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*Diet Matters:  
Approaches and Indicators to Assess the Role of Agriculture in Nutrition*

*(English only)*

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## **Diet Matters: Approaches and Indicators to Assess the Role of Agriculture in Nutrition**

### **Introduction**

How can agriculture improve nutrition? In the well-accepted and recently updated UNICEF conceptual framework (UNICEF 1990; 2013), nutritional outcomes are influenced through three main pathways – food, care, and health. The greatest influence of agriculture on nutrition logically flows through the food pathway. To understand how interventions might have success through this pathway, we need an information base that enables evaluating the impacts of policies and programs on diet. This is a challenging complex question, because diets are multidimensional, and notoriously difficult to assess. And beyond just the evaluation questions of program efficacy and effectiveness, we also want to monitor population status over time, understand the role of policies, and advocate for more resources for the 'nutrition problem', when needed.

The broad objective of this paper is to review indicators and data collection approaches which have the potential to measure the impact of nutrition-enhancing food and agriculture policies, programs, and interventions. More specifically, we intend to: (1) outline plausible mechanisms in which agriculture and food-based interventions can improve nutrition through diet; (2) examine accumulated research on the validity of specific food-related indicators; (3) review broad scale data collection systems that use these indicators; and (4) identify gaps in knowledge and recommend specific actions to improve our understanding in these areas.

This paper begins with a discussion of an augmented causal framework that provides more details on the links between agriculture, household food security, and dietary intake and references these links to entry points for specific interventions. Because some interventions might include nutrition education or other aspects that influence care-giving behavior, we divide the discussion of this framework into food-based and care-based interventions. Then the paper explores measures of assessment at three levels – individual, household, and nation – with sections describing indicators at each level. This is followed by a section on data systems that are used to monitor and evaluate outcomes in these areas. The paper closes with a section on recommendations for practice and future research.

### **Food-Based Interventions**

The choice of indicators should depend on the objectives of measurement. To monitor or evaluate the impact of interventions, indicators should be chosen that assess aspects that the program or policy directly aims to influence. The use of indicators to assess outcomes that are too distal from the main effects of an intervention can give misleading results on the intervention's effectiveness.

Anthropometric measures are often used to assess nutritional status. There is general consensus on the details of how they should be implemented, and the widespread availability of data to calculate indicators make them an obvious choice to consider. However, nutritional

outcomes, like growth, are jointly determined by diet and illness. Using anthropometry to assess the effects of food-based interventions can give misleading results, if other aspects which contribute to illness, such as sanitation, health services, and care are not addressed.

As helpful as the UNICEF framework has been for addressing the multiple simultaneous determinants of poor nutrition, there are many details left out of the picture. So we have adapted that framework to get a more fine grain view of determinants. In **Figure 1**, we zoom in on the "household food security" box to propose additional factors to be considered in a more detailed causal framework, borrowing from the work of the World Food Program (WFP 2005).

A household's access to food is a key determinant of both the quantity and quality of individual diets. For most households, access to food comes from four main sources: (1) their own agricultural or livestock production; (2) gathering, fishing, or hunting; (3) receipt of foods either as gifts or loans from neighbors or from organized food assistance programs; and/or (4) from their own purchases. The first three of these sources can be sold which yields cash income that can be used to purchase foods. Cash income can also come from trading, employment, cash assistance, or from borrowing for most rural households

### Increasing own production

This framework is useful for thinking about the types of interventions that can have an impact on household access to food. Agricultural interventions to increase or diversify production of food crops can impact household food security status through both direct and indirect causal pathways. Horticultural interventions focus on the production of micronutrient dense fruits and vegetables for home consumption and sale, potentially improving nutrition through increased dietary diversity and household incomes (Leroy et al. 2008). Homestead gardening programs have demonstrated increases in year-round vegetable consumption and higher garden incomes which was devoted mainly to food purchases (HKI et al. 1993; Gillespie et al. 1994; Bushamuka et al. 2005). These and other interventions discussed below are listed in **Table 1** with an indication of the most likely levels (individual, household, or nation) at which they will have impact.

Animal husbandry and aquaculture interventions can increase consumption of animal source foods such as meat, dairy, poultry, eggs and fish provides various nutrients, such as iron, zinc, vitamin A and others, that are found in limited quantities in plant source foods. These interventions can also increase incomes through sales, thus leading to higher food expenditures.

Bio-fortification interventions can enhance concentrations of micronutrients and/or micronutrient absorption modifiers in staple foods through agronomic practices, plant breeding and genetic engineering. The principal advantage of biofortification is that it does not depend on central processing and therefore has the potential to improve the nutrition of the rural households that rely on home production of staples or purchase staples from local growers. Biofortification is not capable of achieving the high concentrations of micronutrients necessary to treat acute deficiencies or meet the elevated needs of pregnant and lactating women (Ruel et al. 2013), but can be part of a longer term sustainable strategy to achieve dietary objectives.

Shifting farming strategies from subsistence production to more market-oriented production has demonstrated some success in increasing household food consumption (Arimond et al. 2011). Improvements in household dietary energy intakes were largely attributable to increases in household income associated with farm sales (Arimond et al. 2011; Hoddinott et al. 2013).

A number of other policies and programs can also have an impact on agriculture. For example, subsidies that reduce the cost of farm inputs can stimulate production of certain crops. Pricing policies on agricultural commodities can also encourage production.

Some households obtain a portion of their food from wild sources, through gathering, fishing, and/or hunting. Agricultural conservation approaches can affect the landscapes where rural households live, by preventing deforestation or pollution of rivers, and thus allow for some of these activities to continue.

#### Increasing purchasing power and the quality of food purchased

Since a substantial amount of food is purchased, even in agricultural households, any interventions that affect the income of households, the prices that they pay for foods, or the dietary quality of these foods, can have an impact on their dietary intake. Consumer subsidies, such as price controls on staple foods, subsidized sales to area-targeted or means-tested households, and direct distributions to targeted households can all increase access to food either through the direct receipt of food, or by increasing purchasing power of households. In-kind food distributions targeted to low-income households have been shown to increase food consumption in beneficiary households (Reutlinger et al. 1984).

Rising incomes are associated with improved nutritional outcomes (Ruel et al. 2013). Unconditional cash transfers to low-income households have been shown to increase food expenditures in recipient households (Schady et al. 2008; Attanasio et al. 2012). Conditional cash transfers, i.e. benefits are conditional on participation in health and/or nutrition education programs, can reduce household food insecurity and can increase micronutrient intake among children in participating households (UNICEF 1990; Begum 1994; Nielsen 1997; Geniez et al. 2013; UNICEF 2013).

Interventions to improve the nutritional quality of foods purchased in the marketplace can also be important. Commercially processed foods fortified with micronutrients has been shown to be one of the most cost-effective strategies to reduce micronutrient deficiencies at the population level (Horton et al. 2008). Iodization of salt has been demonstrated to improve iodine status and prevent goiter (Wu et al. 2002; Golkowski et al. 2003; Kusic et al. 2005). Cereal staples may be sprayed with zinc or iron and iodine added to salt. Fortified foods targeted to children include milk powder, biscuits, sugar, spreads such as peanut butter, vegetable oils, and cereal based complementary foods.

### Reducing energy expenditure

Ultimately, the adequacy of individual diets is shaped by both intakes and requirements. By reducing energy expenditures and thus requirements, labor-saving agricultural technologies can improve the adequacy of diets. A prime example of this is conservation agriculture, focused on no-till farming, which can reduce labor requirements for tillage, land preparation, and weeding (Friedrich et al. 2007). Similarly, water conservation and forestry projects can reduce the time spent and the energy needed for collecting water or firewood.

### **Care-Based Interventions Linked to Food**

Since many of the interventions described above can increase incomes and therefore the purchase of foods, the net impact of increases in household availability on household consumption is shaped by consumer knowledge and preferences, as well as prices and total income. It is clear from our understanding of the causes of malnutrition that care and feeding practices play a key role, both through the food and the health sides of the equation. In short, food acquisition, allocation, and preparation behaviors influence how household food security gets turned into the dietary intake of individuals.

In **Figure 2**, we zoom in on the care portion of the UNICEF framework to explore some of the detailed relationships involved in explaining how interventions might shape outcomes. Care and feeding practices are shaped by a care-giver's educational background, her specific knowledge related to nutrition practices, the amount of resources over which she has control, and her available time for care and feeding. As with Figure 1, this is a highly simplified model that leaves out many causal arrows that shape factors in the zoom-in box, as well as how they, in turn, influence factors outside the box. But it is useful as a first approximation for understanding how specific interventions fit in the causal chain of influences on nutrition.

### Increasing control over resources

Most caregivers in most households in low-income countries are women, so a number of interventions have focused on increasing the amount of resources over which they have control. Interventions targeted to women have shown to have the greatest impact in improving the nutrition and health of children. Women's social status, empowerment, resource control, time allocation, health and knowledge are associated with child nutrition and health (Quisumbing et al. 1995; Kurz et al. 2007). Many cash transfer programs target transfers to women on the premise that women's control of financial resources promotes greater investment in children (Ruel et al. 2013). Homestead gardening programs targeted to women that incorporate a nutritional education component have been effective in diversifying household nutrient intakes (Ruel 2001; Berti et al. 2004; Ruel et al. 2013). Increases in women's income are associated with higher marginal food expenditures and greater household dietary energy consumption than increases in men's incomes (Quisumbing et al. 1995; Peña et al. 1996; Quisumbing et al. 2000).

Many women are farmers, so institutional limitations can not only decrease their productivity, but result in lower household dietary intakes. Women agriculturalists experience constraints to increasing agricultural incomes due to weak land rights and lack of access to tools, inputs,

financial credit, extension services and markets (Quisumbing et al. 1995). These constraints lower the productivity of women farmers compared to men with lower subsequent returns to women's labor, thus limiting potential improvements in household food security and nutrition. Labor-saving technologies, mentioned above, can increase the availability of the caregiver's time and allow for greater attention to the feeding of small children.

### Increasing caregiver nutrition knowledge, practices, and education

Breastfeeding and complementary feeding are of key importance to the nutrition and development of infants and young children. After six months of age, infants need to be gradually introduced to safe and nutritious foods. Maternal education programs addressing proper complementary feeding promote the diversity of complementary foods and timely feeding intervals to achieve optimal growth (Caulfield et al. 1999). Proper preparation of complementary foods can also increase energy density and micronutrient availability in complementary foods. Germination, fermentation and soaking of unrefined cereals and legumes have been shown to be effective in reducing the phytate content of porridges that inhibits uptake of iron, zinc and calcium (Gibson et al. 1998; Gibson et al. 1998; Ruel 2001; Gibson et al. 2009). The energy density of porridges may also be enhanced through inclusion of germinated cereal flours to thicken porridges which reduces the viscosity without dilution (Gibson et al. 2006).

Education that informs consumer choices that increase dietary diversity to achieve a balanced diet has the potential to prevent many micronutrient deficiencies (Faber et al. 2002; Berti et al. 2004; Leroy et al. 2007). Education programs must be sensitive to food costs and availability, preferences, preparation and competing demands on the time of caregivers. The inclusion of animal source foods in the diets of young children has been demonstrated to be an effective method of increasing protein and energy intake as well as iron, zinc and B vitamins (Krebs 2007).

Successful approaches to enhancing the knowledge and practices of caregivers have included community health workers (Imdad et al. 2011). Community-based management of uncomplicated severe acute malnutrition (SAM) and moderate acute malnutrition (MAM) has been effective (Lenters et al. 2013) in transitioning from clinic-based care to effective home-based care through individualized maternal education and provision of ready-to-use therapeutic foods (RUTF).

Parental education has been consistently associated with child nutritional status (Semba et al. 2008; Chou et al. 2010) in part because a higher educational level facilitates increased knowledge on specific feeding practices.

## **Individual Level Measures**

### Rigorous Measures of Dietary Status for Single Nutrients

Rigorous measures of dietary status are based on complete quantitative information about the individual's diet. Three types of data collection tools have been used to assess this. The most rigorous is the food record, in which detailed recording of foods eaten by an individual or

household are made on the same day, and this often times include weighing of foods. This requires highly motivated and trained respondents, and it is rarely done in low-income countries without assistance from trained enumerators. Even then it is only feasible for well-financed research projects. The approach is not without bias. For one, training and motivation imply that the sample of individuals who actually carry this out will be biased towards the more educated and/or those with fewer time constraints. Even when this is addressed with assistance from enumerators, Dop and colleagues (Dop et al. 1994) have documented the "Hawthorne effect," in which the act of observation – i.e. enumerators in a house all day long – affects the behavior of subjects, so as to bias measurement.

Given the challenges with the food record, the 24-hour recall method has become the de facto gold standard for attaining accurate dietary data. Trained enumerators lead respondents through a series of open-ended questions to elicit information on everything that was consumed in the previous day. The approach is completely flexible as to what foods can be recorded, and information on the amounts consumed is obtained by having respondents compare their consumption to standard units or displays of food models. The approach is typically used to elicit information on a specific individual in the household, but can also be done for an entire household, which is sometimes easier in contexts where people eat from a common pot. A main limitation to the approach is that diets vary substantially within individuals from one day to the next, so a single recall cannot be used to assess usual intake. Multiple recalls on non-consecutive days allows for estimation of usual intakes, but this, of course, implies more cost.

Semi-quantitative food frequency tools are based on pre-determined lists of foods in which the respondent reports the frequency of consumption over a given time interval. This time interval has varied widely from a day to several months. There is a trade-off between getting a better picture of usual intake by increasing the time interval, and introducing more bias, since respondents are better able to recall foods eaten that are more proximate to the interview. Because the food frequency instrument relies on pre-printed lists, research-grade tools must be designed and validated with each new population. These tools are not used for providing absolute levels of intake, but rather are used in epidemiological studies to rank individuals by relative usual consumption so that links to disease outcomes can be studied.

Nutrient intake data from one of these tools, most commonly the 24-hour recall, are then evaluated to make statements about the nutritional adequacy of an individual's diet. Historically, the Nutrient Adequacy Ratio was used to do this, and is calculated by taking the nutrient intake of the individual, dividing it by the Recommended Dietary Allowance for that individual, and expressing it in percentage terms (Guthrie et al. 1981). Nowadays, a probabilistic approach is used, since, in practice, one can never know the true requirements of an individual. Conceptual and analytic refinements in the nutrient requirement field led to this probabilistic approach (Yates et al. 1998; IOM 2000). The Probability of Adequacy for a specific nutrient and individual is calculated by mapping usual intake information for that individual onto a cumulative probability distribution of requirements for like individuals. These requirement distributions are obtained by combining published information on estimated average requirements with typical variances for these distributions (Yates et al. 1998; IOM 2000).

### Aggregate Measures of Dietary Status

One of the difficult challenges with dietary assessment, and nutritional health in general, is its multi-dimensional nature. There are some 40 nutrients, all of them, by definition, essential, and over 1000 compounds in food that may have beneficial effects (Burlingame 2013). This presents problems for use in monitoring and evaluation. Having too many outcomes not only makes analysis challenging, it creates difficulties in understanding which interventions are more successful, and thus providing guidance on what works. This may not be a problem for single nutrient intervention fortification-type programs, but it is for integrated approaches that seek to improve overall diet. A second problem concerns the use of complex dietary information in advocacy. Policymakers might pay attention to "the nutrition problem", but are less likely to focus on 40 of them. The issue is also a concern to researchers attempting to study the links between nutrition and health outcomes. For some, the focus has shifted to dietary patterns rather than a study of isolated nutrients (Hu 2002). This is because the analysis of single nutrients ignores complex interactions between nutrients. Moreover, people eat food, not eat isolated nutrients.

Realizing all of this, nutritionists have developed ways to synthesize dietary information into single index numbers. One of the earliest approaches was the Mean Adequacy Ratio (MAR) (Guthrie et al. 1981), which is simply an average of the Nutrient Adequacy Ratios (described above) for each of the nutrients for which dietary information is available. The MAR is a simple average, so that all nutrients are implicitly weighted equally. Some analysts would truncate all NARs at 100% before averaging, so that excesses in one nutrient would not mask shortfalls in others.

A newer aggregate measure is based on the probabilistic approach described above. The Mean Probability of Adequacy (MPA) is developed by averaging together the probabilities of adequacy for all nutrients for which intake information is available. Like the MAR that preceded it, a simple average is used, so implicitly nutrients are all weighted equally (Arimond et al. 2010).

In the United States, a Healthy Eating Index (HEI) has been used since 1995 to represent overall dietary quality (Bowman et al. 1998; Guenther et al. 2007). The approach has been used to assess diets in relation to current dietary guidance, which includes recommendations for consumption of specific food groups to achieve a balanced diet, as well as recommendations to restrict consumption of specific components of the diet. The original version assigned up to 10 points for consumption of each of five different food groups (grains, fruits, vegetables, dairy, meats), up to 10 points for restrictions of each of 4 components (fat, saturated fat, cholesterol, and sodium), and another 10 points for a measure of variety (Bowman et al. 1998). As dietary guidance has changed, so too has the HEI, being revised twice since the original. The latest version continues with 50 points on positive consumption from different food groups, but the assignment of points is more targeted to specific foods within each group – whole fruits (as opposed to just juices), whole grains, seafood and plant proteins, etc. Points on fat intake are assigned based on a desired ratio of poly- and mono-unsaturated to saturated fatty acids. And, points are assigned based on restrictions of refined grains, sodium, and "empty calories".

Another indicator that has garnered favor among nutritionists, particularly in Europe, is the Mediterranean Diet Score, which has been used in epidemiological studies to assess the links between diet and health outcomes (Trichopoulou et al. 2003). Food frequency tools are typically used to assess diet in epidemiological studies because investigators are concerned with relative intakes, among study participants over time, rather than absolute levels. The score is composed of a nine-point scale with each point based on the relative consumption of foods from a particular food group. For example, individuals consuming above the median level of beneficial foods (e.g. vegetables, legumes, fish, etc.) receive a point for each group, whereas those below the median get zero. The reverse scoring would be used for 'detrimental' foods, such as meats. This score has been used to show the benefits of the Mediterranean Diet with respect to chronic diseases and associated mortality (Trichopoulou et al. 2003).

### *Proxy Tools to Assess Diet Diversity*

Rigorous assessment of diets, typically conducted with 24-hour recall measures on repeated non-consecutive days, requires considerable resources, both in time and training. Beginning in the late 1990's, nutritionists began to develop inexpensive ways to conduct dietary assessments in resource-poor areas that could proxy for these more rigorous assessments. By focusing on diet quality, rather than quantity, they removed the need to collect elaborate intake data with 24-hour recall measures on repeated non-consecutive days. To get at overall quality, they focused on the variety dimension, i.e. how diverse were the food sources that composed the diet. Given that so many nutrients must be derived from the diet and the concentration of these nutrients varies considerably among food groups, a diversity of intake has long been advised. Building on analytic work done earlier in high-income countries (Krebs-Smith et al. 1987; Kant et al. 1991), nutritionists working in West and Southern Africa began to develop and test simple tools to assess dietary intakes using a proxy measure known as diet diversity (Food Health and Nutrition Information System 1998; Hatløy et al. 1998; Rose 2000; Rose et al. 2002). Substantial analytic work has been conducted on diet diversity indicators since that time. Simple qualitative food frequency instruments, which query about consumption of either specific foods or food groups, are used in these proxy tools, but information on portions and cooking methods are not collected. The time interval can be either the previous 24 hours or the previous week. Indicators based on a count of individual foods are typically called variety scores, and those based on a count of food groups are called diversity scores.

Dietary diversity scores have been validated against nutrient adequacy for children in a number of populations. Hatløy and colleagues used data on 13-58 month old children from a 3-day weighed food record to calculate nutrient adequacy ratios for energy, protein, fat and eight micronutrients. Both food variety and food group diversity were significantly correlated with the mean adequacy ratio (MAR). To identify individuals with MAR's below 75%, they found that a cut-point of 23 foods was optimal, yielding a sensitivity (percentage of those with the low value that are identified) of 87%. However, at this threshold, the specificity was only 29%, meaning that the indicator would misclassify 71% of individuals that did not have low values (Hatløy et al. 1998). They also evaluated diversity scores to choose a threshold, and this had similar properties.

Arimond and Ruel studied dietary diversity among children 6-23 months of age sampled in Demographic and Health Surveys (DHS) in 11 countries (6 in Africa, 3 in Latin America, and 2 in Asia). They created the diversity scores based on 7 aggregated food groups from a simple food frequency instrument on consumption during the previous week. They validated their work against height-for-age Z-scores, in the context of multi-variate models that controlled for composite indicators of household wealth based on household assets, source of drinking water, sanitation facilities, and other variables. Diversity was significantly associated with height-for-age Z-scores, either as a main effect, or in an interaction in 10 of the 11 countries.

A number of other studies have looked at proxy indicators to assess individual diets, typically using correlational and/or sensitivity and specificity analysis. A significant positive correlation was found between dietary diversity scores and the nutrient adequacy ratios of macro- and micronutrients among adolescents in Tehran, Iran (Mirmiran et al. 2004). Steyn and colleagues analyzed dietary data from 1-8 year old children in South Africa and found that diversity scores based either on foods or food groups were significantly correlated with mean adequacy ratios for the children (Steyn et al. 2006). Among Filipino children 24-71 months of age, Kennedy also found that diet diversity scores were significantly correlated with micronutrient intake as assessed using the mean probability of adequacy (Kennedy et al. 2007).

Another large multi-country study was conducted on children from 6-23 months using ten existing datasets: Bangladesh, India, Philippines, Ghana, Madagascar, Malawi, Honduras, Peru (Huascar and Trujillo), and Brazil (FANTA 2007). Sensitivity and specificity analysis concluded cutoff points of  $\geq 3$  or  $\geq 4$  food groups for micronutrient adequacy depending on the age of the child. Area under the curve (AUC) for the receiver operating characteristic (ROC) analysis was also conducted and showed that the indicator had good predictive power for dietary quality (AUC > 0.7 for a majority of tests).

Several studies also validated the use of food variety and food group diversity indicators among adults. In a study among Vietnamese women living in the Mekong Delta or the Central Highlands, a positive correlation was found between nutrient adequacy and food variety as determined from 1-week food frequency questionnaires (Ogle et al. 2001).

The Women's Dietary Diversity Project, a study of women from Burkina Faso, Mali, Mozambique, Bangladesh, and the Philippines, used regression analysis to test associations between food group indicators and mean probability of micronutrient adequacy as determined from quantitative 24-hour recall data (Arimond et al. 2010). The WDDP used eight food group diversity indicators of varying aggregation of food groups (6, 9, 13, or 21) and varying minimal quantity of food group consumption to be scored (1 gram or 14 gram) (Arimond et al. 2010). The most aggregated groupings (6 and 9) reflect the groupings available from the Demographic and Health Surveys Phase 5 model questionnaire and the most disaggregated groupings (13 or 21) contain subgroups by specific nutrient density. Across all five sites of the WDDP project, each of the eight food group diversity indicators were positively and significantly associated with the mean probability of adequate intake of the micronutrients examined (Arimond et al. 2010). The key food groups to develop proxy indicators of micronutrient adequacy across all sites appeared to be dairy, eggs, fruits, dark green leafy-vegetables, fish, red meat, and legumes and nuts (Kennedy et al. 2010). However, none of the specific indicators performed the best across all

five sites, suggesting there is not a single indicator recommended for global use, but rather that food group diversity indicators should be developed for specific contexts.

In sum, individual proxy measures of dietary diversity are simple tools that can allow for some understanding of the relationship between food groups eaten and micronutrient adequacy in resource-poor settings, and thus can assist in identifying population subgroups particularly at risk of consuming inadequate diets. These measures can also be used to describe trends over time, target specific populations at risk for interventions and policy decisions, and monitor interventions (Hatløy et al. 1998; FANTA 2007; Arimond et al. 2010). Further, by using the tool to identify site-specific key food groups that contribute to mean probability of adequacy of micronutrients, these indicators can help to identify diet-based interventions that could improve dietary quality (Kennedy et al. 2010).

One challenge with evaluating this research is the wide diversity of indicators and validation approaches that investigators have used (**Table 2**). Indicators have been based on either foods or foods groups, with or without exclusion of minimum quantities (used to improve predictions), and collected using different dietary methods. Many different benchmarks and cut-off points, as well as different statistical criteria, have been used to validate them. The lack of a universal approach or the joint validation of multiple indicators makes it difficult to draw conclusions about which is best. Moreover, there are limitations to how far these tools can be used. In general, their predictive value is only modest at best. An indicator with the area under the ROC curve greater than 0.70 is considered to predict well, but this implies the tool may be wrong 30% of the time. Thus, these tools may be helpful for population monitoring or the design of programs, they should probably not be used for rigorous evaluation research on the effects of interventions.

### Assessing Energy Expenditure

An individual's energy requirement is the "amount of food energy needed to balance energy expenditure in order to maintain body size, body composition and a level of necessary and desirable physical activity consistent with long-term good health." (FAO/WHO/UNU 2001). Physical activity expenditure is the most variable part of one's total energy expenditure. By reducing the energy required to perform occupational tasks, labor-saving agricultural technologies can reduce energy requirements, all else equal. Similarly, water conservation and forestry projects can reduce the time spent and the energy needed for collecting water or firewood. However, assessment of the overall savings in energy needs from such projects is difficult.

Research methods exist for assessing total energy expenditure, but they are not practical in a field context. This includes whole body indirect calorimetry in which subjects live in enclosed chambers and energy expended is estimated indirectly based on the amount of oxygen consumed and carbon dioxide produced. A second method is based on the use of doubly-labeled water, in which subjects drink a sample of water with two different stable isotopes, and excretion is measured over one to three weeks. This allows for calculation of carbon dioxide production, and total energy expenditure. Although not practical as a monitoring tool, it has been used to study energy expenditure among rural Gambian farmers during the peak agricultural season (Singh et al. 1989; Heini et al. 1996).

There are also research methods for assessing energy expended in specific activities. Indirect calorimetry is used, with a portable apparatus, which, again, allows for the calculation of energy expended from oxygen and carbon dioxide exchange. A larger variety of specific activities have been assessed with this approach by researchers throughout the world, and this information has been collated into the Compendium of Physical Activities, using a common metric to rate the intensity level of energy expenditure of these activities (Ainsworth et al. 2011).

One field method for assessing the intensity and duration of common activities is accelerometry, in which subjects wear a small apparatus usually for a period of a week. Depending on the device, they can measure acceleration in one to three directions. Those typically worn on a waist belt do not capture upper body movement or cycling, and underestimate intensity of energy expended in walking uphill, or in carrying heavy loads. Accelerometers were used on a large sample of thousands of individuals in the 2003-06 U.S. National Health and Nutrition Examination Survey (Tudor-Locke et al. 2012). Body acceleration captured from these devices can be expressed as activity counts per minute. A number of prediction equations have been developed to estimate energy expenditure based on accelerometry data, and using thresholds, analysts can convert this information to the amount of time spent in sedentary, light, moderate, or vigorous activities. In recent work attempting to validate this approach against indirect calorimetry, prediction equations have not been found to be particularly accurate at classifying across a range of activities. Misclassification rates were particularly high in vigorous intensity activities (Crouter et al. 2006; Lyden et al. 2011).

Another field method relies on respondent reporting of time spent in various activities, and so-called time use modules have been included in surveys such as the LSMS. These modules typically ask about time spent in occupational activities of individual household members, and may also elicit information about time spent in collection of firewood and water, food preparation and other domestic duties. Occupational activities are typically expressed in broad categories, such as farm labor, off-farm labor or trading. Modules in these surveys are focused more on social and economic concerns involving labor inputs, rather than on physiological concerns about energy expenditure. Moreover, research indicates that individuals tend to overestimate the time allocated to specific activities when directly asked about those activities, with so-called stylized questions (Ver Ploeg et al. 2000).

For those measuring time allocation, the gold standard is the 24-hour time diary, in which respondents are led through a series of prompts about how they spent the previous day in defined time increments (Ver Ploeg et al. 2000). The approach is open-ended, allowing for a long list of specific activities to be recorded, rather than the broad aggregates described above. Routine fielding of time use surveys has become commonplace in Europe and the United States, in understanding and monitoring various aspects related to the labor force as well as to home production activities. Though they are less common in low and middle-income countries, they have been implemented in many countries throughout the world (Budlender 2007; Hirway 2010). Research has begun to link time-use surveys with the Compendium of Physical Activities. Such work could lead to a better understanding of the time spent in activities classified by type and intensity (Tudor-Locke et al. 2009).

In sum, various techniques exist that could be adapted to improve our understanding of how agricultural interventions could reduce labor requirements and energy expenditure of individuals from farm households. First approximation studies could be done that link existing data on the metabolic costs of activities to time use diary information (or perhaps even specific stylized questions), which provide details on how much time is spent in specific activities. This could work well, for example, with interventions that reduce the time spent walking to get firewood or water, since these are well studied activities, and the distance savings relates well to the time and energy cost savings. When more precision is needed in the amount of time spent in walking, accelerometers, or even pedometers, could provide more rigorous estimates. For activities with new tools or technologies for which there are no existing data, very small-scale studies could use portable indirect calorimetry to identify the energy costs of their use. However, ultimately, people live 24-hour days, so that savings in occupational activity might be used for some other activity, with unknown consequence for overall energy expenditure. Clearly more research is needed to understand how agricultural interventions could reduce overall energy expenditure.

## Household Level Measures

### Quantitative Measures from Food Expenditure Surveys

A household food consumption module is typically implemented as part of an income and expenditure or household budget survey, such as those used in the Living Standards Measurement Study. A key objective of these surveys is to assess poverty (Houghton et al. 2009; Ravallion 2010). Since food typically occupies the largest share of the poor's spending, substantial detail is recorded in this module. Information on spending or amounts consumed is collected on a substantial list of purchased items along with the value of food consumed from own production, from gifts, or from assistance. The reference period is commonly one week, but can also be the previous month. This type of survey is being used more commonly now to assess food security (Rose et al. 2002; 2002), and to provide insights on the design of fortification and other food based interventions (Rose et al. 2009; Dary et al. 2012; Imhoff-Kunsch et al. 2012). One limitation of this approach for nutritional purposes is that it does not address intakes by specific members of a household (Murphy et al. 2012). A second limitation is that household consumption is based on purchases during the interview-recall period, which makes sense for items that are purchased and consumed daily. But some bulk purchases may not reflect actual intake during the interview period. Food away from home and gifts of food to non-household members are often missed using this module, unless a separate set of questions are included to address each of these concerns. Another limitation is the categorization of the list of foods, which traditionally have been aggregated with an economist's eye towards expenditures, rather than a nutritionist's eye towards nutrient content. For example, vegetables are often grouped together irrespective of carotenoid content, since spending on them is relatively minor compared to staple grains. The latter, though nutritionally similar, are usually listed in a disaggregated way, since cereals often account for a large share of the budget.

One indicator that comes from this food consumption module is the per capita energy available to a household in their food consumption, which is derived from quantities consumed of each of the foods in the module and the amounts of energy in those foods obtained from food

composition databases. There are many sources of error in its calculation from respondent recall bias, to errors in assumptions about purchased versus cooked weight, edible portion and refuse considerations, as well as errors in food composition tables and the matching process therein. Despite this, the statistic is often used as the gold standard for validation of qualitative household diet diversity proxies discussed below (Hoddinott et al. 2002; IFPRI 2006). Rose and Charlton also used the statistic to develop a food security indicator based on a low energy availability to the household (Rose et al. 2002).

Food poverty is a second indicator that comes from household expenditure surveys. A household's expenditures are compared to the cost of a basic culturally-appropriate food basket that has been adjusted to be adequate in food energy. In the developing country context, calculation of food poverty thresholds is typically the first step in calculation of overall poverty. Rose used food poverty as a household food security indicator in South Africa (Rose et al. 2002; 2002). More recently Geniez and colleagues developed techniques to calculate both food poverty and nutrient poverty on the same population in Nepal as an illustration of the potential for an improved targeting of food security interventions (Geniez et al. 2013; Geniez et al. 2013).

In the last couple of years, the food consumption modules found on income and expenditure surveys are getting more attention by nutritionists (Dary et al. 2012; Fiedler et al. 2012). Assessing household consumption of food groups has been used for planning fortification studies, and so could shed light on bio-fortification and other specific crop/livestock interventions. Dary and Jariseta compared food group consumption from this type of module to that of a standard 24-hour recall using data from Uganda. They found that the consumption module accurately predicted the proportion of population that consumed the foods, and for these individuals, approximated the intakes from the 24-hour recall for most of the main potential food vehicles being explored (Dary et al. 2012). One of the advantages of this approach is the ready availability of such survey data in many countries of the world.

#### Household Proxy Indicators of Dietary Diversity

The Household Diet Diversity Score (HDDS) is a proxy measure of diet quality that relies on information about the household's consumption of foods from various food groups over the previous 24 hours. It has been refined recently by FAO nutritionists (Kennedy et al. 2010), based on earlier work on diversity measures by analysts at IFPRI and FANTA (Hoddinott et al. 2002; Swindale et al. 2006). Information is solicited from the household respondent simply on whether or not food was consumed from each of 16 food groups. This means that the interview process is much easier and quicker than a full quantitative 24-hour recall. After data collection, there is aggregation typically into 12 food groups to create a score, with one point allocated per food group, if any food in that group was consumed by the household in the previous day. Ranging from 0 to 12, the HDDS is typically analyzed using terciles or quartiles of the population distribution of scores.

Validation of the HDDS has been done using a variety of criteria to compare the scores to food security indicators, such as total and per capita food expenditure, number of meals consumed by different age groups, and total per capita energy availability. Perhaps the most comprehensive study was done by Hoddinot and Yohannes (Hoddinott et al. 2002), who

analyzed data from 10 countries to assess the validity of a diversity indicator using data from the food consumption modules on income and expenditure surveys. In a majority of samples, they found a positive statistically significant association with household energy availability, and even stronger associations with energy availability from non-staples, which they argue could be thought of as a measure of dietary quality. In a 3-country study of Burkina Faso, Lao PDR, and Northern Uganda, Kennedy and colleagues found a 12-item HDDS based on a 24-hour recall period to be significantly correlated with per capita food expenditures, and other related indicators of food security. Since universal thresholds have not been developed for the HDDS, it is difficult to evaluate it in terms of sensitivity, specificity, ROC area, or using other such measures of validation for categorical indicators.

Another proxy measure of household dietary diversity is the Food Consumption Score (FCS), a summary measure used by the World Food Program in vulnerability analysis and mapping. Developed in the mid-1990s in southern Africa, and used extensively in WFP reports since the mid-2000s, the measure is based on a household-level interview that collects information on the frequency with which basic food items or groups (e.g. maize, rice, cassava, vegetables) were consumed over the previous week (WFP 2009). Foods are grouped into 9 main groups, and the frequency of consumption (days/week) is multiplied by a weight for each group (0 to 4 points), representing nutrient density, and then summed to yield the FCS, which ranges from a minimum of 0 (no food consumption over the past week) to a maximum of 112 (consumption of all groups on all days). The measure combines information on both dietary quality and quantity, and households are typically divided into 3 groups based on pre-established cut-points representing poor, borderline, and acceptable consumption.

Weismann and colleagues at IFPRI (IFPRI 2006) compared a series of indicators, including food frequencies, diet diversity, and coping strategies to household energy availability per adult equivalent as determined from a full expenditure module. Using household data from Mali, Malawi, Philippines, Bangladesh, and Sri Lanka, probit analyses were conducted with a dichotomous variable of energy adequacy, and the ROC statistic derived from this analysis was used to assess the validity of the indicators. The set of food group frequency scores performed the best of the indicators, followed by coping strategies, diet diversity based on foods, diet diversity based on food groups, and meal frequency. For the food frequency variables, 'good' predictions (an ROC-statistic  $\geq 0.70$ ) were found in less than half of the tests. Coping strategies yielded good predictions in one third of tests, and the diversity indicators in less than 5% of tests. The WFP food consumption score which is based on weighting of food frequency variables was also tested, but did worse than using the full set of food frequency variables or a summary index of these variables based on equal weighting.

Weismann and colleagues (Weismann et al. 2009) also conducted a more focused study on the FCS in 3 countries – Haiti, Burundi, and Sri Lanka. They found positive and significant associations of the FCS with calorie consumption, particularly when small quantities were excluded from the calculations of food group consumption. And in two of the sites, they found the food frequency scores performed better than simpler measures such as diet diversity as determined by food or food group counts. Higher levels of disaggregation, i.e. going from the typical 8 food groups to 12, improved prediction but only marginally. The biggest concern with

the FCS score was that cut-offs for defining poor and borderline consumption were too low when assessed on comparisons to estimated energy deficiency from survey data.

Lovon also evaluated the performance of the FCS in three countries in Central America – El Salvador, Honduras, and Guatemala, using both the standard FCS survey approach as well as a detailed household food consumption module (Lovon 2012). They came to similar findings as the IFPRI study. That is, there were good correlations of the FCS with household energy availability, but the cut-points used by WFP were too low to accurately predict energy shortfalls. Mathiassen used household income and expenditure data from Nepal, Malawi, and Uganda to do further validation testing of the FCS (Mathiassen 2013). She found similar shortcomings in the ROC-tests of the FCS food consumption groups when compared to household food energy availability, as had been seen by previous authors. Mathiassen argues that the real problem is the choice of 'gold standard', because there are known errors in the household energy availability statistic, and because the FCS also measures quality aspects of the diet, not just overall energy consumption. She recommends further research into using a food poverty-type benchmark (i.e. household food expenditures in relation to food poverty thresholds), since this would incorporate elements of both diet quantity and quality.

Some analysts have recommended the exclusion of foods with small quantities of consumption from a validation of diet diversity indicators, because they may falsely inflate a diversity score. For example, inclusion of a small amount of milk in a cup of tea, or some onions to season a dish does not have nutritional significance, but would still increase the overall diversity score. The advantage of this approach for prediction was demonstrated by Weismann (Weismann et al. 2009). The WFP study in Central America also showed the benefit of this, but went even further in understanding how this might be done in the field. Small dietary amounts of foods were excluded in one of two ways: (1) with a direct question of respondents about how many days each food item was consumed in small amounts (1 tbsp or less); or (2) exclusion of food items with quantities less than 15g, as identified by the comprehensive food consumption data module. Interestingly, the second option worked to improve predictive power of the FCS, but the first did not. The authors attribute this to the difficulties in the interview process for the respondent to identify what was consumed in small quantities – particularly for food groups like vegetables, which contain many possible food items. This is problematic, because elimination of small amounts for a proxy technique will need to occur in the interview process itself, as there will be no gold standard survey to delete food items in a post-hoc manner.

In sum, a number of indicators of household food consumption have been used to assess the food security situation of households, and could be used in the design of food security as well as food fortification interventions. These include quantitative indicators from a food expenditure module that include the total energy available to the household, food poverty, and the consumption of specific food groups. They also include the simpler proxy indicators, such as the Household Diet Diversity Score and the Food Consumption Score. The latter indicators have done fairly well for broad classification, but are probably not adequate for rigorous evaluation research. Recent validation studies evaluating performance of these indicators show only moderate predictive power, and by using 'small quantity' adjustments, may have overstated their accuracy. Improved field techniques would need to be developed to address this small quantity exclusion problem.

## National Level Measures

Food supply data is collected at the national level, and typically assembled by ministries of agriculture, or statistical agencies, with the technical assistance from FAO on their Food Balance Sheet methodology. The process involves collating agriculture, livestock, and aquaculture production data by commodity, with information on losses, usage for seed and feed, imports, exports, and existing stocks. The amount available for human consumption is calculated by subtraction for each commodity, and the nutrient content in that supply is assessed from food composition data. FAO has used the energy available in the food supply, along with demographic and other information to estimate its prevalence of undernourishment indicator, and others have attempted to assess overall diet quality with food supply data. There are numerous places for error to be introduced in this approach, and since data are national in character, statements about variation of nutrient availability, or problems, within a country cannot be made. Still, the approach is one of the few that allows for long-run trend analysis within countries, or comparisons between countries. Three specific indicators have been derived from these data and are discussed below.

### Prevalence of Undernourishment (PoU)

The prevalence of undernourishment (PoU) is the estimated proportion of a population with dietary energy consumption below an acceptable minimum. This is the main indicator that FAO uses in monitoring progress in meeting the Millennium Development Goal hunger targets. The PoU is derived using multiple data sources to create a synthetic distribution of energy intake, assumed to be skew-normal. The mean of this distribution is the dietary energy available per person, and is calculated from Food Balance Sheet data. The coefficient of variation and skewness of this synthetic distribution is estimated from nationally representative household survey data on food consumption, which typically comes from income and expenditure surveys. The PoU estimate is the percentage of the population below a given threshold of this energy consumption distribution. This threshold is defined as the minimum level of dietary energy required to maintain a minimum acceptable adult weight for height while performing sedentary levels of physical activity. This threshold comes from aggregating established energy standards for different age and gender groups using data on population structures compiled by the U.N. Population Division from national censuses or surveys, and anthropometric data from national surveys.

The validity of the indicator is subject to the quality of the data used in its construction, and because there are so many components, there are many sources of error (Cafiero 2013). This also means that results may vary systematically between countries. Svedberg notes that agricultural production data from Sub-Saharan Africa can vary greatly by source and may underestimate smallholder production and consumption leading to systematic overestimates of the PoU and wide margins of error in the estimates (Svedberg 1999). Better agricultural production estimates from South Asia relative to SSA may explain why South Asian countries tend to have lower prevalence of undernourishment but higher prevalence of stunting and underweight. Masset reported a correlation coefficient of only 0.38 between countries' PoU and prevalence of underweight, and a correlation of 0.44 with stunting (Masset 2011). However,

PoU may vary from anthropometric outcomes due to the effects of health on child growth. The PoU is based on aggregate data, so may not be sensitive to within-country variation in consumption due to variation in household resources or market level fluctuations in commodity price and wages. The minimum energy requirement assumes sedentary activity which may not be accurate for low-income populations that are dependent on manual labor for their livelihoods, so the PoU is best thought of as a conservative estimate of food deprivation (Cafiero 2013).

### Healthy Eating Index – Food Supply

Recent research in the United States has examined the composition of the food supply at a national level to assess the overall dietary quality of the food available for consumption. Krebs-Smith and colleagues have applied the Healthy Eating Index criteria to evaluate the degree to which the U.S. food supply is consistent with dietary recommendations (Krebs-Smith et al. 2010). Their analysis was based on Food Availability Data compiled by the U.S. Department of Agriculture's Economic Research Service, as well as other national datasets on food losses, nutrient composition, and salt consumption. The Healthy Eating Index from 2005 was used for this analysis, which rates diets on a 100-point scale based on the consumption of different food groups (e.g. dairy products, meats and beans, fruits, etc.), as well as saturated fats, sodium, and calories from solid fats, sugar, and alcohol (Guenther et al. 2007). The research showed that although this index of the quality of the U.S. food supply improved by about 10 points between 1970 and 2007, it never reached 60 points on the 100-point scale. The authors suggest that more deliberate efforts on the part of policymakers are needed to supply foods that are more closely aligned with nutritional recommendations. This study demonstrates that the composition of national food supply data can be monitored over time to assess progress in aligning the supply with overall nutritional goals. As with the other uses of national point estimate data, there are limitations to this approach. As Cafiero has pointed out, one major concern is that there may have been improvements in the overall quality, but this could be a result of improvements in some segments of the population, combined with a worsening of dietary quality in other segments (Cafiero 2013).

### Q -Score

Work on evaluating the diet quality of the food supply was initially developed over 30 years ago by Qreshi, an FAO regional nutrition officer (Qreshi 1982). He also proposed a 100-point index, known as the Q-scor, in which points were awarded based on the percentage contribution to the dietary energy supply from different food groups, such as cereals, animal products, pulses and beans, etc. This score was used to evaluate differences in diet quality of the food supply among 30 countries in Asia and the Pacific regions, and to monitor changes over the period from the early- to late-1980s. The same concerns with data quality and aggregation for the previously- discussed national measures apply to this indicator as well.

### **Data systems for monitoring and evaluation**

A number of active data collection systems are currently in place that capture the indicators at the individual, household, and national levels described above and that shed light on the connections between agriculture and nutrition. This section describes those systems.

### Demographic and Health Surveys (DHS)

Demographic and Health Surveys (DHS) are large, nationally representative surveys that collect data on population, health and nutrition and focus mostly on women of reproductive age, and their children under 5 years of age (DHS). They are usually done every 5 years, and have been conducted in 90 low and middle income countries of Africa, the Near East, Asia and Latin America. The surveys began in 1985 and have been conducted almost 300 times since. DHS surveys cover a diverse range of health and family planning topics. The nutrition information collected by DHS includes data on breastfeeding practices, anemia prevalence, child feeding practices, use of supplements, use of iodized salt and child anthropometrics. Some DHS protocols collect blood samples and test for hemoglobin, cholesterol and serum retinol. Questions on child feeding practices include information on the frequency of consumption of food groups over the past 24 hours or 1 week. Similar questions were asked of women in one of the recent DHS cycles. USAID funds much of this work, ICF International manages the data consultation and dissemination, and the actual surveys are conducted by national statistical offices (Fiedler et al. 2012).

### Multiple Indicator Cluster Surveys (MICS)

Multiple Indicator Cluster Surveys (MICS) collect nationally representative data on women and children for many of the same indicators as the DHS. These include anthropometric measurements of children, breastfeeding and complementary feeding indicators, measures of anemia, use of iodized salt, multivitamins among pregnant women, vitamin A supplements and use of oral rehydration salts and zinc to manage diarrhea. The complementary feeding information can be used to generate indicators of minimum dietary diversity among children. MICS surveys began in 1995 in more than 60 countries, and have been conducted approximately every five years since then. UNICEF assists countries in collecting and analyzing this survey data (UNICEF). MICS surveys are validated and standardized to generate internationally comparable indicators to inform evidence-based policies and programs. Because data collected under MICS is similar to DHS, the two organizations have coordinated to avoid duplication and to expand their potential coverage (UNICEF).

### Living Standards Measurement Study (LSMS)

The Living Standard Measurement Study (LSMS) is a program that fields nationally representative household income and expenditure surveys to assess living standards, measure poverty, and address other social and economic policy questions. A key component of the LSMS is the food consumption module, which includes detailed information on household foods purchased and consumed from own production, usually for a 1-week period. The LSMS collects data on a number of other topics, including education, agriculture, housing and utilities, health and social welfare programs. The surveys may also include food security questions, health utilization questions, child anthropometry, and maternal time use questions. The data are collected and analyzed by national statistical offices according to policy priorities within those countries. One hundred LSMS surveys have been conducted in 38 countries since 1985. The Development Research Group (DECRG) within the World Bank established the LSMS in 1980

to improve the type and quality of household data collected for policy decisions (WorldBank 2012).

### International Household Survey Network (IHSN)

The International Household Survey Network (IHSN) was created to improve the availability, accessibility and quality of survey data in developing countries to facilitate analysis and use of the data by policy makers and researchers (IHSN). The organization works to coordinate survey timing and methodology to achieve internationally comparable data collected under best practices. While the IHSN does not distribute survey data, the website provides a central survey data catalog containing metadata on surveys collected by national statistical offices in 100 countries. By informing data users of the availability and content of data from various countries, IHSN can facilitate the construction of indicators for cross country comparisons. The IHSN also conducts special projects to identify survey data across countries relevant to specific uses. Two such projects include Measuring Food Consumption, which documents data items from household expenditure and consumption surveys, and Data for Food Fortification Programs, which documents data from household income and expenditure surveys.

### Vulnerability Analysis and Mapping Surveys (VAM)

The Vulnerability Analysis and Mapping (VAM) unit at the World Food Programme collects and analyzes household food security and market-level price data with the objective of identifying vulnerable populations in need of assistance, especially in emergency situations (WFP). Comprehensive food security assessments in developing countries are conducted during non-crisis periods to understand the ongoing determinants of food insecurity and to establish baseline measurements for subsequent survey work. Emergency food security assessments are conducted in response to shocks on an as-need basis, and a food security monitoring system is used to collect data on an ongoing basis in specific areas or countries experiencing chronic vulnerability. Common to all of these household surveys is a food consumption module that contains information on the frequency of foods consumed by the household in the previous week, and allows for calculation of the Food Consumption Score. They also contain a module on coping strategies, and a brief module on food expenditures. A variety of other socio-economic and demographic variables are collected depending on the survey. The unit also coordinates the collection of food price data in 72 countries, and uses this for market assessments, including price trend analysis. Several key indicators are produced and tracked, including a "terms of trade" variable (the price of a kilo of cereal divided by the monthly casual labor wage) and a consumer food price index. Indicators generated from remotely sensed and field collected data are also used by VAM to assess the vulnerability of agricultural communities that are dependent on home production.

### FAOSTAT

FAOSTAT is a repository of information from agricultural sources that includes data on national food supplies, including food balance sheet data, for 178 countries from 1961 to 2009 (FAO 2013). Items listed include agricultural, livestock, and fisheries products, including alcohol, oils, and sweeteners, and quantities are reported for trade, production, inventory, waste, and, by

subtraction, amounts left over for human consumption. FAOSTAT provides descriptive statistics of the variables in the database as well as the capacity to perform some correlational analyses in multiple variables. Population by country broken down by gender, urban/rural, agricultural and non-agricultural populations, and the total economically active population are available for the years 1961 through 2010. In addition to food balance sheet data, producer prices by commodity and a producer price index are expressed in local currencies with a conversion table provided to compare across time periods.

## Recommendations

Recommendations have been developed based on the findings above. These are placed into three broad groups: those concerning current best practices, those related to research and development in the indicator field, and those related to improved interagency collaboration in nutritional measurement, or what we refer to as nutritional diplomacy.

### Best Practices

To evaluate agricultural programs and policies, assess outcomes proximal to interventions. Clarity is needed on where interventions are made within the causal framework and what they plan to change. Assessing outcomes close to the point of intervention allows for understanding if objectives were met. Distal impacts can also be measured, but would likely reflect on other factors not addressed by a programme. For example, using anthropometry to evaluate an agricultural intervention can be misleading since nutritional status is influenced by health, sanitation, and care.

Continue to foster multiple data systems with a diverse set of indicators for monitoring of food and nutrition security. Diverse indicators allow for triangulation and a better understanding of changes, so we should continue to foster multiple data systems that can collect a diverse set of indicators for monitoring of food and nutrition security. The women's diet diversity score has been well validated and the instrument that it is based on, as well as the one for young children, can get widespread use if it is continued on the DHS and MICS survey platform. This is a relatively quick tool that can provide useful information on diversity of diets in key target populations. The food consumption score and the household diet diversity score provide simple ways to monitor diversity of household consumption, and should continue to be included in WFP's VAM survey system, in addition to the LSMS. Where possible, it would make sense for LSMS to begin experimenting with a 24-hour recall approach on a target individual in the household. This would allow for a greater understanding of how household food gets translated into individual consumption. Finally, the food balance sheet data, and the related prevalence of undernourishment indicator should be continued, as a way of providing insights into the quantitative availability dimension of food security. For all its critiques, it is the longest running and most widespread indicator we have in food security measurement that allows us to draw comparisons across countries or over time.

### Research and Development

New validation research should integrate several indicators and include information on costs. Often researchers focus their validation efforts on a new indicator they are trying to develop. But, there is wide variation in the gold standards employed, the criteria for judging success, and the country-level data employed to test hypotheses. This makes it difficult to draw conclusions on which of the many indicators is more effective at capturing specific dimensions of a problem. More integrated research is needed that allows us to understand, in a comparative way, how different types of indicators perform under the same conditions.

Much of the testing of new proxy indicators has been justified on the grounds that the gold standard method (e.g. multiple 24-hour recalls) is too costly. Yet many of these validation studies have tested new indicators using the very same instruments for which the gold standard measure was obtained. Would there have been much savings if the survey still needed to be fielded throughout the country, but used a shorter interview module? We need to find out more about the cost savings of these proxy tools in order to make useful decisions about which indicator to support.

Focus more on making gold standards less expensive, rather than making more cheap proxies. It would seem that a significant part of the cost of doing nationally representative surveys is in sampling remote households. If so, the additional cost of spending a bit longer in the interview process to implement a gold standard measure might be a wise investment. Technological changes have opened up new possibilities for implementing surveys that could bring down overall costs. Distance learning using online courses has increased tremendously, perhaps making it possible to develop human capacity to understand and implement complex modules (e.g. 24-hour recall), or at least reduce the cost of interviewer training. Smart phones and tablets offer applications that can simplify the interview process, reduce data entry errors and costs, and offer rapid uploading of data. Given these developments and new ones that are unforeseen, as well as the relatively mediocre performance of many diet proxies, over the long range it seems to make more sense to develop our abilities to implement state-of-the-art measurement procedures more economically, than to continue down the road of proxy approaches.

### Nutritional Diplomacy

Seek collaboration in survey implementation. The costs involved with reliable data collection imply that we should look for synergies wherever possible. Teaming up in data collection can take lots of different forms. One approach is to have agencies pay for a module to be included in an existing survey data collection. For example, the World Food Programme has sponsored the data collection of food security modules on the World Bank's LSMS surveys. The cost of including a household food frequency module is much less for WFP than fielding an entire survey, and it allows them to calculate the food consumption score on a nationally representative sample. The World Bank also benefits by having a widely-used indicator of food consumption, allowing researchers to conduct additional analyses on country-level situations. Collaboration also makes sense when agencies collect similar sorts of data. The Demographic and Health Surveys are very similar to the Multiple Indicator Cluster Survey. Realizing this,

UNICEF and the USAID-sponsored Measure program have worked together to coordinate survey implementation. The end result is less duplication and better spacing of data-points in a country.

Seek collaboration in instrument and indicator development. Many specific indicators within a broad class are very similar in nature and are based on many of the same raw data elements. This is certainly true for the diet diversity indicators. While we continue to advance our understanding of which specific approaches work best, we suggest an open, harmonized platform of data collection that would allow for different indicators of the same class to be calculated from the same data. A specific example of this has taken place with collaboration between FAO, which supports the household diet diversity score and WFP, which collects the data for the food consumption score. The two agencies coordinated a harmonization conference on the diversity indicators. One result was for each to modify their data collection instrument, so that both types of indicators could be calculated from the same data, allowing both agencies to meet their needs.

Use representative expert panels to develop consensus on specific indicators and on an overall measurement approach. Currently, there is a good amount of published literature on the performance of specific indicators. But, as indicated previously, testing has been done in diverse ways, with different populations. And there are many different variations of dietary indicators, for example, with different weighting schemes and cut-points. Perhaps more difficult is that institutions and individuals develop attachments and even constituencies around the specific variation of indicator they have developed. To be more efficient in our understanding of population-level changes, we should develop some standardization in the way indicator data are collected and analyzed. Weather forecasters, particularly in the prediction of hurricanes, use a number of different models that were developed at different institutions. But they are standardized models, so another forecaster understands what went into the prediction, and there is constant learning from their application.

To standardize and develop widespread use of specific tools, agreement is needed by authoritative sources. Use of expert panels is a way to bring some consensus and clarity to the issue. Panels composed of a diverse set of experts from a broad set of disciplines and countries, and financed jointly by diverse agencies can facilitate this approach. 'Diplomacy' to promote recommendations from current scientific output is needed periodically, and it is long overdue in this field. Results of these panels should be distributed widely, including to academic journal editors, so that researchers, agency officers and ministry officials use common approaches to collecting and analyzing data. Having a small set of different indicators that are well known allows the international community to improve understanding of a situation, rather than constantly being confused by new and different measurement methods.

The threshold problem in food security assessment needs particular attention. Many indicators have been validated using continuous measures. Ultimately, thresholds are needed so we can count the affected and determine the magnitude of a problem. Unfortunately, too often cut-off points have been determined in a case-specific or ad-hoc way. There are no God-given thresholds, they require judgment. Expert interdisciplinary panels are needed to make these judgments about where cut-points should be drawn, and to communicate the method and

reasoning behind their approach in a transparent way. This occurred in the anthropometry field decades ago. Everyone knows that stunting refers to the condition of a child's height for a given age being less than 2 standard deviations below the reference median. This is a statistics-based cut-off, but it has clear meaning and has achieved widespread acceptance. If we really want to highlight the importance of diet, we need similar easy to understand thresholds for dietary indicators. At a minimum, the expert panels should include professionals from nutrition, economics, statistics, communications, and policy fields.

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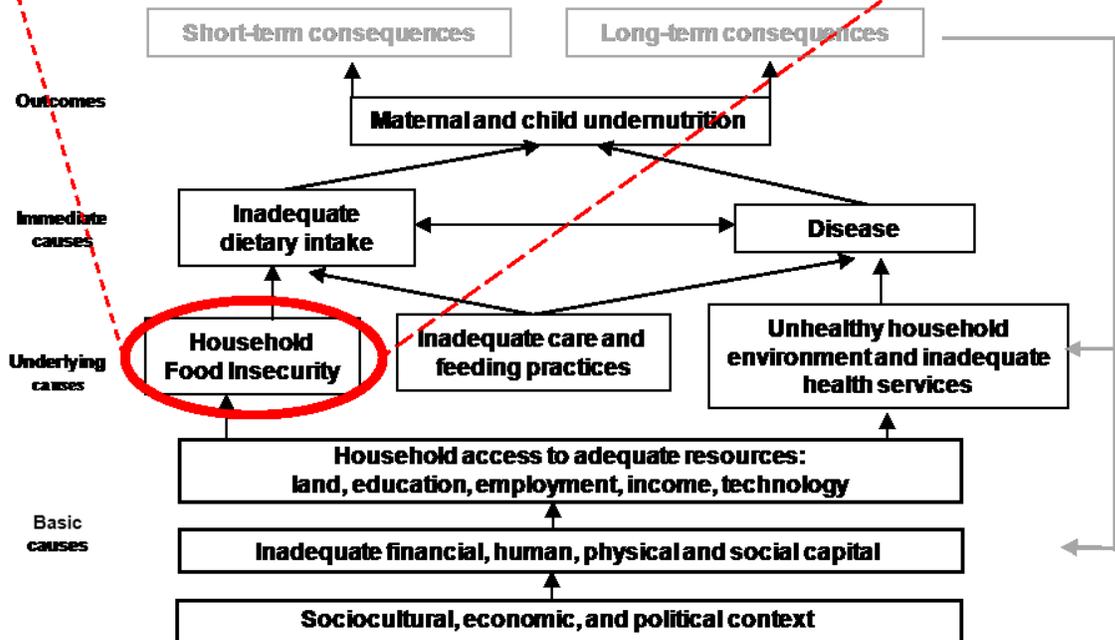
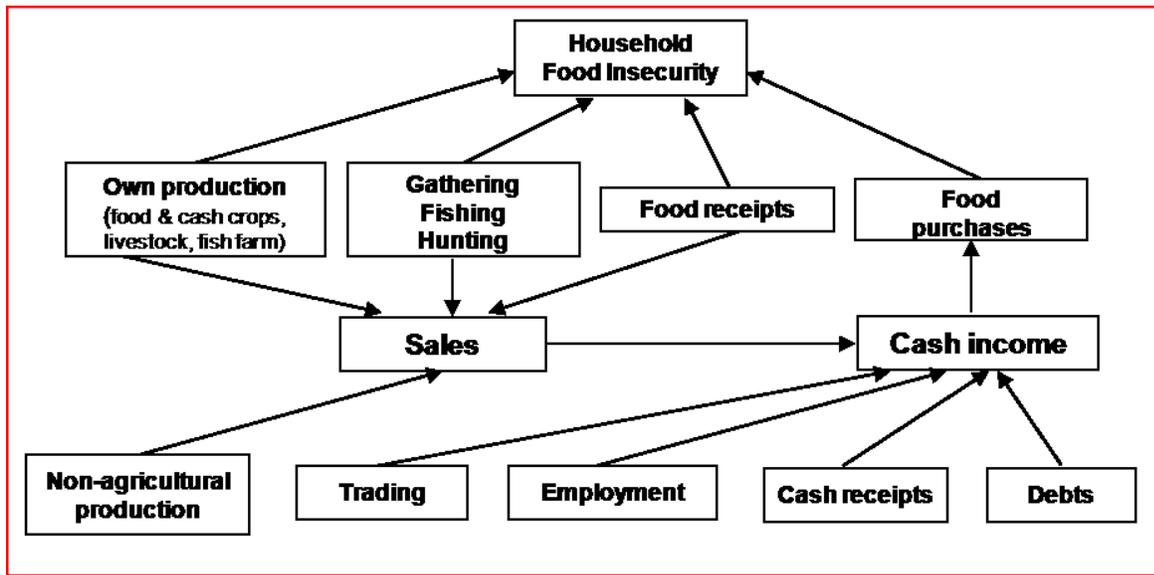
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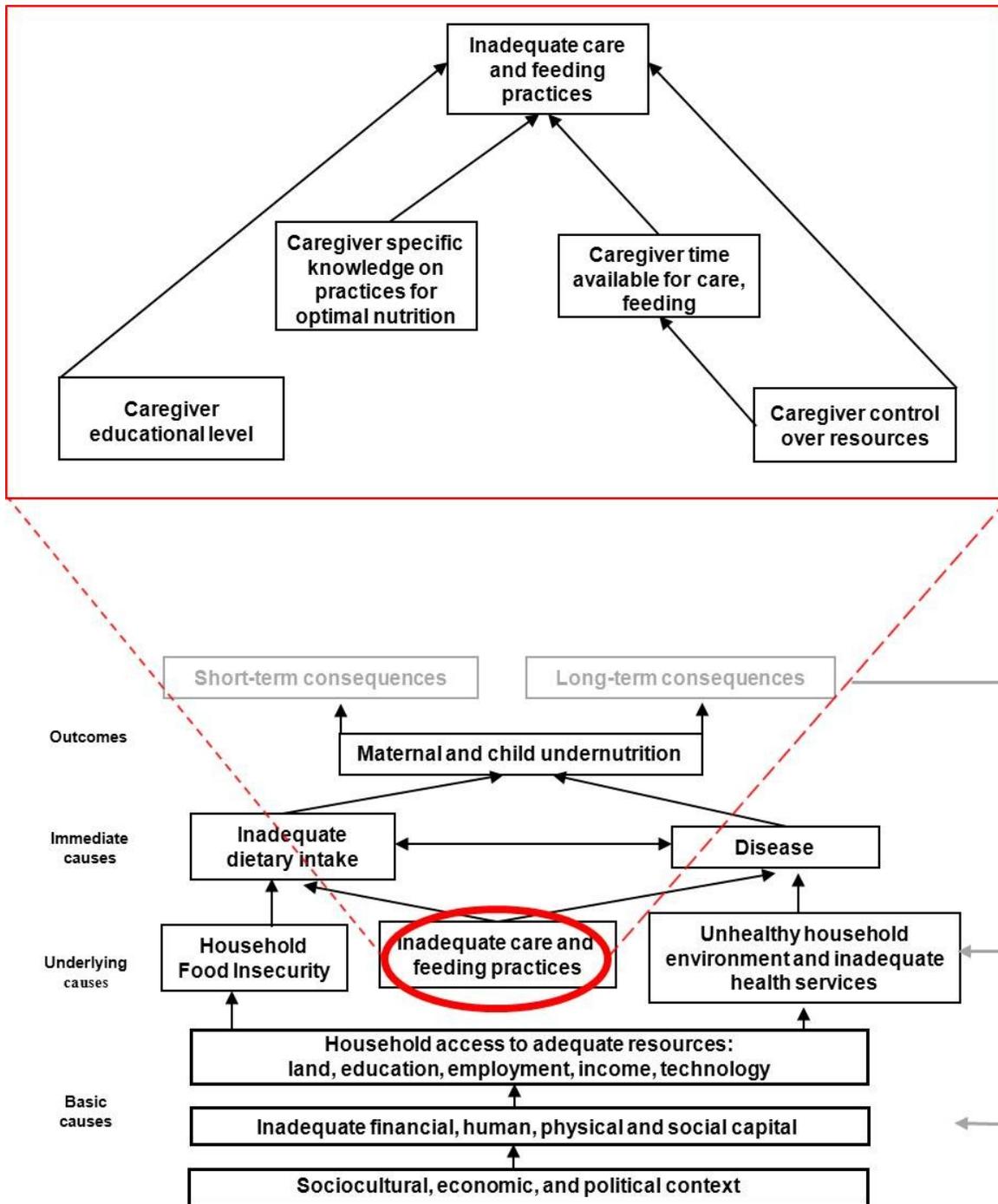
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**Figure 1. Causal framework on malnutrition with zoom-in on household food security**



Adapted from: Fanzo et al. 2013; UNICEF 2013; WFP, 2005

**Figure 2. Causal framework on malnutrition with zoom-in on care and feeding practices**



Adapted from: UNICEF 2013; WFP, 2005

**Table 1. Agricultural and food-based interventions that can improve dietary status**

<b>Intervention</b>	<b>Individual*</b>	<b>Household*</b>	<b>Nation*</b>
<b>Increasing Own Production</b>			
Horticultural Interventions	1	2	
Homestead Gardening	1	2	
Animal Husbandry and Aquaculture	1	2	
Biofortification	1		
Gender-Sensitive Agriculture		1	2
Agricultural Commercialization		1	2
Farm Subsidies and Pricing Policies		1	2
Agricultural Conservation	2	1	
<b>Increasing Purchasing Power and Food Quality</b>			
Consumer Subsidies		1	2
Unconditional Cash Transfers	2	1	
Conditional Cash Transfers	2	1	
Fortification of Foods	1	2	
Iodized Salt	1	2	
<b>Reducing Energy Expenditure</b>			
Labor-saving agricultural technologies	1	2	
Water conservation	1	2	
Forestry projects	1	2	
<b>Care-Based Interventions Linked to Food</b>			
Women's Empowerment, Income Projects	2	1	
Breastfeeding Promotion	1		
Complementary Feeding Practices Education	1		
Dietary Diversity Promotion	1	2	
Community Health Workers	1		
General Education	2	1	

\* Outcomes should be measured at levels most proximal to the intervention. The numbers in these columns indicate the order in which outcomes are proximal to the intervention with 1

being the more proximal and 2 being more distal. No number indicates that impacts are unlikely to be measurable at that level.

**Table 2. Selected validation studies of proxy indicators to assess dietary diversity of individuals**

Author	Sample	Benchmark	Data collection	Proxy indicators	Eliminated small quantities	Type of analysis		
						Sensitivity/Specificity	AUC	Other
Hatloy '98	Mali 13-58 months	MAR	3 day weighed record	Foods, Groups	No	Yes	No	SC
Mirmiran '04	Tehran 10-18 years	MAR	2 day 24-hour recall	Groups	No	No	No	SC
Steyn '06	South Africa 1-8 years	MAR	1-3 day 24-hour recall	Foods, Groups	No	Yes	No	SC
Kennedy '07	Philippines 24-71 months	MPA	1 day 24-hour recall	Groups	No/Yes	Yes	No	SC, LR
FANTA '07	9 countries 6-23 months	MMDA	1-2 day food frequency	2 Grouping systems	No/Yes	Yes	Yes	SC
Arimond '10	5 countries adult women	MPA	1 day 24-hour recall	4 Grouping systems	No/Yes	Yes	Yes	SC, LR

MAR = mean adequacy ratio; MPA = mean probability of adequacy; MMDA = mean micronutrient density adequacy  
 AUC = area under the receiver operating characteristic curve; SC = simple correlation; LR = linear regression