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Food Security as a Water Grand Challenge

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Abstract: Perhaps the biggest challenge the world faces is providing sufficient, nutritious, and safe food at the right time for its ever-increasing population. Considering current world population growth trends, it is estimated that the global population will be about 10 billion by the year 2050. Therefore, food production should at least double in the same period if food security is to be satisfied. Water and land resources play a pivotal role in agriculture and directly connect to food security. At the same time, the capacity to produce food is constrained by global climate changes and increased pressure on land resources. These challenges are more severe in Southern Asia, Sub-Saharan Africa, and East Asia, where conflict and lack of capacity to fund agricultural research and food production are common. Strategies that simultaneously increase food production and reduce threats to food security are therefore needed. The objectives of this paper are to review the grand challenges of global food security and to propose strategies for mitigating food insecurity, with an emphasis on the link between water resources and food production.

Keywords: *food security, water, land, food access*

The world's population is estimated at seven billion and it is expected to grow by another two billion people by 2050 (Barron 2009). This population growth demands that there be adequate, safe, and nutritious food at the right time and place. Food and nutrition security is a broad and complex issue that encompasses a number of dimensions. Food and nutrition security is defined as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (FAO 2009). Food security was defined by the Food and Agriculture Organization (FAO) (FAO 1996) as follows: "Food security, at the individual, household, national and regional levels 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" (Hilderink et al. 2012). Three aspects are commonly addressed in food security studies, namely availability, access, and utilization (Hilderink et al. 2012). Availability addresses the supply side of food security and is determined by the level of domestic food production, stock levels, and net trade. Access to food is ensured when all households and individuals within those households have sufficient resources for acquiring the appropriate foods that make up a nutritious diet. Whether this can be achieved depends on the level of household resources (capital, labor, and knowledge), food prices, and the presence of a social safety net. Under access to food is the ability of households to generate sufficient income which, together with own production, can be used for meeting their nutritional needs. Utilization of food has a socio-economic and biological aspect. If sufficient and nutritious food is available and accessible, households must decide which foods to consume and in what proportions. Appropriate food intake (balanced and nutrient-rich food) for young children and mothers is very important for nutritious status. This requires not only an adequate diet, but also a healthy physical environment, including safe drinking water and adequate sanitary facilities, as well as an understanding of proper health care, food preparation, and storage processes (Hilderink et al. 2012).

Globally, the number of chronically malnourished people is estimated to be 815 million (FAO 2017). Food insecurity is greatest in Sub-Saharan Africa (SSA) and Asia with about 239 and 578 million undernourished people, respectively.

Although the world has made significant progress in reducing the number of hungry people over the last several decades, individuals need more than calories for health and well-being; they also need a nutritious and balanced diet. Along these lines, many countries are facing the "triple burden of malnutrition": insufficient intake of dietary energy (hunger), micronutrient deficiencies (hidden hunger), and excessive intake of dietary energy and nutrients (overweight and obesity) (Fan and Brzeska 2014).

Food Availability

The availability of food is largely controlled by how much resource has been allocated to food production. Water is key to food production and agriculture is the largest economic sector, using about 70% of the freshwater worldwide (UN 2016). For example, about 3,000-5,000 liters of water are needed to produce a kilogram of rice and 2,000 liters of water for a kilogram of soya (UN 2016). Attempts to increase food security require a corresponding increase in water consumption. Agricultural water use is projected to increase by about 20% globally by 2050 (WWAP 2012). Most global food production is from rainfed agriculture, which accounts for 80% of the cultivated land and produces about 60% of the global crop output (FAO 2011). Africa contributes the largest proportion of rainfed agriculture, about 90% of its cultivated land (UN 2016). However, due to climate change that would potentially reduce the rainfall patterns in some parts of the world, intensification of irrigation agriculture and improvements in water-use efficiency are considered vital in addressing water demand and food security (UNEP 2011). However, the projected increase in demand for water for manufacturing (400% by 2050), energy, and domestic use will likely impact the availability of water for food production (OECD and FAO 2012). It is estimated that 52% of the world's population and 40% of grain production could be at risk due to water stress by 2050 (UN 2016).

Food Access

Despite an overall improvement in the global availability of food, lack of nutrition has remained a serious problem. Over the period 1969-1971, 920 million people were undernourished globally. This was 35% of developing countries' population (McCalla 1999). From 1990-1992, 840 million people were undernourished throughout the world, amounting to 20% of developing countries' population (McCalla 1999).

Different rates of progress across regions have led to global and regional shifts in the distribution of undernourished populations. While a noteworthy reduction of absolute hunger in the world has occurred, roughly one out of eight people continues to be undernourished (Fan and Brzeska 2014). The overwhelming majority of these people (827 million) live in developing countries, where the prevalence of undernourishment has decreased from 23.6% to 14.3% (Fan and Brzeska 2014).

According to the FAO (FAO et al. 2013), most of the world's undernourished people are still found in Southern Asia, closely followed by SSA, and Eastern Asia (Belesky 2014). There are important trends within the distribution of undernourished peoples across Asian regions, with the regional share of undernourished people declining most in Eastern Asia and South-Eastern Asia, but increasing in Southern Asia, SSA, Western Asia, and Northern Africa (Belesky 2014).

The incidence of undernourishment in SSA has also fallen (from 32.7% to 24.8%) but remains the highest in the world (Fan and Brzeska 2014). A large part of the progress in reducing global hunger occurred in China, where the number of hungry people decreased from 272 million to 158 million between 2011-2013 (Fan and Brzeska 2014). In fact, two-thirds of the people who escaped hunger globally over the past two decades reside in China. Similarly, the prevalence of under-nutrition in China dropped from 22.9% to 11.4% over the same time period. However, China continues to be home to the second largest population of hungry people (19% of the world's hungry) after India (Fan and Brzeska 2014).

Food Utilization

Over the period 1961-1990, close to one billion people suffered from deficiencies in one or more micronutrients (e.g., vitamin A, iron, iodine, zinc, and copper). During 1994-1996, 1.6 billion were at risk of iodine deficiency. Deficiencies in important micronutrients such as vitamin A, iron, and zinc, known as hidden hunger, plague more than two billion people globally, again primarily in the developing world (Fan and Brzeska 2014). Significant numbers of children in developing countries suffer from micronutrient deficiencies, including anemia (52.4%), vitamin A deficiency (34%), and iodine deficiency (29.6%) (FAO et al. 2013). The inadequate intake of these essential micronutrients can potentially weaken the mental and physical development of children and adolescents and reduce the productivity of adults due to illness and reduced work capacity.

Food Security Threats and Challenges

Food production systems need to feed a growing and increasingly wealthy population amidst emerging challenges that include a progressively more fragile natural resource base, climate change, and food safety (Fan and Brzeska 2014). Many systemic issues affect food production, including price surges (Brown 2012) and unpredictable crop growing conditions resulting from climate change events such as droughts, floods, and changes in rainfall. Other global socio-political, economic, and ecological issues influencing food production include rapid urbanization; competition for the use of declining arable land; and systemic soil degradation, water scarcity, and loss of biodiversity. Food production systems are also affected by decreased quality of river ecosystems; over-exploitation of fish stocks; increased diversion of food for animal feed; rising energy costs; diversion of food and animal feed for bio-fuel; global population growth; critical resource constraints; global food wastage; reduced agricultural research and development support; and decreasing world grain reserves. Additionally, there is a trend toward excessive financial speculation on agricultural derivatives, primarily through over the counter (OTC) commodity index funds (CIFs) (Cribb 2010; Dawe and Slayton 2010; Lawrence et al. 2010). These multi- faceted, transnational issues are contributing to ongoing food price volatility and global food insecurity. Such complex and interconnected issues cannot be adequately addressed solely at the local or national level, but instead require broader regional cooperation (Belesky 2014).

A growing and urbanizing global population will put enormous stress on global food and nutrition security going forward (Fan and Brzeska 2014). A significant portion of this growth is predicted to occur in urban areas in Asia and SSA, where urban populations will almost double and triple in size by 2050, respectively (Fan and Brzeska 2014).

Natural Resource Pressures

Economic and population growth across the globe have come at a high environmental cost. Increasing natural resource constraints and degradation mean that the food demands of a growing and more affluent global population will have to be met with fewer resources (Fan and Brzeska 2014). Nearly a quarter of all global land has been affected by degradation, which equals a 1% loss in global land area annually – an area which could produce 20 million tons of grain per year (1% of global production) (IFPRI 2011; UN 2018).

Water Resources and Food Security

In terms of water stress, about 36% of the global population lives in water scarce areas, while 22% of the world's gross domestic product (GDP) is derived from water stressed areas (Veolia Water 2011). Especially relevant for the discussion on food and nutrition security is the fact that currently, 39% of global grain stores are produced through unsustainable water use (Fan and Brzeska 2014). In fact, the continuation of current water management practices threatens to expose 52% of the global population to severe water scarcity by 2050 (Fan and Brzeska 2014). Food production systems are both a cause and casualty of increasing climate change (Fan and Brzeska 2014). Activities associated with the production of food are estimated to generate between a quarter and a third of global greenhouse gas emissions that are responsible for climate change, mainly from the clearing of land for agricultural cultivation, fertilizer use, and farm animal digestion and manure management (Beddington et al. 2012).

The Special Challenge of Sub-Saharan Africa

Global models predict that SSA will have an increasing food deficit due to low crop yields, largely attributable to low water use efficiency and minimal use of fertilizer and agrochemicals (Neumann et al. 2010; FAO 2011). Several studies (Mauser et al. 2015; Pradhan et al. 2015; Erb et al. 2016) have argued that SSA can meet its projected global food demand by narrowing the gap between actual and potential yield. Yield gap closure is only achievable by applying the correct quantities of plant nutrients, adopting best agronomic management practices (such as good pest and weed control), and soil water management. These authors have also underscored the need for investment in research and development and good policies by governments that promote increased crop production. Analysis of the capacity of ten selected SSA countries to feed themselves by 2050 has shown the need for increased crop intensity on the current land and expansion of area under irrigation, in addition to yield gap closure and accelerated crop growth rates (van Ittersum et al. 2016). The latter option calls for additional availability of water, which is projected to be between 23% and 42% above agricultural water availability in 2010 (Burek et al. 2016). In Africa, water availability for food production is further threatened by the pollution of water bodies that has been occurring over the last two decades (UN 2018). Lack of adequate soil moisture caused by periodic droughts and poor soil fertility will probably be the biggest challenges to closing yield gap. Despite allocating about 70% of its fresh water resources to agriculture, Southern African Development Community countries still face food insecurity (Malzbender and Earle 2009). Therefore, there is need to critically consider other factors that impact food security such as land tenure, availability of inputs, and medium- to long-term financial support for agriculture.

Sub-Saharan Africa has significantly less land area under irrigation with less than 4% of its total cultivated land and an estimated 20% of the potentially irrigable land being irrigated (Burney et al. 2013). These data are in sharp contrast to Asia that has about 40% of its land under irrigation. (UN 2016). Therefore, most crop production in SSA is rainfed which, for countries in the semi-arid regions, is erratic with more frequent occurrences of drought (Rockstrom et al. 2010; FAO 2011). Such climatic and weather patterns have significantly contributed to crop and livestock failure and further worsened food security. For example, the drought of 2015-2016 agricultural season caused more than 40 million and 2.2 million people to be food insecure in southern African countries (SADC 2016) and Kenya (FAO 2017), respectively. During the dry seasons, dam water levels can decline by up to two meters (Swenson and Wahr 2009) and more than 90% of the water can be lost through evaporation (Mugabe et al. 2003).

Given that Africa alone has more than 90% of potentially irrigable land, this region offers opportunity for investment in water resources and irrigated agriculture. Although some countries in this region have policies that aim to boost crop productivity by expanding area under irrigation, water availability and accessibility will remain the limiting factors for improved crop and livestock productivity. Fereres et al. (2011) commented that future availability of water for food production using irrigation was more doubtful than the ability to produce sufficient food in the future. Indeed, with about 75% of the Southern African Development Community countries classified as water-scarce (Nhamo et al. 2018), it is unlikely that its population will be food-secure by 2050.

Strategies for Mitigating Food Insecurity in Sub-Saharan Africa

Water is central to food security in SSA, and several strategies that make it more available, accessible, and improve its utilization efficiency are necessary. Allocation and distribution of water resources have always been a big challenge in SSA (Dos Santos et al. 2017). In order to promote water accessibility and availability for food production, there is need for policies and legislation that govern water resources. This is particularly important in view of the shared water resources worldwide. Sub-Saharan countries that lie in the arid and semi-arid regions have shown interests. There have been some interests in technologies and practices that save water and improve water-use efficiencies in agriculture. For example, about 4-6 million hectares and 20 million hectares of land use untreated wastewater for irrigation (Jimenez and Asano 2004; Keraita et al. 2008). Rainwater harvesting practices such as collecting water from rooftops with corrugated iron sheets (Barron 2009), in-field water harvesting (Motsi et al. 2004; Munamati and Nyagumbo 2010), and the construction of sand dams (Nilsson 1988) have been widely promoted. In general, these strategies include investment and better management of water resources at farm, catchment, and regional scale. A summary of these strategies is shown in Table 1.

Conclusion

Food security is not only about supply, but also access, which calls for generating employment and income. Water availability and access are central to agricultural production and food security. Satisfying food security for the ever-increasing global population requires the implementation of effective water policies and strategies. Globally, the long-term strategies to food security remain technology development, productivity improvement, and continued investment in agricultural research. Although expansion of arable land has resulted in an increase in food production in SSA, developing more irrigation and intensifying crop productivity will likely be more sustainable strategies. These strategies will require additional exploitation of water resources and subsequent integrated water resources management. The availability and consumption of nutritious foods can be promoted through the development of high water-use, efficient, high yielding, and more nutritious crop varieties (for example, using biotechnology), public information campaigns, and pricing policies. The dwindling of arable land and water resources calls for the development of resource-efficient agricultural technologies and practices that enable the production of more food using less resources. Food security will also require sustainable intensification of complex production systems, and appropriate national and international policies. Policies and investments should promote food production systems that are adapted to the emerging climatic, natural resource, and nutrition challenges facing food security.

Table 1. Selected strategies for mitigating food insecurity in Sub-Saharan Africa.

Strategy	Implementation	Challenges	References
Increase Water Availability	• Construct more water reservoirs • Adopt integrated water resources management • Use water harvesting technologies • Re-use and re-cycle water	• High initial cost of irrigation development • Some technologies are labor intensive	FAO 2011 Keys and Falkenmark 2018 Motsi et al. 2004 Ngigi et al. 2005 Moges et al. 2011
Increase Water Productivity	• Adopt soil and water conservation technologies • Use water harvesting technologies	• Some technologies are labor intensive	Tilman et al. 2011 Keys and Falkenmark 2018 Dile et al. 2013
Expand Irrigated Agriculture	• Open up new area • Rehabilitate irrigation • Use water saving irrigation technologies	• High initial cost of irrigation development • Threats of salinization of soil and reduced groundwater quality	Fereres et al. 2011 Nakawuka et al. 2018 van Ittersum et al. 2016
Research and Development	• Breeding for drought tolerant and early maturing crop varieties • Precise application of water to plants	• Requires longer time for positive results	Hadebe et al. 2017

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