality-of-life improvements in target regions.

The pathways by which agricultural interventions achieve impact are not fully clear. There is evidence that production for own-consumption and production for income are both important, often within the same community or even the same household.

Constraints to dietary and on-farm diversification are highly variable, but lack of access and potentially diminishing biodiversity are recurring themes in the nutrition literature. Constraints to on-farm diversification may mirror constraints to production changes in general; examples include market access, credit access, and suitable planting materials for harsh local agro-ecological conditions.

The greatest knowledge gaps are directly related to the lack of integration between program design and evaluation. Many evaluations are based on small sample sizes, lack control groups or baseline data, are subject to selection bias, or face other challenges to rigorous statistical analysis. Long-term follow-ups are uncommon, and conclusions about the sustainability of different programs are therefore difficult to support empirically. There is also a dearth of information about cost-effectiveness. The difficulty of assigning costs and benefits is exacerbated by the scarcity of good experimental data, as well as by the variation in studied outcomes.

As noted in the 2007 World Bank report, there is a need for more data around the effects of agricultural and nutritional interventions on women's time. Interventions may have negative effects if they increase women's time or labor inputs without increasing energy intake or dietary quality. In addition, it appears there may be different pathways to improved health outcomes in the urban versus rural settings, but the differences are not well characterized.

Finally, there is little individual- or household-level information about the constraints to diversification in particular, the constraints to on-farm change in general, and how those constraints may vary by household- or farm-level characteristics. Increased attention to evaluating the agricultural component of complex food and health programs may help address all of the issues raised above.

On a broader scale, there is a need for large-scale data addressing overall patterns of production diversification, consumption patterns, and nutrient adequacy. There is a body of literature addressing the importance of the nutrition transition in the context of urbanization (Pingali, 2004; Haddad, 2003), but there is room for similar work addressing macro-level constraints, transitions, and patterns in the rural context as well as in relation to other health indicators such as access to clean water and health services.

Please direct comments or questions about this research to Leigh Anderson, at eparx@u.washington.edu.

Works Cited

- Adish, A., Esrey, S., Gyorkos, T., Jean-Baptiste, J. & Rojhani, A. (1999). Effect of consumption of food cooked in iron pots on iron status and growth of young children: A randomized trial. *The Lancet*, 353(9154): 712-176.
- Alderman, H. (1987). Cooperative Dairy Development in Karnata, India: An Assessment. Research Report No. 64, International Food Policy Research Institute, Washington, D. C.
- Allen, L. (2003). Interventions for Micronutrient Deficiency Control in Developing Countries: Past, Present and Future. *Journal of Nutrition*, 133(Suppl.):3875-3878.
- Allen, L. & Gillespie, R. (2001) What works? A review of the efficacy and effectiveness of nutrition interventions. United Nations Administrative Committee on Coordination, Sub-Committee on Nutrition, Geneva in collaboration with the Asian Development Bank, Manila.
- Asian Productivity Organization (2004). Agricultural Commercialization and International Competitiveness. Report of the APO Study Meeting on Agricultural Diversification and International Competitiveness, Tokyo, 16–23 May 2001.
- Ayalew, W., Wolde, G., & Kassa, H. (1999). Reducing vitamin A deficiency in Ethiopia: Linkages with a women-focused dairy goat farming project. *Opportunities for Micronutrients Interventions, Research Report Series No. 4*, International Center for Research on Women, Washington D.C.
- Babu, S. (2000). Rural nutrition interventions with indigenous plant foods – a case study of vitamin A deficiency in Malawi. International Food Policy Research Institute. Washington, DC.
- Babu SC., Chale B. (1994). Indigenous vegetables for rural nutrition: An evaluation of Moringa in Salima. BUNDA/IFPRI Working Paper No. 6. Bunda College of Agriculture, Lilongwe.
- Baltussen, R., Knai, C. & Sharan, M. (2004). Iron Fortification and Iron Supplementation are Cost-Effective Interventions to Reduce Iron Deficiency in Four Subregions of the World. *Journal of Nutrition* (134): 2678–2684.
- Belanger, J., & Johns, T. (2008). Biological diversity, dietary diversity, and eye health in developing country populations: Establishing the evidence base. *EcoHealth* (5): 244-256.
- Berti, P., Krasevec, J. & FitzGerald, S. A review of the effectiveness of agriculture interventions in improving nutrition outcomes. *Public Health Nutrition*, 7(5): 599-609.
- Bhandari N., Mazumder S., Bahl R., Martinez J., Black R. & Bhan M. (2004) An educational intervention to promote appropriate complementary feeding practices and physical growth in infants and young children in rural Haryana, India. *Journal of Nutrition*, 134: 2342–2348.
- Bhattacharjee, L., Saha, S. & Nandi, B. (2007). Food-based nutrition strategies in Bangladesh: Experience of integrated horticulture and nutrition development. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific. Bangkok.
- Bioversity International (2010). The effects of market integration on the nutritional contributions of traditional foods to the wellbeing of the rural poor in Africa. Proposal submitted to the Bill and Melinda Gates Foundation.
- Birol, E., Smale, M. & Gyovai, A. (2006). Using a choice experiment to estimate farmers' valuation of agrobiodiversity on Hungarian small farms. *Environmental and Resource Economics*, 34(4): 439-469.
- Bonnard, P. (1999). Increasing the Nutritional Impacts of Agricultural Interventions. Report for the Food and Nutrition Technical Assistance Project, presented at the Greater Horn of Africa Regional Workshop on Agricultural Policy, Resource Access, and Human Nutrition. Addis Ababa, Ethiopia.
- Borigato, E. & Martinez, F. (1998). Iron nutritional status is improved in Brazilian preterm infants fed food cooked in iron pots. *Journal of Nutrition*, 128: 855
- Bouis, H. (1999). Economics of enhanced micronutrient density in food staples. *Field Crops Research*, 60: 165-173.
- Bouis, H. & Haddad, L. (1992). Are estimates of calorie-income elasticities too high? A recalibration of the plausible range. *Journal of Development Economics*, 39(2): 333-364.
- Bouis, H., de la Briere, B., Guitierrez, L., Hallman, K.,

- Hassan, N., Hels, O., Quabili, W., Quisumbing, A., Thilsted, S., et al. (2000). Commercial vegetable and polyculture fish production in Bangladesh: their impacts on income, household resource allocation, and nutrition. Washington, DC: International Food Policy Research Institute.
- Bushamuka VN, de Pee S, Talukder A, Kiess L, Panagides D, Taher A, Bloem M. (2005). Impact of a homestead gardening program on household food security and empowerment of women in Bangladesh. *Food and Nutrition Bulletin* 26(1): 17-25.
- Castenmiller, J. & West, C. (1998). Bioavailability and bioconversion of carotenoids. *Annual Review of Nutrition*, 18:19-38.
- Chakravarty, I. (2000). Food-based strategies to control vitamin A deficiency. *Food and Nutrition Bulletin*, 21:135-43.
- Creed-Kanashiro, H., Bartolini, H., Fukumoto, M., Uribe, T., Robert, R. & Bentley, M. (2003). Formative research to develop a nutrition education intervention to improve dietary iron intake among women and adolescent girls through community kitchens in Lima, Peru. *Journal of Nutrition* 133: 3987-3991.
- de Pee, S., Bloem, M., Satoto, Yip, R., Sukaton, A., Tjiong, R., Shrimpton, R., Muhilal & Kodyat, B. (1998). Impact of a social marketing campaign promoting dark-green leafy vegetables and eggs in central Java, Indonesia. *International Journal of Vitamin and Nutrition Research*, 68: 389-398.
- Delgado, C. (1995). Agricultural diversification and export promotion in sub-Saharan Africa. *Agricultural Commercialization and Diversification*, 20(3): 225-243.
- Devi, P. & Geervani, P. (1994). Determinants of nutrition status of rural preschool children in Andhra Pradesh, India. *Food and Nutrition Bulletin*, 15(4): 335-342.
- DeWalt, K. (1993). Nutrition and the Commercialization of Agriculture: Ten Years Later. *Social Science and Medicine*, 36: 1407-16. Cited in: World Bank (2007). From agriculture to nutrition: Pathways, synergies, and outcomes. The World Bank, Washington, DC.
- Dewey, K. & Adu-Afarweh, S. (2008). Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries. *Maternal and Child Nutrition*, 4: 25-85.
- Dolan, C. (2002). Gender and witchcraft in agrarian transition: The case of Kenyan horticulture. *Development and Change*, 33(4): 659-681.
- Edejer, T., Aikins, M., Black, R., Wolfson, L., Hutubessy, R. & Evans, D. (2005). Cost effectiveness analysis of strategies for child health in developing countries. *British Medical Journal*, epub, doi:10.1136/bmj.38652.550278.7C
- English, R. & Badcock, J. (1998). A community nutrition project in Viet Nam: Effects on child morbidity. *Food, Nutrition, and Agriculture*, 22(15): 15-21.
- Faber, M., Phungula, M., Venter, S., Dhansay, M., Benade, A. (2002). Home gardens focusing on the production of yellow and dark-green leafy vegetables increase the serum retinol concentrations of 2-5-y-old children in South Africa. *American Journal of Clinical Nutrition*, 76: 1048-54.
- Feder, G., & Umali, L. (1993). The adoption of agricultural innovations: A review. *Technological Forecasting and Social Change*, 43(3-4), 215-239.
- Fiedler, J., Sanghvi, T. & Saunders, M. (2007). The costs of micronutrient interventions: Policy issues and interventions. Technical report prepared for A2Z: The USAID Micronutrient and Child Blindness Project. USAID: Washington, DC.
- Galal, O., Harrison, G., Abdou, A., Zein, A. (1987). The impact of a small-scale agricultural intervention on socio-economic and health status. *Food and Nutrition*, 13: 35-43.
- Gibson, R., Yeudall, F., Drost, N., Mtitimuni, B. & Cullinan, T. Experiences of a community-based dietary intervention to enhance micronutrient adequacy of diets low in animal source foods and high in phytate: A case study in rural Malawian children. *Journal of Nutrition* 133: 3992S-3999S, 2003.
- Golden, B. & Golden, M. (1991). Relationships among dietary quality, children's appetites, growth stunting and efficiency of growth in poor populations. *Food and Nutrition Bulletin*, 13(2): 105-109.
- Gopalan, C. & Tamber, B. (2003). Food-based approaches to prevent and control micronutrient malnutrition: Scientific evidence and policy implications. In: Simopolous, A. & Gopalan, C. (Eds). *Plants in Human Health and Nutrition Policy*. World Review of Nutrition and Diet (91): 76-131.

- Greiner, T. & Mitra, S. (1995). Evaluation of the impact of a food-based approach to solving vitamin A deficiency in Bangladesh. *Food and Nutrition Bulletin*, 16:193-205.
- Grivetti, L. & Ogle, B. (2000). Value of traditional foods in meeting macro- and micronutrient needs: the wild plant connection. *Nutrition Research Reviews*, 13(1): 31-46.
- Gruère, G. Giuliani, A. and Smale, M., 2009. Marketing underutilized plant species for the poor. A conceptual framework. In: Kontoleon, A., Pascual, U. and Smale, M. (Eds). In press.
- Guldan G., Fan H., Ma X., Ni Z., Xiang X. & Tang M. (2000) Culturally appropriate nutrition education improves infant feeding and growth in rural Sichuan, China. *Journal of Nutrition*, 130: 1204–1211. Cited in: World Bank (2007). From agriculture to nutrition: Pathways, synergies, and outcomes. The World Bank, Washington, DC.
- Haddad, L. (2003). Redirecting the diet transition: What can food policy do? *Development Policy Review*, 21(5-6): 599-614.
- Hagenimana, V., Anyango Oyunga, M., Low, J., Njoroge, S., Gichuki, S. & Kabira, J. (1999). Testing the effects of women farmers' adoption and production of orange-fleshed sweet potatoes on dietary vitamin A intake in Kenya. *Opportunities for Micronutrients Interventions, Research Report Series No. 3*, International Center for Research on Women, Washington D.C.
- Hagenimana, V. & Low, J. (2000). Potential of orange-fleshed sweet potatoes for raising vitamin A intake in Africa. *Food and Nutrition Bulletin*, 21: 414-418
- Harris, S. (1991). Coordinated strategies for controlling micronutrient malnutrition: A technical workshop. Summary of International Life Sciences Institute workshop, Atlanta, GA.
- HarvestPlus program (2010). Preliminary results of an intervention to promote orange-fleshed sweet potato in Uganda and Mozambique. Unpublished report submitted to the Bill and Melinda Gates Foundation.
- Hatloy, A., Hallund, J., Diarra, M., Oshaug, A. (2000). Food variety, socioeconomic status and nutritional status in urban and rural areas in Koutiala (Mali). *Public Health Nutrition*, 3:57-65
- Hawkes, C. (2005). The role of foreign direct investment in the nutrition transition. *Public Health Nutrition*, 8: 357-365.
- Hop, L. (2003). Programs to improve production and consumption of animal source foods and malnutrition in Vietnam. *Journal of Nutrition*, 133(Suppl.): 4006-4009.
- Horton, S. (1999). Opportunities for Investments in Nutrition in Low-income Asia. *Asian Development Review*, 17(1): 246-273.
- Horton, S., Alderman, H. & Rivera, J. (2008). Copenhagen Consensus 2008: Malnutrition and Hunger. Copenhagen Consensus Center, Denmark.
- Horton, S., Shekar, M., McDonald, C., Mahal, A. & Brooks, J.K. (2010). Scaling up nutrition: what will it cost? The World Bank, Washington, D.C.
- Hussain, A. & Kvale, G. (1996). Sustainability of a nutrition education programme to prevent night-blindness in Bangladesh. *Tropical Medicine and International Health*, 1(1): 43-51.
- Ianotti, L., Cunningham, K. & Ruel, M. Diversifying into health diets: Homestead food production in Bangladesh, in *Millions Fed: Proven Successes in Agricultural Development*, ed. By DJ Spielman and R Pandya-Lorch. Washington, DC: International Food Policy Research Institute, 2009.
- Immink, M. & Alarcon, J. (1992) Household food security and crop diversification among smallholder farmers in Guatemala. *Food, Nutrition, and Agriculture*, 4: 32-41
- Jalal, F., Nesheim, M., Agus, Z., Sanjur, D. & Habicht, J. (1998). Serum retinol concentrations in children are affected by food sources of beta-carotene, fat intake, and anthelmintic drug treatment. *American Journal of Clinical Nutrition*, 68: 623-629.
- Jha, B., Tripathi, A. & Mohanty, B. (2009). Agricultural Diversification in India, Haryana, and the Greenbelt Farms of India. *Working Paper Series No. 303*, University of Delhi Institute of Economic Growth.
- Johns, T. & Eyzaguirre, P. (2007). Biofortification, biodiversity and diet: A search for complementary applications against poverty and malnutrition. *Food Policy*, 32 (1), pp 1-24.

- Johns, T & Sthapit, B. (2004). Biocultural diversity in the sustainability of developing-country food systems. *Food and Nutrition Bulletin*, 25(2): 143-155.
- Joshi, P., Gulati, A. & Cummings, R. (2007). Agricultural diversification and smallholders in South Asia. Academic Foundation, New Delhi, India.
- Kant, A. (1996). Indexes of Overall Diet Quality: A Review. *Journal of the American Dietetic Association*, 96(8): 785-791.
- Kant, A., Schatzkin, A. & Ziegler, R. (1995). Dietary diversity and subsequent cause-specific mortality in the NHANES I epidemiologic follow-up study. *Journal of the American College of Nutrition*, 14(3): 233-238.
- Kayizzi-Mugerwa, S. A review of macroeconomic impediments to technology adoption in African agriculture. *African Development Review*, 10(1), 211–225.
- Kebede, Y., Gunjal, K., & Coffin, G. (1990). Adoption of new technologies in Ethiopian agriculture: The case of Tegulet Bulga district, Shoa province. *Agricultural Economics*, 4, 27–33.
- Kennedy, E., Bouis, H. & von Braun, J. (1992), Health and Nutrition Effects of Cash-Crop Production in Developing Countries: A Comparative Analysis. *Social Science and Medicine*, 35: 689-697. Cited in: World Bank (2007). From agriculture to nutrition: Pathways, synergies, and outcomes. The World Bank, Washington, DC.
- Kennedy, G., Burlingame, B. & Nguyen, VN. (2003). Nutritional contribution of rice and impact of biotechnology and biodiversity in rice-consuming countries. Food and Agriculture Organization of the United Nations, Rome.
- Kennedy, G., Islam, O., Eyzaguirre, P. & Kennedy, S. (2005). Field testing of plant genetic diversity indicators for nutrition surveys: rice-based diet of rural Bangladesh as a model. *Journal of Food Composition and Analysis*, 18(4): 255-268.
- Kidala, D., Greiner, T. & Gebre-Medhin, M. (2000). Five-year follow-up of a food-based vitamin A intervention in Tanzania. *Public Health Nutrition*, 3: 425-31.
- Kimmons, J.E., Dewey, K.G., Haque, E., Chakraborty, M.S., Osendarp, S.J.M. & Brown, K.H. (2004). Behavior-change trials to assess the feasibility of improving complementary feeding practices and micronutrient intake of infants in rural Bangladesh. *Food and Nutrition Bulletin*, 25:228- 238.
- Lee, D. (2005). Agricultural sustainability and technology adoption: Issues and policies for developing countries. *American Journal of Agricultural Economics*, 87(5), 1325–1334.
- Leroy, J. & Frongillo, E. (2007). Can interventions to promote animal production ameliorate undernutrition? *Journal of Nutrition*, 137: 2311-2316.
- Leroy, JL, Ruel, M, Verhofstad, E & Olney, D. (2008). The micronutrient impact of multisectoral programs focusing on nutrition: examples from conditional cash transfer, microcredit with education, and agricultural programs. *Micronutrient Forum/USAID/IFPI/AED*.
- Lipper, Leslie, C. Leigh Anderson and Timothy J. Dalton, eds. (2010). *Seed Trade in Rural Markets: Implications for Crop Diversity and Agricultural Development*. London: Earthscan publishing company.
- Loevinsohn, M. & Gillespie, S. HIV/AIDS, food security, and rural livelihoods: Understanding and responding. Food Consumption and Nutrition Division Discussion Paper Number 157. International Food Policy Research Institute: Washington, DC.
- Low, J., Arimond, M., Osman, N., Cunguara, B., Zano, F. & Tschirley, D. (2007). A Food-Based Approach Introducing Orange-Fleshed Sweet Potatoes Increased Vitamin A Intake and Serum Retinol Concentrations in Young Children in Rural Mozambique. *Journal of Nutrition*, 137(5): 1320-1327.
- Low, J., Walker, T. & Hijmans, R. (2001). The potential impact of orange-fleshed sweetpotatoes on vitamin A intake in Sub-Saharan Africa. *Paper presented at a meeting of the VITAA project*, Nairobi, Kenya, May 9-11.
- Marsh, R. (1998). Building on traditional gardening to improve household food security. *Food, Nutrition, and Agriculture*, 22(4): 4-14.
- Maunder, E., Matji, J. & Hiatswayo-Molea, T. (2001). Enjoy a variety of foods—difficult but necessary in developing countries. *South African Journal of Clinical Nutrition*, 14(3): S7-S11.

- Mirmiran P, Azadbakht L & Azizi F. (2006). Dietary diversity within food groups: An indicator of specific nutrient adequacy in Tehranian women. *Journal of the American College of Nutrition*, 25(4): 354-361.
- Moursi M, Arimond M, Dewey K, Treche S, Ruel M & Delpuech F. (2008). Dietary diversity is a good predictor of the micronutrient density of the diet of 6- to 23-month-old children in Madagascar. *Journal of Nutrition*, 138(12): 2448-2453.
- Mbago, M. & Namfua, P. (1992). Some determinants of nutritional status of one- to four-year-old children in low income urban areas in Tanzania. *Journal of Tropical Pediatrics*, 38(6): 299-306.
- Mullins, G., Wahome, L., Tsangiri, P. & Maarse, L. (1996). Impacts of intensive dairy production on smallholder farm women in coastal Kenya. *Human Ecology*, 24(2): 231-253.
- Murphy, S. & Allen, L. (2003). Nutritional importance of animal-source foods. *Journal of Clinical Nutrition*, 103(Suppl.): 3932-3935.
- Neilsen, H., Roos, N. & Thilsted, S. (2003). The Impact of Semi-Scavenging Poultry Production on the Consumption of Animal Source Foods by Women and Girls in Bangladesh. *Journal of Clinical Nutrition*, 103(Suppl.): 4027-4030.
- Neumann, C.G., Murphy, S.P., Gewa, C., Grillenberger, M., Bwibo, N.O. (2007). Meat supplementation improves growth, cognitive, and behavioral outcomes in Kenyan children. *Journal of Nutrition*, 137:1119-1123.
- Olney DK, Talukder A, Ianotti LL, Ruel MT, Quinn V. (2009) Assessing impact and impact pathways of a homestead food production program on household and child nutrition in Cambodia. *Food and Nutrition Bulletin* 30(4): 355-369.
- Onyango A. (2002). Dietary diversity, child nutrition, and health in contemporary African communities. *Comparative Biochemistry and Physiology*, 136: 61-69.
- Onyango, A., Kuski, K. & Tucker, K. (1998). Food diversity versus breastfeeding choice in determining anthropometric status in rural Kenyan toddlers. *International Journal of Epidemiology*, 27: 484-489.
- Penny M., Creed-Kanashiro H., Robert R., Narro M., Caulfield L. & Black R. (2005) Effectiveness of an educational intervention delivered through the health services to improve nutrition in young children: a cluster-randomised controlled trial. *Lancet*, 365: 1863– 1872.
- Phillips, M., Sanghvi, T., Suarez, R., McKigney, J. & Fiedler, J. (1996). The costs and effectiveness of three vitamin A interventions in Guatemala. *Social Science and Medicine*, 42:1661-1668.
- Pingali, P. (2004). Westernization of Asian Diets and the transformation of food systems: Implications for research and policy. *Working Paper 04-17*, Agriculture and Development Economics Division of the Food and Agriculture Association of the United Nations, Rome.
- Pingali, P. & Rosegrant, M. (1995). Agricultural commercialization and diversification: processes and policies. *Food Policy*, 20(3): 171-185.
- Ponce X, Ramirez E & Delisle H. (2006). A more diversified diet among Mexican men may also be more atherogenic. *Journal of Nutrition*, 136: 2921-2927.
- Qaim, M. (2005). Agricultural biotechnology adoption in developing countries. *American Journal of Agricultural Economics*, 87(5):1317–1324.
- Rao, P.P., BIRTHAL, P.S., JOSHI, P.K. & KAR, D. (2004). Agricultural diversification in India and role of urbanization. *Market Trade and Institutions Division Discussion Paper No. 77*, International Food Policy Research Institute, Washington, D.C.
- Reardon, T., Henson, S. & Gulati, A. (2010). Links between supermarkets and food prices, diet diversity and food safety in developing countries. Chapter in: Hawkes, C., Blouin C., Henson S., Drager N & Dube, L. (Eds.) *Trade, food, diet and health: Perspectives and Policy Options*. Wiley-Blackwell, Oxford, UK. Pp: 111-130.
- Rouse, D. (2003). Potential cost-effectiveness of nutrition interventions to prevent adverse pregnancy outcomes in the developing world. *Journal of Nutrition*, 133 (Suppl.):1640-1644.
- Roy S., Fuchs G., Mahmud Z., Ara G., Islam S., Shafique S. et al. (2005) Intensive nutrition education with or without supplementary feeding improves the nutritional status of moderately-malnourished children in Bangladesh. *Journal of Health, Population, and Nutrition*, 23: 320–330.

- Ruel M. (2002). Is dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs. *Food Consumption and Nutrition Division, Discussion Paper 140*. International Food Policy Research Institute, Washington D.C.
- Ruel M & Levin C. (2000). Assessing the potential for food-based strategies to reduce vitamin A and iron deficiencies: A review of recent evidence. *Food Consumption and Nutrition Division, Discussion Paper 92*. International Food Policy Research Institute, Washington D.C.
- Savy M, Martin-Prevel Y, Sawadogo P, Kameli Y & Delpuech F. (2005). Use of variety/diversity scores for diet quality measurement: Relation with nutritional status of women in a rural area in Burkina Faso. *European Journal of Clinical Nutrition*, 59(5): 703-716.
- Savy M, Martin-Prevel Y, Danel P, Traissac P, Dabire H & Delpuech F. (2008). Are dietary diversity scores related to the socio-economic and anthropometric status of women living in an urban area in Burkina Faso? *Public Health Nutrition*, 11(2): 132-141.
- Seshadri, S., Shah, A & Bhade, S. (1995). Haematologic response of anaemic preschool children to ascorbic acid supplementation. *Human Nutrition, Applied Nutrition*, 39(2): 151-154.
- Sharieff, W., Dofonsou, J. & Zlotkin, S. Is cooking food in iron pots an appropriate solution for the control of anaemia in developing countries? A randomised clinical trial in Benin. *Public Health Nutrition*, 11(9): 971-977.
- Smitasiri, S. & Chotiboriboon, S. (2003). Experience with programs to increase animal source food intake in Thailand. *Journal of Nutrition* 133: 4006-4009.
- Stein, A. (2007). Can agriculture meet the challenge of micronutrient deficiencies? Paper presented at a meeting of the Food and Agriculture Organization of the United Nations, Near East Regional Office. Cairo, Egypt.
- Steyn N, Nel J, Nantel G, Kennedy G & Labadarios D. (2006). Food variety and dietary diversity scores in children: Are they good indicators of dietary adequacy? *Public Health Nutrition*, 9(5): 644-650.
- Talukder A, Haselow N, Osei A, Villate E, Reario D, Kroeun H, SokHoing L, Uddin A, Dhungel S & Quinn V. (2010). Homestead food production model contributes to improved household food security and nutrition status of young children and women in poor populations: Lessons learned from scaling-up programs in Asia (Bangladesh, Cambodia, Nepal and Philippines). *Field Actions Science Report*, factsreports.org.
- Tangka F.K., Emerson R.D. and Jabbar M.A. (2002). Food security effects of intensified dairying: Evidence from the Ethiopian highlands. Socio-economics and Policy Research Working Paper Number 44. International Livestock Research Institute, Nairobi, Kenya.
- Tontisirin, K. & Gillespie, S. (1999). Linking community-based programs and service delivery for improving maternal and child nutrition. *Asian Development Review*, 17(1-2): 33-65.
- Tontisirin K, Nantal G, and Battacharjee L. (2002). Food-based strategies to meet the challenges of micronutrient malnutrition in the developing world. *Proceedings of the Nutrition Society*, 61: 243-250.
- Torheim LE, Ouattara F, Diarra M, Thiam F, Barikmo I, Hatloy A & Oshaug A. Nutrient adequacy and dietary diversity in rural Mali: Association and determinants. *European Journal of Clinical Nutrition*, 58(4): 594-604.
- von Braun, J., and Kennedy, E., eds. (1994). Agricultural commercialization, economic development, and nutrition. Johns Hopkins University Press, Baltimore, MD. Cited in: World Bank (2007). From agriculture to nutrition: Pathways, synergies, and outcomes. The World Bank, Washington, DC.
- Waters, H., Penny, M., Creed-Kanashiro, H., Robert, R., Narro, R., Willis, J., Caulfield, L. & Black, R. (2006). The cost-effectiveness of a child nutrition education programme in Peru. *Health Policy and Planning*, 21(4): 257-264.
- West C, Eilander A & van Lieshout M. (2002). Consequences of revised estimates of carotenoid bioefficacy for dietary control of vitamin A deficiency in developing countries. *Journal of Nutrition*, 32: 2920S-2926S.
- Wispelwey, B. & Deckelbaum, R. (2010). Econutrition: Preventing Malnutrition with Agrodiversity Interventions. Chapter in: Bendich, A. & Deckelbaum, R. (Eds). Preventive Nutrition: The comprehensive guide for health professionals. Humana Press, New York.

World Bank (1994). *Enriching lives: Overcoming vitamin and mineral malnutrition in developing countries*. The World Bank, Washington, DC.

World Bank (2007). *From agriculture to nutrition: Pathways, synergies, and outcomes*. The World Bank, Washington, DC.

Yip, R. (1997). The challenge of improving iron nutrition: Limitations and potentials of major intervention approaches. *European Journal of Clinical Nutrition*, 51 (Suppl. 4): 16-24.

Yorgey, G. (2008). Literature review on the links between agriculture and health. Unpublished report for the University of Washington, Evans Policy Analysis and Research Group.

Yesuf, M. & Kohlin, G. (2008). Market imperfections and farm technology adoption decisions. Environment for Development Discussion Paper 08-04. Gothenberg, Sweden: EFD.

Zeller, M., Diagne, A., & Mataya, C. (1997). Market access for smallholder farmers in Malawi: Implications for technology adoption, agricultural productivity, and crop income. FCND Discussion Paper No. 35. Washington, DC: IFPRI.

Zeza, A. & Tasciotti, L. (2008). Does urban agriculture enhance dietary diversity? Empirical evidence from a sample of developing countries. Paper prepared for presentation at 12th Congress of the European Association of Agricultural Economists, Gent, Belgium.