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Strengthening the engagement of food and health systems to improve nutrition security: Synthesis and overview of approaches to address malnutrition

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ABSTRACT

The nutritional status of populations often serves as a proxy for the world's wider progress and setbacks. Currently, we are facing a crisis: a double burden of both undernutrition and overweight and obesity compounded with food insecurity in many countries. In an increasingly globalized world and interconnected food system, subjected to the pressures of growing populations, climate variability and food price volatility, no country or population is immune to the challenges that lay ahead. While unsettling, we now have more information, both in science and in practice, on how to improve the global food system. The solutions are inherently trans-sectoral, engaging practitioners and experts across agriculture, rural development and public health. Improvements can be driven by resilient food system approaches to ensure better utilization of food and dietary diversity and quality. Strengthening food systems should be complemented with engagement of the public health and the water, sanitation and hygiene systems to ensure adequate food and nutrition security, health and wellbeing for all.

1. Introduction: the current global nutrition situation

Despite increased attention to nutrition in recent years and its importance in development, undernutrition remains a devastating multi-faceted problem for infants, young children, and women around the world. Undernutrition results in poor health, increased morbidity, mortality, and poor health into adulthood, affecting social and economic development of nations. Overweight and obesity are concurrently growing problems in all segments of the global population, linked to changing diets and activity patterns, which also increase the risk of serious health problems, notably non-communicable diseases. The overweight and obesity pandemic is not just a problem of high-income countries. Increased prevalence of overweight in both children and adults is on the rise in low- and middle-income countries as well (Popkin et al., 2012).

This paper reviews and summarizes the sectors and systems that are critically important in mitigating the current, global malnutrition situation. Working trans-sectorally and trans-disciplinary across agriculture, health and water sectors and systems for improved nutrition, in theory, are necessary but how to effectively engage is less straightforward. Using an extensive literature base, newer approaches that propose the engagement of multiple systems are presented as potential ways to integrate interventions.

1.1. The global burden of malnutrition

Global prevalence of stunting, which reflects chronic undernutrition during the early stages of life causing children the inability to grow to their full genetic potential, both mentally and physically, has declined from 40% in 1990 to 26% currently (Black et al., 2013; UNICEF, 2013). Yet there are still an estimated 162 million children who remain moderately or severely stunted (Black et al., 2013; UNICEF, 2013). Wasting, which reflects acute malnutrition and is a strong predictor of mortality among children, impacts 52 million children under five years of age, with the highest prevalence in South Asia. There has been an 11% decrease since 1990 (Black et al., 2013). Deficiencies of essential vitamins and minerals continue to be widespread. A larger number of the world's population is affected by micronutrient deficiencies than overt hunger. The most common micronutrient deficiencies include iron, zinc, vitamin A, and also iodine, folate, vitamin B12 and other B vitamins (Micronutrient Initiative, 2009). Deficiencies in these key nutrients have significant adverse effects on child survival and development, as well as maternal health.

On the other end of the malnutrition spectrum, an estimated 43 million children under five years of age are overweight, and two-thirds of those children reside in low- and middle-income countries (Black et al., 2013; UNICEF, 2013). Prevalence of low body mass index (BMI) in adult women has decreased in Africa and Asia

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in the last four decades, but still exceeds 10% in the two regions. At the same time, prevalence of overweight and obesity has increased in all regions (Black et al., 2013).

1.2. The causal, vicious cycle of malnutrition

Over one billion people live in extreme poverty, earning less than $1.25 a day (Chen and Ravallion, 2008). More than two-thirds of these extremely poor people go hungry (FAO, 2012) and are five times more likely to die before 5 years of age (UNICEF, 2013). In the past, poverty was associated with severe forms of acute undernutrition, particularly in children, that were frequently seen in times of famine and hunger. Today, we know that poverty affects nutrition throughout the whole life-span and has a broad spectrum of manifestations, such as increased propensity to many diseases, both infectious and non-communicable, reduced physical work capacity, a lower learning and intellectual capacity, increased exposure and vulnerability to lifestyle-related and environmental risks, reduced participation in social decisions, and negligible capacity of resolution in the face of environmental challenges (Peña and Bacallao, 2002). This lack of food and poor nutrition impacts a person's ability to earn a living, creating a vicious cycle of poverty and malnutrition. Individuals lose 10% of their potential lifetime earnings, and countries lose 2–3% of their GDP due to undernutrition (World Bank, 2006).

Groups vulnerable to malnutrition typically include those with increased nutrient requirements throughout the lifecycle, but also those who often have less control over (or the privilege of) making food choices and purchases. Young children, adolescent girls, pregnant and lactating women, and people who are ill or immune-compromised are particularly vulnerable to poor nutritional outcomes (Black et al., 2008). Inadequate nutrition during the first year of life has important consequences into adulthood (Martorell et al., 2010; Adair et al., 2013). The nutritional needs of children under two years of age are critical for growth, cognitive development and long-lasting productivity into adulthood (Victora et al., 2008). Most growth faltering occurs between the ages of six and 24 months when a child is no longer protected by exclusive breastfeeding and is more exposed to disease and infection through contaminated food or water. Some evidence suggests that a child adequately nourished after 24 months of age is unlikely to recover growth 'lost' in the first two years as a result of malnutrition (Shrimpton et al., 2001; Victora et al., 2010).

Adolescence is a period of rapid growth during which many important physical, intellectual, and psychological events take place. There is a pronounced increase in the nutritional demand rarely satisfied in the poor, who carry the cumulative burden of past deprivation and lack of access to adequate nutrition and sanitation. Nourished girls have earlier menarche and optimal growth, particularly height. Girls living in poverty take longer to grow and are usually still growing during their first pregnancy and competing for nutrients with the developing fetus (Prentice et al., 2013), resulting in potentially devastating outcomes for both the young mother and her newborn child.

There are also increased nutrient needs during pregnancy. Inadequate food intake during pregnancy can increase the risk of delivering an undernourished baby. During pregnancy, poor nutrition is a common cause of intrauterine growth restriction and low birth weight (Black et al., 2008, 2013). Newborns with low birth weight have greater mortality risk, are more frequently affected and less resistant to infectious diseases during early postnatal life, and are candidates for future non-communicable diseases largely due to fetal programming (Godfrey and Barker, 2001). Maternal obesity and excessive weight gain during pregnancy are also associated with socio-demographic, lifestyle, and genetic factors and with increased risks of adverse maternal, fetal and childhood outcomes (Gaillard et al., 2013; Kramer et al., 1990). When mothers are breastfeeding they require extra energy, which they can get from the reserves they have built up during pregnancy and from eating extra food after birth in optimal environments where food is available and of nutritional quality (Black et al., 2008).

2. Nutrition Is a central component of food security

Nutrition is the process of obtaining, utilizing and absorbing nutrients in relation to what is required for growth, health and social wellbeing. Not receiving the right amount of food and nutrients or the right types of nutrients can lead to undernutrition or overweight, which in turn, has serious deleterious effects on health, development, and productivity. If one looks back over the last twenty years, explicitly defining and including nutrition in the "food security" mandate has proven difficult. The 1996 World Food Summit (WFS) adopted the following definition: "Food security exists when all people at all times have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). For an active and healthy life, people need the right balance of macro and micronutrients, making nutrition central to attaining food security. While the definition includes nutrition, the focus remains solely on food aspects, which does not provide a holistic picture of how to improve nutritional status of populations. A more holistic picture would be one that includes health, sanitation, water access, education and gender dimensions.

In 2012, FAO developed the following draft formulation for the Committee on Food Security (CFS): to include nutrition: "Nutrition security exists when all people at all times consume food of sufficient quantity and quality in terms of variety, diversity, nutrient content and safety to meet their dietary needs and food preferences for an active and healthy life, coupled with a sanitary environment, adequate health, education and care" (FAO/AGN, 2012). While more comprehensive, this definition was not officially endorsed or adopted by Member States.

The achievement of food security depends upon four distinct but connected components of a dynamic food system. The first is *food availability*, which refers to ensuring sufficient quantity and diversity of food is available for consumption from the farm, the marketplace or elsewhere. Such food can be supplied through household production, other domestic output, commercial imports, or food assistance. Second, *food access* refers to households having the physical and financial resources required to obtain appropriate foods for a nutritious diet. Access depends on income available to the household, on the distribution of income within the household, distance to markets, and on the price of food. Third, *food utilization* implies the capacity and resources necessary to use food appropriately to support healthy diets including sufficient energy and essential nutrients, potable water and adequate sanitation. Effective food utilization depends, in large measure, on knowledge within the household of food storage and processing techniques, basic principles of nutrition and proper child-care, and illness management (FAO, 1996; USAID, 2000). *Stability* is often considered a fourth component, which constitutes the stability of the food supply. Stability is reliant on food imports and domestic production, and can be negatively impacted by disruptions in the food supply such as with price volatility and conflicts. Instability can immediately affect consumers, especially those in low-income countries who spend a large share of their income on food. Often, what is purchased can be of low nutritional quality, made up mainly of grain staple crops (Bouis et al., 2011).

3. Engaging the key sectors and systems

To ensure improvements in food and nutrition security for individuals, households or communities, multi-sectoral approaches

have been proposed to be essential (World Bank, 2012). While well intentioned, effectively engaging across diverse sectors and distinct systems has proven to be complex. At minimum, there are three key sectors that need to engage, collaborate and contribute to nutrition improvements: agriculture, health and water sectors. These sectors have the capability of injecting nutrition across functioning and effective food, health, and water and sanitation systems (Field, 1987). The interactions between health, nutrition, water and agriculture are mutual: agriculture and water affects nutrition and health, and nutrition and health affects agriculture – both positively and negatively (Hawkes and Ruel, 2006).

Food Systems: Synergistically, if food production systems are inadequate, there can be negative effects on health, whereas an interconnected and sustainable food system can improve health of communities. Health is considered a primary goal and endpoint of food systems (Pinstrup-Andersen, 2012). Similarly, poor health and dysfunctional health systems can limit agricultural productivity but improved health and nutrition allows for enhancements in agriculture outputs (Hawkes and Ruel, 2006). With improvements in agricultural production, household income can potentially increase and with that, more can be spent on household healthcare and other goods. Additional income can also be used to purchase higher-quality more nutritious food for a more diverse diet. Changes in agricultural production can also result in the introduction of new foods into diets (Hoddinott, 2012).

A food system is a process that turns natural and human-made resources and inputs into food. It consists of the resources (such as land, water, a healthy workforce, and sunshine); inputs (such as plant nutrients, pest-control measures, and knowledge); primary agricultural production; secondary production or processing; and transport, storage, and exchange activities to make the food available at the time and place and in the form desired by consumers (Pinstrup-Andersen, 2012).

Health and Water Systems: A functioning primary health care system, complemented with improved water and sanitation, can improve nutritional status. Infectious disease burden impedes consumption of food and the body's ability to metabolize nutrients, resulting in poor nutrient absorption and nutritional deficiencies. Subsequently, one of the most important ways to improve nutrition is to control and prevent most common childhood infectious diseases by expanding immunization programs, providing diarrhea and malaria control and treatment programs, and decreasing parasitic burden. The backbone of some of these programs is water supply improvements and improving sanitation and hygiene at the household level and in schools.

Joint action in agriculture, health, and water for nutrition could have benefits for food security and development and could substantially reduce risks for the poor as well as improving women's status, improving incomes for the purchase and demand of higher quality foods as consumers (Haddad, 2002; World Bank, 2007). However the linkages between the sectors are still theorized and evidence remains weak (Webb and Kennedy, 2014; World Bank, 2007; Ruel et al., 2013). The main challenge is to understand how food, health and water systems can work at the country policy level and how systems approaches can be implemented on the ground (Burchi et al., 2011).

3.1. The agriculture sector and food Systems

Agriculture remains the backbone of the rural economy and livelihoods in many countries. Increasing agricultural outputs impacts economic growth by enhancing farm productivity and food availability (Diao, 2007), while providing an economic and employment buffer during times of crisis (FAO, 2009). In the course of the second half of the 21st century, an agricultural revolution occurred which mainly focused on increasing productivity of major staple crops (Mazoyer and Roudart, 2006). In the 1970s and 80s, large investments in agriculture, technology, roads and irrigation led to significant improvements in food production, particularly in Asia and Latin America. During this period the proportion of official development assistance devoted towards agriculture peaked at 15–20% (FAO, 2009). The agriculture sector then progressed towards a larger goal of food security that went beyond just production. Now, there are petitions to ensure that agriculture explicitly achieves nutrition goals as well (Haddad, 2013).

Over the past two decades, decreasing levels of agriculture aid and investment, particularly the dismantling of input, credit and market subsidies, reducing public support to research and extension, and declining infrastructure investments have been linked to rising numbers of people being undernourished (FAO, 2009). The reverse relationship has also been suggested, with hunger and undernourishment carrying substantive economic and social costs with reduced labor productivity, investment in human capital, and escalating poverty (Bliss, 1978; Haddad, 2002; World Bank, 2006).

The hypothesis and story goes as follows: Supporting an agriculture model that increases food security and dietary diversity can contribute to reductions in undernutrition by improving production while at the same time, providing increased availability of a variety/diversity of quality foods. Attempts have been made to better understand this dynamic. Studies have shown that agriculture research, programs and policy have put less emphasis on maximizing nutrition outputs from farming systems and many agriculture interventions have failed to improve nutrition outcomes (Berti and FitzGerald, 2004; Girard et al., 2012; Masset et al., 2012). Agriculture has instead had substantive impact on economic growth by enhancing farm productivity and food availability (Webb and Block, 2012). A recent longitudinal analysis found that agricultural per capita income was more strongly associated with reductions in undernutrition than non-agricultural income. After controlling for income, the analysis indicated that as economic transformation proceeded, stunting declined at a faster pace in countries that supported growth in the agricultural sector than in those that did not. However, the absolute reductions in stunting were quite modest; a doubling of per capita agricultural income is associated with approximately a 15% decline in stunting (Webb and Block, 2012). Similarly, a World Bank study indicates only a 15% reduction in stunting and an 11% reduction in underweight with a doubling of total GDP (World Bank, 2012). Thus, while economic growth and poverty reduction strategies can at times contribute to better nutrition, in most countries, gains in economic growth or agricultural productivity alone have been insufficient to improve child nutrition outcomes (World Bank, 2012).

3.2. The health sector and health Systems

Strengthening and equitizing health systems have been recognized as a key strategy to fight poverty and foster development (World Health Organization, 2005). Functioning health systems often do not include nutrition services, outcomes, or goals. Nutrition is frequently dwindled down to providing supplements (iron and folic acid) for women during antenatal care visits, and some basic counseling on maternal diets and breastfeeding of infants. There is very little done beyond these basic care services, and very little integration of food or water elements for nutrition within the health sector.

Yet, the links between the public health, water system and food system are evident. A healthy, sustainable food system is one that accounts for the public health impacts across the entire lifecycle of how food is produced, processed, packaged, labeled, distributed, marketed, consumed and disposed. The health sector takes the

responsibility to emphasize, support and ensure physical and mental health of all farmers and consumers, especially women. Water, sanitation and hygiene can decrease infectious disease burden and access to safe water and improved sanitation explains 35% of the variation in stunting rates across countries and time periods (Smith and Haddad, 2014).

The health sector is the most essential sector to prevent and treat communicable and non-communicable diseases (CDs and NCDs), which can have deleterious effects on nutrition. In turn, poor nutrition can serve as a risk factor for CDs and NCDs and compromised immunity and health can put one at risk for poor dietary intake and compromised nutritional status. Strengthening health systems is essential for building a supportive environment for nutrition assessment, counseling, and support and to integrate nutrition into existing health care services. Reinvigorations of guidelines and standards, which provide community- and facility-based health providers a way to implement new approaches, can be a source of improved services for mothers and children. By creating an institutional culture where health care providers in the health system value nutrition, and understand their role in providing nutrition care, more can be achieved. However, there must be new, innovative ways of acknowledging and identifying nutrition issues, providing and implementing comprehensive nutrition interventions, and delivering nutrition education for preventative purposes (Tappenden et al., 2013).

3.3. The water sector and sanitation and hygiene systems

Water, sanitation and hygiene (WASH) play a fundamental role in improving nutritional outcomes. Fifty percent of malnutrition is associated with repeated diarrhea or intestinal worm infections as a result of unsafe water, inadequate sanitation or insufficient hygiene (World Health Organization, 2013). A lack of safe water close to home has many indirect effects on nutrition, and people are often left with no choice but to drink unsafe water from unprotected sources. A recent meta-analysis examined the impact of WASH interventions (which included solar disinfection of water, provision of soap, and improvement of water quality) on stunting reductions in children under five years of age. Although the studies investigated were of short duration and the methodological quality of many of the trials was sub-standard, the review identified WASH as having an impact (albeit quite small) on stunting reductions (Dangour et al., 2013).

It has been suggested that environmental enteropathy afflicts many children in the developing world (Humphrey, 2009). Environmental enteropathy is a syndrome that causes changes in the small intestine of individuals who lack basic sanitary facilities and are chronically exposed to fecal contamination. This in turn, decreases the ability of the intestinal tract to absorb critical nutrients necessary for optimum growth and development, leading to serious consequences in nutritional status. Environmental enteropathy is often seen in young children when complementary foods are introduced along with breastfeeding. Not only are children eating more solid foods, but have increased exposure to the outside environment itself, leading to an increased risk of consuming contaminated foods. The provision of toilets and community led sanitation and hygiene programs and improved food systems that ensure food safety can reduce the incidence of enteropathy (Guerrant et al., 2008; Motarjemi, 2000).

Recent evidence has demonstrated that the nutritional value of food is influenced by the structure and functionality of a consumer's gut microbial community, and that food and the sanitation and hygiene environment, can shape the composition of the microbiota. The breakdown of the intestinal mucosal barrier function with environmental enteropathy can lead to increased susceptibility to pathogenic infections. Recurrent infections predispose individuals to nutritional deficiencies and further compromise barrier function, leading to a vicious cycle of further susceptibility to infection and worsening nutritional status. The microbiota may play a critical, protective role here. Malnutrition could delay the maturation of the gut's microbial metabolic organ or skew it towards a different configuration that lacks the necessary functions for health or increases the risk of diseases (Kau et al., 2011). Research is also emerging that microbiota disruption during early development can result in syndromes of metabolic dysfunction including obesity. (Cox and Blaser, 2013).

Research has demonstrated that changes in the ecology of our indigenous microbiota have important roles in the emergence of many of the modern diseases we have today (Blaser, 2006). This view corroborates the hygiene hypothesis, which proposes that reduced exposure to parasites and pathogens early in life with better immunizations, antibiotics and an improved sanitation and hygiene environment may be partly responsible for an increased prevalence of allergic and autoimmune disorders (Cookson and Moffatt, 1997; Strachan, 1989). The hygiene status of the environment in which a child is delivered and raised is significant, typically leading to higher levels of bacterial pathogens where sanitation is poor (Bennet et al., 1991).

4. Food utilization and dietary diversity and quality

Food utilization, a neglected pillar of the food security framework, and dietary diversity and quality are two areas where the interactions between food, health and water systems are important.

4.1. Food utilization: the forgotten component of food security

In an attempt to achieve global food security, most of the focus within the development agenda has been on food availability and accessibility, with less emphasis on food utilization. Food utilization is often the forgotten or neglected “pillar” of food security. This is because utilization, squarely rooted within nutrition, is less understood in its underlying mechanisms as well as solutions. Focusing on the individual, food utilization takes into consideration the biological utilization of food. Biological utilization refers to the ability of the human body to take food and convert it into energy for storage or for immediate use. This conversion also releases other vital nutrients (including essential fats, protein, vitamins, minerals and health promoting compounds) as food is digested and metabolized. The optimum utilization of food requires not only consuming a nutritious, high quality diet provided by a functional food system, but also other factors such as a healthy physical environment, including safe drinking water, adequate sanitation and hygiene, decreased burden of infectious disease, sufficient health and education services, and the knowledge and understanding of proper care and feeding practices for children and mothers. The human microbiome is also essential in the utilization of nutrients. This is where other sectors, such as water and agriculture come into play (Fanzo and Pronyk, 2011).

Although less practiced, solutions exist to ensure food is utilized and nutrients in foods are absorbed, digested, metabolized and harnessed. Some post-harvest practices can retain or sometimes increase the nutrient density of foods during cooking, processing and storage. Combinations of diverse foods are also important to ensure that nutrient requirements by the body are met. Depending on the food, a healthy combination of nuts, legumes and grains can ensure the consumption of complete proteins, which compromise all the essential amino acids needed by the diet for human health. Ensuring foods rich in fat-soluble vitamins are cooked with oils can improve absorption of those vitamins. Cooking with iron cookware can improve iron absorption particularly if acidic foods are cooked in

iron pots at high temperatures (Kuligowski and Halperin, 1992). Acidic foods are often rich in vitamin C, which can also improve iron absorption (Seshadri et al., 1985). Cooking leafy green vegetables in minimal water and reusing the water can ensure that water-soluble vitamins contained in these vegetables are not lost through cooking practices. Parboiling rice and minimal-milling grains in general, ensures that the nutritious parts of the seed are retained during consumption. Dehulling, peeling, soaking, germination, fermentation, and drying certain foods can also remove anti-nutrients and preserve key micronutrients (Mensah and Tomkins, 2003). These practices require new knowledge and behavior change, which should be an integral part of nutrition education and messaging that fit squarely in the food system and agriculture sector.

Another area that requires more research and evidence is on food toxins and their implications on utilization and ultimately, nutritional status. Aflatoxins are fungal metabolites that contaminate staple food crops in many developing countries and have been loosely associated with growth impairments in children (Leroy, 2013). Foodborne aflatoxin exposure in maize and groundnuts is common in Africa and Asia (Khlangwiset et al., 2011). More mechanistic evidence is needed on how these toxins, once consumed, impair nutritional status. On the prevention side, more operational research is also needed on how post-harvest storage and handing can control for aflatoxin (Leroy, 2013; Wild, 2007).

Contaminated food is a major cause of undernutrition, morbidity and mortality in low- and middle-income settings, particularly among children who become vulnerable to diarrheal diseases when transitioning from breast milk to complementary foods (Montarjemi, 2000). Contaminated food significantly impairs food utilization. Solving problems of contaminated food requires a multidisciplinary approach involving experts in clean water resources, sanitation, public health, epidemiology, nutrition and of course, agriculture, as the major food source of local complementary foods. Decreasing the exposure to E. Coli and other contaminants can also lessen insult to the intestinal wall and minimize environmental enteropathy. Ensuring food is safely stored in proper bins and in hygienic containers should also be ensured to decrease loss and food spoilage and contamination. As part of this, cooks and consumers should wash hands with soap to minimize contamination of food and drink. Water, public health, education, and agriculture sectors all play critical roles ensuring food safety and nutrient availability for infants and young children transitioning from breastmilk to foods.

Further, with plant foods being the predominant source of the diet in many low-income countries, anti-nutrients and promoters contained in these plant foods should be taken into consideration with regard to bioavailability and utilization of nutrients. Most anti-nutrients in foods inhibit the absorption of micronutrients that are essential for proper development and that are often deficient in many low- and middle-income countries – predominantly iron and zinc (De Pee and Bloem, 2009). Anti-nutrients include phytic acid, fiber, tannins, oxalic acid, goitrogens and hemagglutinins (Welch and Graham, 2002; Welch, 2002). Phytic acid or phytates, one of the greater concerns, are often found in whole legumes, and cereal grains – the staples of the diets in resource-poor communities. The influence of oxalic acid on mineral absorption is less clear, particularly with iron absorption (Gillooly et al., 1983; Genannt Bonsmann et al., 2007). An abundant fiber intake may have a considerable inhibitory effect on mineral status (Freeland-Graves et al., 2014). Polyphenols, found in tea, red berries and some grains and legumes, interfere with the absorption of iron and zinc (Freeland-Graves et al., 2014).

4.2. Putting nutrient dense food back into food security

Dietary diversity is a vital element of diet quality and both are critical within each component of food and nutrition security. The consumption of a variety of foods across and within food groups helps assure adequate intake of essential nutrients and important health enhancers and is strongly associated with adequate nutritional status of children, as well as a sound predictor of the micronutrient density of the diet (Arimond and Ruel, 2004; Kennedy et al., 2007; Moursi et al., 2008; Rah et al., 2010; Sawadogo et al., 2006). However, availability, accessibility and affordability of diverse and quality foods either on farms or in markets are a challenge in both urban and rural poverty-stricken areas.

Diets rich in cereals and of vegetable origin do not contain all the key nutrients needed for adequate growth and development (FAO, 2013a). In contrast, animal source foods, such as meat, poultry, eggs, fish, milk, and cheese provide most of the essential amino acids, fats and micronutrients necessary for the body, but are not consumed on a daily basis by the majority living in low and middle-income countries due to high cost and low supply (de Pee et al. 2009).

During the period of complementary feeding of children usually during the ages 6 to 24 months, some households may be able to provide their young children with sufficient energy and protein from locally sourced complementary foods, but adequate nutrient density or the number of meals per day is often not sufficient (Reeds and Garlick, 2003). In addition, low dietary diversity and inadequate intake of micronutrients is common amongst preschoolers because of a lack of sufficient animal source foods, fruits and vegetables, and have been associated with micronutrient deficiencies and delayed child development (Allen, 2006).

To achieve dietary diversity and quality, the agriculture, water and health sectors play vital roles. Agriculture has the potential to produce nutrient-dense foods. Engagement in markets and value chains can improve the nutritive value of foods produced through post-harvest production and processing. The water system is important to ensure that the food that is prepared is sanitary and the person preparing the food is practicing appropriate hygiene. A functional and accessible health system can ensure that a person is healthy to utilize those nutrients in the diverse food basket for metabolism and optimal nutritional status.

5. Challenges to achieving food and nutrition security

There are many challenges that impact whether an individual, household or community achieves food and nutrition security and whether that security can be maintained. Resiliency is essential in ensuring that communities are able to withstand shocks stemming from food and health systems bottlenecks. There are other determinants such as socioeconomic status, social norms and behavior choices and changes that can impact nutritional status as well. Climate variability and population growth are two external challenges that could profoundly affect availability, accessibility and utilization of nutritious food across all populations. These challenges are serious threats (and at times, opportunities) that need careful consideration within the post 2015 food and nutrition security agenda.

5.1. Climate change and variability

As a global community, we must address the risks that climate variability and its potential impact on food production will bring. The world is experiencing climate change and variability and increased severity and frequency of natural disasters. Both floods and droughts will continue to occur. Predicting weather patterns will become much more difficult as the variability of climate systems increases (Hansen et al., 2007). These changes are likely

to have the greatest impact on the agricultural output of many low-resource regions, reducing yields of crops, soil fertility, and forest and animal productivity, which may result in lower income, reduced climate resiliency, and subsequently, decreased access to sufficient, nutrient dense foods, impairing the nutritional status of many low-income communities (Mason and Shrimpton, 2010). Even in the optimistic scenario, the number of malnourished children in 2050 increases from 76 million to 84 million, depending on climate change modeling (as measured by the average per capita caloric consumption, female access to secondary education, the quality of maternal and child care and health and sanitation) (Nelson et al., 2010). Some studies estimate an even greater impact, with stunting increasing by as much as 30% as compared to a scenario in which climate is stable (Lloyd et al., 2011). Climate change and variability may eliminate much of the improvement in child malnourishment levels that would occur in the absence of increased climate change and variability.

5.2. Population growth and pressure

Demographic and epidemiological shifts are occurring along with the nutrition transition. Population growth will put pressure not only on the planet, but also on how the human populations lives sustainably. Many families will leave behind their rural livelihoods and move to urban centers. As of 2010, more than half of all people live in an urban area. By 2030, this number will increase to 6 out of every 10 people living in cities, resulting in a total urban population of over 5 billion people with most living in African and Asian mega-cities. Currently, an estimated one third of urban dwellers live in poorly constructed shantytowns (Crisp et al., 2012). Limited access to social services, safe and nutritious food, and poor public health infrastructure leave shantytown populations at risk for both communicable and non-communicable diseases (Ghosh and Shah, 2004; Popkin et al., 2012; Popkin, 2006). These shifts will require delicate decisions on how much food should be produced, what type, where, and how. Nutrition outcomes will surely be affected without the proper planning, infrastructure, and health and social services that many of the lower- and middle-income countries lack. Our food system networks will have to change to not only feed the growing population but to ensure nutritious food is accessed in an equitable way that crosses geopolitical boundaries.

6. Considerations of innovative concepts across sectors and systems

To strengthen systems and to achieve cohesive synergies, there needs to be thoughtful integration between interventions or approaches, especially when an already existing collection of distinct vertical programs exists (Frenk, 2009). “Every intervention, from the simplest to the most complex, has an effect on the overall system, and the overall system has an effect on every intervention” (de Savigny and Taghreed, 2009). Services, interventions and solutions that are bundled or packaged across food, health and water systems can be more effective and advantageous.

Approaching nutrition through a multi-sectoral lens is in theory a starting point but the realities of making that work effectively is another beast all together. It is often said that nutrition should incorporate agriculture, health, education, social protection, gender, and environment, however historically, trans-sectoral collaboration does not work so well (Field, 1987). There is now more evidence and tools, through scientific discovery and through operations research, of new ways of assimilating these sectors and systems approaches to incorporate nutrition into food security, which are driven through one sector but engaged others. Some of these concepts are illustrated below.

6.1. Nutritional benefits of ecosystems: econutrition

“Ecologists work in multidimensional systems, composed of organisms, energy, and the physical environment interacting at various spatial and temporal scales, which can be described in terms of composition, structure, functions, fluxes, resilience, or other dynamics” (DeClerk et al., 2011). Traditionally, humans have maximized the potential of the ecosystem in which they work within. As humans modify their environment, they select and protect some species, crops, and foods and exclude others to maximize the provisioning of ecosystem services. Ecologists have focused on the impact of communities and their interactions on *ecosystem services,* however there has been little focus on the role that ecosystems play in providing the essential nutrients of human diets.

Increasing species richness increases the capacity of the agro-ecosystem to meet food and medicinal needs and optimizing the nutrient density of a landscape (DeClerk et al., 2011; Remans et al., 2011). More research is now in progress demonstrating how the combination of environment, farming communities, and species, food and human modification can impact human nutrition (DeClerk et al., 2011; Remans et al., 2011). This idea that nutrition, human and agricultural productivity, and environmental sustainability are interrelated has been described as “econutrition” in which much can be gained by linking agriculture and ecology to human nutrition and health (Deckelbaum et al., 2006). ‘We refer to the nutritional benefits of ecosystem services as econutrition.

“Econutrition” type approaches are being piloted that integrate ecosystems services, with food production and nutrition. For example, ecological complementarity that also results in net nutritional benefit comes from integrated and mixed agriculture systems such as the rice-fish aquaculture systems, poultry-orchard systems, livestock-cover crop systems which provide food production, ecological, diet and nutrition benefits (De Clerck et al., 2006; Fanzo and Hunter, 2013a). In Malawi for example, intercropping of maize with legumes, to improve soil health and dietary diversity, along with nutrition education at the community level. The impact resulted in a significant improvement in weight for age (measure of undernutrition) in children under five years of age (Bezner Kerr et al., 2011).

6.2. Flipping the value chain for dietary quality

The links between what is produced on the farm and the income received by the producer does not stop at production (Hawkes and Ruel, 2010). Food is stored, distributed, processed, retailed, prepared and consumed in a range of ways that influences access, acceptability, safety and nutritional quality of foods for the consumer. Value chains are fundamental in this connected process. Value chain approaches focus on the processes and actors involved from the producer's perspective (i.e. the supply side) and then follow a product's value along a chain that ends at the consumer.

Value chain approaches have infrequently been used explicitly as a mechanism to achieve nutritional goals. Yet the characteristics of value chains have critical implications for food availability, affordability, quality, and acceptability. Hawkes and Ruel suggest reorienting the food value chains to have four goals for nutrition. They are: Increase the supply of accessible (available and affordable) nutritious foods for the poor (and for different target groups) all year round, Increase the demand for and acceptability of nutritious foods for the poor, Increase the coordination among value-chain actors and activities that are essential to increasing

the supply of and demand for nutritious foods for the poor, and address the trade-offs between the economic returns and nutritional benefits of agriculture in the value chain (Hawkes and Ruel, 2010).

On the supply side, more emphasis can be paid to informing farmers and other actors how to enhance the nutritional value of local foods through agro-processing and storage, along with value added horticulture. On the demand side, more attention can be given to how consumers play a role in garnering knowledge, how they influence the value chain through purchasing power, and how changing their demand for specific foods can influence the processes and outputs of value chains (IFPRI/ILRI, 2010). This demand side relates to household decisions regarding purchase of food, allocation of resources to different household members, and knowledge of safe and nutritious food preparation and child feeding practices. By focusing on the consumer, the value chain can be reexamined from the demand side, or "flipped." Demand-side approaches focus on consumer awareness, behavioral change, knowledge transfer, and empowerment in order to increase demand for nutritious foods and improve dietary intake. To date however, the adaptation of value chains, which incorporate nutrition, has been limited with only a few examples of how consumer demand can drive the injection of nutrition along the value chain (Hawkes and Ruel, 2012).

6.3. Sustainable and affordable diets

Looking forward, we need a future where food systems or food environments are constructed around human needs, but with a view towards sustainability, where low carbon, accessible, culturally relevant and nutritionally adequate food is the norm (Fanzo et al., 2012). Projections for the next 10–50 years further strengthen the need to improve the quality and environmental sustainability of the diet, especially given the challenges imposed by climate change and increasing population growth with a rising appetite for environment-costly animal source foods (Rosen et al., 2012; Termote et al, 2012b). In 2012, FAO and Bioversity defined sustainable diets: Sustainable diets are those diets with low environmental impacts, which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources (FAO and Bioversity, 2010). Putting this definition into practice is still in its infancy.

The commitment to improving food and nutrition security requires an understanding of what is meant by sustainable diets for different populations and contexts, how these diets can be assessed within our global food system, and how we can achieve environmental sustainability in our consumption patterns and dietary goals (Fanzo et al., 2012). The complex web of determinants of sustainable diets makes it challenging for programmers and policymakers to understand the benefits and considerations for promoting, processing, and consuming such diets. "To advance this work, better measurements and indicators must be developed to assess the impact of the various determinants on the sustainability of a diet and the tradeoffs associated with any recommendations aimed at increasing the sustainability of our food system" (Johnston et al. 2014).

In some low-income countries or in countries that rely mainly on food imports with high price volatility, the total available income of the poorest households is not enough to afford a nutritious diet, especially given that not all income is spent on food. And the limited income that is available in poor households, 70 to 80% is spent on food (Briend et al., 2003; Chastre et al., 2007; de Pee et al., 2010). Biofortification of affordable staple crops is one approach to filling this nutrient and cost gap (Bouis et al., 2011).

One study demonstrated that traditional, undervalued and sometimes neglected foods can be often free or very low in cost, and can be, nutrient dense (Termote et al., 2013). However stigma of these foods remains a challenge and regardless of the nutritive value, if the food is not valued, there is less likelihood that it will also be consumed (Termote et al., 2012a,b). More solutions are needed that incorporate sustainability and cost-effectiveness into diets for individuals and households to ensure resiliency is embedded within food and nutrition security.

6.4. Harnessing technology

Information and Communication Technologies for Development (ICT4D) refers to the application of information and communication technologies, including the Internet and mobile phone, video and audio, to development goals and poverty reduction. The field is relatively new, since the late 1990s when infrastructure began to expand telecommunications into poor and remote areas and development organizations invested in 'telecentres' to provide ICT-enabled nutrition services to poor communities. In the last few years, with the expansion of mobile networks, the nutrition field has expanded and evolved rapidly. Mobile technology can be used to provide nutrition education and messages, allow for innovative participation of food markets, and reach the most nutritionally vulnerable households.

U-report, developed by UNICEF, is a communications technology utilizing social mobilization, monitoring and response efforts to address human rights issues throughout the country. In doing so, it is also equipping mobile phone users with the tools to establish and enforce new standards of transparency and accountability in development programming and the delivery of services.

6.5. Reaching communities

Interventions and solutions need to reach communities, particularly the disadvantaged and vulnerable, food insecure households. In a recent study that examined the integration of nutrition into rural extension services, it was found that a diverse array of community actors works in nutrition, though none who are entirely capable of taking on nutrition alone. Overall, results indicate that there is little duplication in duties at the community level with regard to nutrition and it is often that nutrition falls through the cracks for both agriculture extension agents as well as community health workers. Nutrition often remains no one's responsibility. Community health workers focus more on screening and on household treatment of malnutrition. Extension agents focus on crop productivity and on the transfer of technology. An area of potential overlap between health and extension is in transfer of knowledge to households on basic dietary guidelines and nutrition counseling. However, very few extension agents provide this type of service to households in an impactful way (Fanzo et al., 2013d). It might be beneficial for health and extension agents to undergo nutrition training together and to determine what fits within each portfolio. Joint trainings also enable the workers to learn across disciplines.

Community health worker activities should be distinct from extension agent activities. Community health workers can screen and treat cases of malnutrition, provide education on care and health-related conditions, and ensure that immunizations and supplementation are provided on a regular basis. Extension agents can focus on the food-related concerns of the household, including production, purchasing, and consumption. The distinct categories of food, health, and childcare, are more effectively covered with each rural worker focusing on their own specific area.

Empowerment of community members to serve as facilitators or change agents for nutrition has been an effective strategy in sectors such as HIV/AIDS and Community-Based Management of Acute Malnutrition. It might prove beneficial to train model farmers who then transfer their knowledge to other farmers, especially in the case of women (Fanzo et al., 2013d).

Different communities of practice (CoP) are already underway in the nutrition community and exchange of information will be utilized through this platform increasingly. A CoP is a group of people who share a profession such as nutrition and if often created specifically with the goal of gaining knowledge related to their field. It is through the process of sharing information and experiences with the group that the members learn from each other, and have an opportunity to develop themselves personally and professionally. Using this type of platform could be transformative in linking those who work in food systems with those who work in health systems. Current CoP that have a larger number of stakeholders and are working across agriculture and health sectors are the Agriculture-Nutrition CoP and the Nutrition and Climate Change eGroup for example. The Scaling Up Nutrition (SUN) movement could be considered a CoP made up of over 52 countries who are committed to scaling up nutrition and sharing information and knowledge at global, regional and national levels.

It must be noted that one of the greatest challenges in all of the above approaches is behavior change. While there can be increased attention to nutrition-sensitive value chains and sustainable diets, and access to technologies, community workers and outreach and communities of practice, changing behavior is dependent on the individual and the choice that is made. How can consumers be motivated to live a more healthy and sustainable lifestyle in today's environment? And do they often have options or choices to be made? There needs to be new ways of thinking about behavior change approaches that are sensitive to equity, social norms and the cultural environment particularly in developing and emerging economies (Newson et al., 2013). Behavior change is dependent on many things including education, knowledge, and beliefs around child care; mental health, minimal stress, and self-confidence; autonomy, control of resources, and intra-household allocation; time and a reasonable workload; and social support from family and the community (IYCN, 2011). Nutrition education should be more than just educating individuals or delivering information about healthy practices for nutrition and adopting healthier food choices. It involves working with communities to understand their perceptions and constraints and ultimately identifying solutions for addressing nutritional problems (IYCN, 2011).

7. Conclusion

Now more than ever, the global community needs to better engage across the key sectors of agriculture, health and water to improve nutrition. This engagement does not just require single, vertical interventions but bundled, integrated solutions that engage and revitalize food, health and water systems to work for nutrition. As we move towards consensus on the sustainable development goals post 2015, there will be much more emphasis on sustainable solutions to the ever growing challenges that lay before us. We need to start pollinating and collaborating across sectors to address these complex problems. There has never been a better time to do so. We have the tools, the innovation and technology and our global community of knowledge to make change.

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