The Need for Accelerated and Sustained Improvements in Food and Nutrition of the Poor

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1. Introduction – Changing Contexts

Fundamental forces of societal and economic change must be considered when searching and advocating technological and institutional innovations to reduce misery and hunger in the unequal world, where science is dominated by wealthy countries. Secular decline in economic growth (in terms of GDP) and possibly reduced power of innovations for growth in high-income countries (Gordon 2016), combined with growing within-country inequalities (Milanovic 2016) has far-reaching implications for changing attitudes and shape of policies. Technology pessimism and globalization skepticism is a factor in parts of the world's wealthier population segments and increases their demand for regulation to fix the status quo. To the extent these trends adversely impact science applications, such as biological sciences of developmental relevance, they adversely affect innovation serving advances of food and nutrition security of the poor. This certainly raises ethical considerations related to the poor today and to future generations, both of which have not much voice in present discourses.

The present food and nutrition problems need to be addressed while future challenges must be considered, too. Due to constraints of natural resources, and due to economic constraints of low-income people, innovations are central to facilitate access to improved nutrition. Innovations are technological and institutional and both are interrelated. Affordability of healthy and nutritious food is critical for low-income households. Technology's role should be viewed in a broad context of action areas for improved nutrition, i.e. together with access to markets, to services, and to income opportunities, all of which are determinants behind access to food and nutrition. Sustained improvements in nutrition must also pay attention to marginality and exclusion of the undernourished (von Braun and Gatzweiler 2014). Peoples' knowledge and behavior importantly shape demand for improved nutrition, too.

Overall, hunger is on the decline as accounted for by the Global Hunger Index (IFPRI et al. 2016), but the various features of hunger and undernutrition remain large global problems. They are most prevalent in low and middle-income countries, but also exist partly unnoticed in industrialized countries, such as the USA and the European Union. The challenge to end hunger – as called for in the Sustainable Development Goals (SDGs) – is confronted with the fact that hunger and undernutrition have become more complex. Urban hunger and undernutrition is of growing importance while most hungry people still live in emerging economies' rural areas and on small farms. Overcoming hunger relates closely to the transformation of rural areas and of small farms' productivity, and to the quality of services reaching out to them, especially health and education services, and social safety nets. Hunger in emergencies and conflict situations is a growing political and social challenge. Micronutrient deficiencies are increasingly recognized as a large food and health problem. Ending undernutrition in South Asia requires different actions than in Africa. Environmental causes of hunger such as climate change seem to be increasing.

All these complexities call for equally complex responses in policies and programs, adjusted to regional and local circumstances, yet the key roles of technological innovations should not be neglected in the portfolio to overcome food and nutrition security. New thinking about policy, institutional and organizational innovations, and technical innovations, i.e. biological, mechanical, and information technological innovations, must come together to end hunger and undernutrition. While mainly aspects of the critically important roles of biological innovations and especially plant innovations for nutritional improvement are discussed in this workshop, this paper serves to provide a background on the needs to expand and sustain improvements in food and nutrition, and positions technological innovations among the range of other actions to meet the needs. It concludes that missing out on technological opportunities would be inefficient and unfair towards the poor.

2. Outlook of Food and Nutrition Needs in the 21st Century

The world population is growing at declining rates and will approach 9.2 billion people in 2050. It is assumed to become more stable by 2070 with about 9.4 billion people and may somewhat decline by 2100 (Lutz et al.

2014). Different global population projections differ greatly with respect to outcome and ingoing assumptions. Projections that neglect the dynamics and endogenous change in fertility, migration and the role of education tend to overstate population growth.

Nevertheless, demand for food will increase substantially in the future due to a growing world population and rising per capita income. Alexandratos and Bruinsma of FAO (2012) estimate the demand for various food groups till 2050 based on the UN population projections. They predict a 46% increase in demand for grains (of which about two thirds would be for animal feeds and other non-food uses), a 76% increase in meat demand and an 89% growth in demand for oilseeds. These expansions are challenges, if they become reality. For instance, in absolute numbers a 46% increase in grains means a global increase from 2.1 to 3.0 billion tons. Yet, it will depend upon whether changes in consumption habits of middle classes come about, such as reduced consumption of feed intensively produced animal products. Behavioural change in food consumption is slow, except when people move from rural to urban areas.

The other hope is that scope to cut losses and waste of food would enhance food availability. Losses occur at different levels of the supply chain (for example during harvest, storage or processing), and waste is mainly related to consumption behavior. Rough estimations suggest that for instance in the case of cereals 35% of the production is lost or wasted in industrialized countries, and about 20% in Africa (FAO 2011). More recent estimates in some countries suggest that losses and waste are in fact probably much smaller. Postharvest losses of maize in selected African countries range around 10 to 20% without interventions and 5 to 10% with interventions (Schuster and Torero 2016), and losses in potatoes in India and Bangladesh are around 3 to 6% (Minten et al. 2016). At such low levels of waste and losses there would be less scope for efficiency gains in the food systems, and production and yield levels need to be increased further to ensure food and nutrition security at affordable prices.

A review of global food security scenarios by van Dijk and Meijerink (2014) finds that most studies only address availability and access, but not nutrition and instability aspects of food security. Overall, they find that the few scenario exercises that attempt to provide outlooks on global child malnutrition and on prevalence of undernutrition indicate for 2050 a range of 100 to 180 million children, and for the latter a decline from about 12% to about 6%. In an increasingly demand driven global food system, food security will ever more emphasize appropriate responses to new and emerging demands (Maggio et al. 2015). Scenarios of future food demands must be part of the broader scenario building about societal, economic and environmental change. Volatility and transitions of economic systems need to be considered, as partly done in the New Lens Scenarios by Shell Corp. (2013). What the future of food and nutrition security will look like clearly depends on readiness of societies to face up to the challenges, and not on predetermined trends. That also includes the willingness to enhance technological innovations and their applications.

3. Science and Innovations to Enhance Food and Nutrition

At an aggregate global level, innovations have become more and more important for improved food security. With three quarters contribution, innovation is now the biggest source of productivity growth in world agriculture. While the overall growth in productivity was maintained, inputs as well as land and water resources have scaled back. Therefore, innovations play a crucial role in ensuring the availability of food for the global population.

3.1 Comprehensive Food and Nutrition Policies

Major innovation examples from the past, such as the cooperative formations in the 1860s in Germany, the crop-innovation based “Green Revolution” in the 1970s, the innovation of conditional cash transfer schemes in Mexico and elsewhere in the 1990s, and the food fortification and supplementation programs in the past three decades show that successful innovations had two characteristics in common. First, they had technical and institutional components and gained highest level political support, and second, they entailed years of research and experimentation before scaling up was possible. Despite great contributions of each of the innovations to the reduction of hunger and food insecurity, none of them alone is a panacea to end hunger.

A broad set of public policies is required to address hunger and nutrition risks, including policies and programs directly targeted at the undernourished and programs that indirectly improve nutrition (Pinstrup-Andersen 2013). Policy actions in three priority areas are called for: (1) expand direct support for overcoming nutrition problems of children and women, (2) adopt actions that prevent health and nutrition damage to avoid long-term negative consequences, (3) take actions to prevent and mitigate food and nutrition risks at large scale, including nutrition risks that result from economic and political disruptions.

Food and nutrition policies and programs have come a long way over the past five decades toward more comprehensiveness, impact orientation, and scale (Gillespie et al. 2016). On that long way to improvement a problem was that selective paradigms dominated and guided actions for nutrition, rather than taking guidance from science more broadly into account and systematically test interventions at scale. This problem is not overcome yet. It may currently lead to approaches that focus on ever better programming based on currently favored interventions (mainly following a public health approach), rather than also factoring in technological innovations (such as micronutrient rich foods) and institutional innovations (such as measures that can drive behavioral change).

3.2 Agricultural Research Reducing Undernutrition and Hunger and Future Potentials

In the past 200 years, several major inventions for the agricultural sector had a great influence on shaping societies (Fogel 1999). Plant nutrition was dramatically changed by Justus von Liebig's discovery of essential plant nutrients in the 1840s. The increase in food safety measures was much improved by Louis Pasteur, who treated milk to stop bacterial contamination in the 1860s. It was Gregor Mendel in the 1850s who revolutionized plant breeding through genetic considerations. Norman Borlaug's work on plant breeding in the 1970s had a huge impact on the food security situation in Latin America and Asia increasing wheat and rice yields by planting high-yielding crop varieties (Gillis 2009).

Since the 1990s, advanced biology has become important in agricultural science. Scientific innovations have made significant contributions to hunger reduction and the Centers of the Consultative Group for International Agricultural Research (CGIAR) have played important roles in that respect together with national research systems of emerging economies. Still, a big gap exists between potential agricultural productivity and yields of crop and livestock between low- and high-income countries. This gap must be further addressed by new ways of cooperation, farmers' vocational training and the strengthening of extension services.

Research increasingly focuses on the goal of achieving higher and more stable yields, on the plant-microbial relations, as well as on advances in molecular and cellular processes. New forms of water saving irrigation systems will become more important. The same applies to innovations in pest and disease resistance in a post antibiotics age, such as chemical control, biological control, sterile insects breeding, and breeding for resistance. In addition, meat substitutes made from pulses or algae have become prominent on research agendas to bridge protein gaps. Demand side innovations focus on consumption and behavior change to overcome food related health problems. Consumer preferences and the willingness of consumers to alter these will be one of the major determinants of the actually adopted change of agricultural products in the next decades, as well as reducing waste and losses. Changing consumer behavior through research-based innovations is an opportunity, but is still mainly at experimental intervention stages, such as with "nudging" and nutrition education in low- and high-income countries. Nutrition-sensitive agriculture aims at making nutritious foods available and accessible, thus focuses on an important cause of malnutrition (Webb and Kennedy 2014, Jaenicke and Virchow 2013, Balz et al. 2015).

The rapidly developing biotechnological tool of gene editing (CRIPSPR-CAS9) is a tool to alter the characteristics of organisms on DNA level (Doudna and Charpentier 2014). The new technologies may be a game changer for improved nutritious quality of food as well as higher and more sustainable yields through improved plant characteristics such as health properties and resistance. They are promising with respect to complementing, but probably not replacing the potentials of transgenics, such as Vitamin A enriched rice, for nutritional improvement. Major advantages of gene editing technology are its preciseness, the cost-effectiveness and ease of application. Extensive research is ongoing in numerous areas of science. The opportunities and risks of CRIPR-CAS9 are intensely discussed in relation to human genome editing (Olson 2015). In crops several applications already emerge in plant innovations and food processing (Wolt et al. 2016; Chen and Gao 2014), and science-informed discussion about the opportunities and limitations of the technology in plants is needed as well. Regulation is an issue, just as with transgenics. Addressing ambiguities regarding the regulatory status of crop genome editing techniques is critical to their application for development of useful crop traits. It should focus on the nature of the novel phenotype developed, rather than the process of innovation development (Wolt et al. 2016).

3.3 Innovations to Improve Nutrition Quality and Address "Hidden Hunger"

Worldwide, an estimated 2 billion people are affected by hidden hunger, which refers to the lack of crucial micronutrients in the daily diet such as vitamin A, iron or iodine. Nutrition science has by now very strong evidence that the effects of a diet based on food with poor nutritional qualities are far-reaching. Reduced productivity, impairment of the cognitive and physical development of children or higher risks for women during childbirth – the consequences for human health, societies and economies are tremendous and deserve increased attention. Poor rural populations in low- and middle-income countries are typically affected most by micronutrient deficiencies. However, a growing focus is also on the problem of overweight and obesity since the (over-)consumption of highly processed foods with poor nutritional quality and lifestyles can be a cause of related malnutrition.

An important evolution in the past 10 years is the increase of the nutrient content of staple foods, such as wheat, maize, rice, beans, and sweet potatoes through plant breeding – an approach called biofortification (Bouis et al. 2013). Biofortification is regarded as one major contributor to eliminating micronutrient deficiencies. Currently there are several complementary approaches to address hidden hunger, i.e. biofortification, fortification (industrial or household based with sprinkles), supplementation, and diet changing behavior (incl. making diverse foods accessible to households, for instance gardening or animal products). Each of them have their strength and limitations in terms of reach and costs, and need to be optimally scaled up in rural and urban settings, rather than pursued in isolation.

New scientific insights from micro-biome research may impact the scope for effective nutrition interventions in significant ways, as nutrient utilization is better understood (Kau et al. 2011). Better understanding interrelationships between diet, nutritional status, the immune system and microbial ecology in humans might open up new types of nutrition interventions. There is increasing evidence that the nutritional value of food is influenced in part by the structure and operations of a consumer's gut microbial community, and that food in turn shapes the microbiota and its vast collection of microbial genes (Kau et al. 2011).

3.3 Innovative Digital Technologies Serving Food and Nutrition

Biological innovations are increasingly unfolding their potentials in conjunction with digital innovations (GIS, precision agriculture, agriculture information on mobile phones and smart phones). The mobile phone has not only become the most important communication technology globally, but also offers numerous additional functions such as access to the internet, audio-visual recordings or financial transactions. Digital technology is a game changer for food and nutrition security. It potentially makes responding to hunger risks more effective. Farmers can be better informed about market opportunities and become strong users of innovations that fit their circumstances. On the consumer side, digital technologies can facilitate the provision and dissemination of information related to malnutrition. Furthermore, costs for nutrition program experts to reach their target groups, especially mothers and children in need, decrease. Much of these opportunities are yet to materialize, but the potentials are large. In particular, the advent of smartphones has opened up a whole new range of services to their users. At the same time, the nature of the internet is changing towards a network of diverse mobile devices which can collect, share, and analyze huge amounts of data and connect users around the globe, including in Africa, through social networks. Several services are already being offered to farmers with the help of mobile technologies (referred to as m-services, Baumüller 2016). Using information and communications technologies (ICT) such as global positioning and information systems, remote sensing or sensors to monitor climatic conditions, soils, or yield, farmers can detect temporal and spatial variability across their fields. They can then selectively treat their crop, either manually or through technologies that adjust their behavior in response to the gathered data. Much of the focus has been on variable rate application of inputs based on yield and soil monitoring (McBratney et al. 2005).

Many of the high-tech agricultural applications used in industrialized and a few developing countries are unlikely to be appropriated soon in development contexts given low levels of literacy, limited access to equipment, and small landholdings. However, the rapid spread of mobile phones and networks as well as advances in the Internet of Things (IoT) could lead to technology applications that are better adapted to the needs and capacities of small-scale producers. Farmers can use IoT services to assist with site-specific management of their fields, monitor the development of their crops, adjust their agricultural practices in response to the data, and track the sales of the produce. The information they gather is complemented by other information to help with planning, such as weather forecasts or price information for inputs and outputs. The inclusion of the next generation of millions of small farmers in ICT opportunities could also contribute to a reduced urban–rural divide.

3.4 Innovations for Small Farms in Transformation

The small farm economies are in structural change. Both Africa and Asia will be approaching a turning point from a farm size decrease to increase, and demand for labor-saving mechanization will rise. This structural change will impact the labor markets, thus spilling over into other economic sectors. Yet, this transition towards larger farms, especially in regions where small farms are dominant, will take a long time. Most of the worldwide 570 million farms are small farms. Such small farms are impacted by a rapidly changing context that affects the food situation – some positive, some risk increasing. Opportunities are increasingly seen outside agriculture labor markets; youth in many countries are leaving farming; the market value of land is rising because of agricultural price changes and the increasing influence of non-agricultural demand for land use, and land speculation.

Since most of the poor in the world reside on small farms (von Braun and Mirzabaev 2015) what happens on these small farms will be decisive to reduce poverty and hunger. By investing more in farms and by increasing efficiency of farming, a large portion of poverty and malnutrition could be reduced. Policy support should be aimed at promoting the dynamism within the family farm sector itself, but also enhancing the dynamic interactions and integration of the family farm sector into the rest of the economy. At the same time, land rights of small farmers must be protected by recording and by enforcing ownership against powerful international and domestic investors. Digitally supported ownership records can help with that, but rule of law is essential. Improved crop technology and improved animal production systems are essential for enhanced income earning capacities on small farms. Crop technologies that enhance healthy diets on millions of farms that partly consume their own food and in rural communities that depend on local markets remain of considerable importance for a long time to come.

Long before formal science institutions were established, farmers' innovations were changing and improving productivity of farming and food systems. It must not be forgotten that this type of bottom up initiatives is still an important force of innovation in which farmers are investing. Gupta (2016), who pioneered the "Honey Bee Network" making grass roots innovations visible and accessible through sharing among thousands of farmers in India, points out that "minds on the margin are not marginal minds". Wünscher and Tambo (2016) studied farmer innovations in Ghana and show that they can be a promising source of locally adapted, site-appropriate solutions which may be suitable for rapid and cost-effective dissemination. They point to the fact that a farmer's innovative capacity remains part of his capability, which can be made use of by changing incentive systems for innovation, e.g. in the form of contests. Farmers become creative, share their knowledge with institutions and other farmers, and engage in experimentation. This strengthens partnerships between farmers, extension officers, and scientists and increases the appreciation for farmer innovations among the involved stakeholders. Other new research points at the important role aspirations or lack thereof play for innovation and technology adoption in agriculture. Mekonnen and Gerber (2016) find in Ethiopia that farmers with less aspiration adopt innovative practices such as improved seeds and fertilizer less often. The upshot of this research is that innovation is endogenous to fundamental drivers, and not just a matter of transfer of knowledge and technology. Yet, transfer of innovation also plays important roles today. Relying just on bottom-up innovations would neglect opportunities offered by new research and applied scientific insights.

3.5 Protecting Nutrition in Volatile Markets and Conflicts

Actions for nutritional improvements must take the increasingly complex macro realities into account, incl. market failures and political conflicts which make interventions for nutrition more difficult. Extreme food price changes adversely affect nutrition of the poor and particularly child nutrition (Kalkuhl et al. 2016). Purchasing power is further constrained for acquiring a healthy diet under such circumstances. Several important factors were found to have been underestimated before the global food price crisis in 2007/08, such as the level of price instability, the exposure of producers and consumers, and potential social unrest. Yet, little protection against price shocks exists currently and the most vulnerable people remain with a limited capacity to quickly adjust to abrupt price changes. Thus, the need to improve resilience of agricultural markets remains as high as ever. Innovations to deal with volatility aim to promote the integration of different markets for improved risk-sharing among them. This does not only apply to an international context but also within countries. Furthermore, integrating markets also helps to cope with seasonality as distant markets have different seasonal patterns. Value chain analyses can help explain why in some cases low-income producers do not profit from market integration, e.g., because product standards exceed their capabilities. Thus, while promoting market integration, it is necessary to equip farmers with the necessary tools and training to enable them to participate and compete in markets. In addition, measures for prevention of excessive volatility include national and regional grain reserves and regulations that restrict excessive speculation in food commodity markets (Tadesse et al. 2014). The international community and many governments have yet to develop an effective risk management strategy to be well prepared for future crises (Kalkuhl et al. 2016). Improved early warning and information sharing is needed at regional and global level.

Of increasing relevance at an international scale is hunger in complex emergencies, i.e., when political conflicts, war, terrorism and environmental emergencies interact. More than 20 countries are affected and about 200 million people suffer from hunger and undernutrition in these countries. Syria, Yemen, Afghanistan, parts of Nigeria, South-Sudan and Burundi are examples. The human right to food is often violated in some of these settings, and hunger is implicitly a weapon when cities or localities are encircled, preventing food and other aid from entering. In these settings, hunger reduction depends on innovative cooperation between security policy, diplomacy, and development policy. Good examples for emergency relief would be innovations such as cash cards for local purchases facilitating positive leakages of essential goods across borders, or cell phone based money transfers that can be locally used to buy foods. Protecting nutrition as much as possible during crises and rebuilding thereafter must consider inequalities and discriminations that determine resilience or the lack thereof.

At first glance, agricultural technologies do not seem fit to play a positive role under circumstances of food price crises and complex emergencies with conflicts, however, in fact they do. Technologies that help reduce prices of healthy diets even under price volatility are important for the poor. Biofortified and fortified foods can be part of that. In some of the settings of complex emergencies, home-grown foods are of critical importance. Systems of dissemination of improved seeds for nutritious diets may be more resilient than public nutrition programs, and can be facilitated by informal distribution systems and civil society organizations, even under some complex emergencies.

4. Summing up Needs for Sustained Improvements and Implications

Efforts to sustainably eradicate hunger and malnutrition much depend on policies and programs that match the growing complexities of its causes and features. Technology pessimism and globalization skepticism is a factor in parts of wealthier world population segments. To the extent such attitudes adversely impact policies of developmental relevance, such as biological science based innovations and trade openness, they adversely affect food and nutrition security, and that would be unfair to the poor. Several concluding points shall be summarized here:

1. Undoubtedly, significant increases for **availability of healthy food that is accessible and affordable by low-income people is needed** in the coming five decades to address the current unmet and the future needs. Much of that increased demand needs to be met by production increases in emerging economies. The nutritional qualities of food need to be enhanced at the same time. This is where new agricultural technologies and improved distribution systems will have to play key roles.

2. Innovation for the sustainable agricultural development in the rural areas affected by malnutrition will remain a major part of solutions in order to facilitate income growth where it is most needed. **Investing in food and agricultural research and development (R&D)** is an important tool for broad based innovation, especially related to improved seeds. Nutrition science itself needs to progress and tap into the potentially promising insights from micro-biome research.

3. **Bio-science advances** help to ensure food security not only with respect to increased food supply, but can also enhance nutritional quality of the food produced. Fortification and biofortification of foods and nutrition sensitive agriculture should be scaled up for overcoming the micronutrient deficiencies soon. Regulations must not unduly constrain access to hunger reducing technological advances.

4. Many of the promising opportunities of the new **digital technologies** are yet to materialize, especially in contexts of developing countries, but the potentials for contributing to hunger reduction are large and need international engagement and support.

5. Since the end-hunger goal among the SDGs is not separable from related **environmental sustainability** goals, the environmental and climate change aspects of agricultural and land and water use change need strong attention. An essential component of resilient agriculture is an end of land and soil degradation.

6. Avoidance of **nutritional burdens from crises** (e.g. price shocks) require information and early warning systems, as well as better preparedness with improved trade and food reserves policies. The role of crop technology to contribute to resilience in complex emergencies should not be underestimated.

7. Innovation initiatives must follow principles of **good governance**. Strong alliances among the private and public sectors and as well nongovernmental organizations (NGOs) guided by rights-based approaches, are needed to end hunger and undernutrition. Access to hunger reducing technologies is part of such a rights-based agenda.

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