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Food and water systems in semi-arid regions – case study: Egypt

by
Catharien Terwisscha van Scheltinga
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Contents

Abstract

Water is a major driver of food systems in arid and semi-arid countries. This paper explores the role of water in the food system by focusing on Egypt, an arid country where freshwater from the Nile is a prerequisite to produce food. The country is facing a fundamental dilemma for its food system, linked to efficient water use: it can focus on raising the level of food self-sufficiency by allocating freshwater resources to food production, or rely on food imports from water-abundant regions worldwide.

An overview of the food system in Egypt is presented, followed by a brief description of the country's water footprint. Using a food system analysis approach, the main drivers and outcomes in the food system of Egypt are described, followed by two examples of food system trade-offs where water plays an important role: wheat and chicken. The paper concludes with a reflection on the role of water in the food system and gives suggestions on how the role of water in the food system can be addressed systematically.

Keywords: food system, drivers, outcomes, water, agriculture, sustainability, Egypt

Preamble

Water is life, water is food. No food without water.

No food system without a working water system.

1. Introduction

To feed the current and future population, an approach going beyond the traditional “more food” perspective is required, paying attention to other relevant issues such as dietary quality, food security, environmental constraints or socio-economic effects of the food chain (Béné et al. 2019). Thus, the concept of sustainable food systems has gained prominence in recent years, aiming to “ensure food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition of future generations are not compromised” (HPLE 2017).

A food system contains all processes and infrastructures involved in feeding the population, including the inputs needed and outputs generated at each step of the food value chain. An oft-used food system framework is shown in figure 1. It has boxes that cover the value chains from production through marketing and processing to consumption (compartments), boxes that show driver groups that cause food systems to transform (upper five boxes), and outcome groups that may be satisfactory or give reason for concern (three boxes on the right-hand side). System transformation – deliberate or not – causes the outcomes to change. An improvement in one may happen at the expense of the other (trade-offs), but if done cleverly, a transformation may also imply improvements in more than one outcome area (synergies).

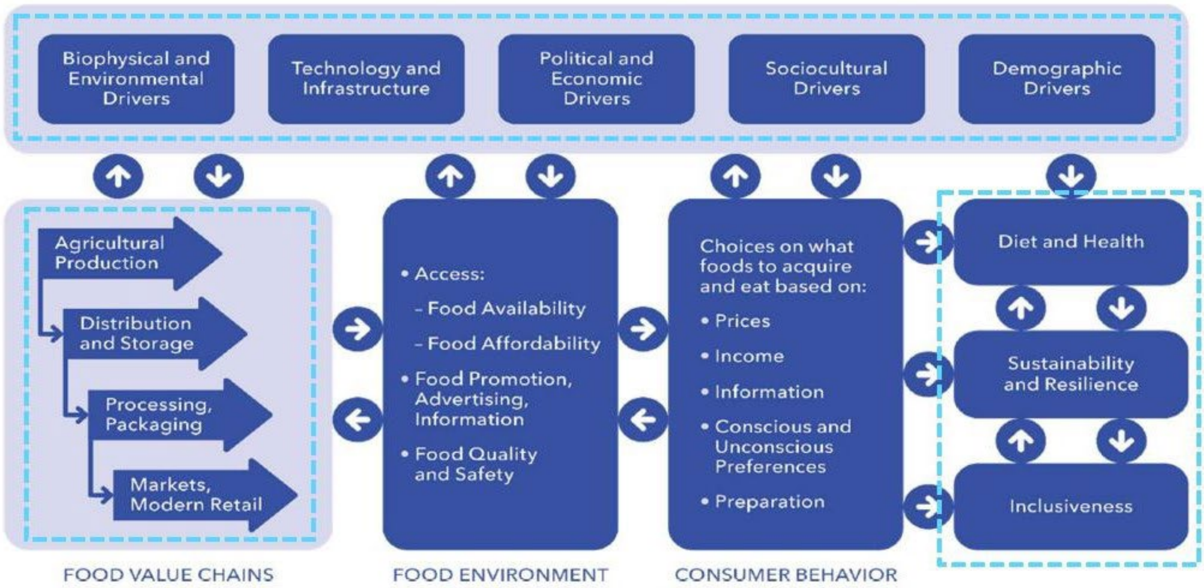

Figure 1: Description of a food system. Blue dotted lines highlight where the authors consider there is a relevant connection between the food system and water.

Source: IFAD (2020), derived from Glopan (2016).

Food is part of agriculture, a water-dependent activity that requires: (i) management to guarantee water availability; (ii) avoiding conflicts between users; and (iii) limiting its potential negative environmental impact. Water is traditionally considered a driver in the food system approach, since it is a prerequisite for growing crops (Arslan et al. 2020).

Approximately 7,000 km^3 of water is consumed by crops every year, with water from rainfall representing the largest share (de Fraiture et al. 2007). Irrigated agriculture, accounting for less than 20 per cent of the world’s total cultivated area, accounts for more than 40 per cent of global food production, while the remaining 60 per cent is reliant on rainfall (FAO 2018a). Irrigation has a positive effect on food production, increasing crop yields and making production more stable and reliable. It allows farmers to increase their margin by growing more profitable crops. For millions of farmers worldwide, access to water for irrigation is a thin line between poverty and prosperity (Oweis 2018).

However, water is also present in the entire food chain, from food production to processing and consumption, either as an input or as a receptor of waste. Access to sufficient and clean water is also essential to guarantee a healthy population. When considering trade-offs for food system outcomes such as nutrition and health versus environmental vulnerability, water plays an important role. In a context of population and economic growth, social fragility, land use and climate change, closing the gaps between water and food is a priority issue to deal with, especially in semi-arid regions, where water availability is a limiting factor. While strong economies can afford to import water-intensive commodities from other regions, other developing countries will be more dependent on their own water availability, requiring smart and well-planned decisions about how to better allocate it (Falkenmark 2013).

The water that is present in agricultural commodities is hardly regarded as yield, and in exported commodities, it may even be considered a rather expensive nuisance because of its weight and/or volume. In arid and importing countries this may be different because the imported food has not required any of the scarce water resources of the arid country itself. Hence, water management strategies can be fully devoted to nutritious and healthy food, to export commodities and to employment in the value chains for these commodities. This then changes the picture of outcomes and trade-offs. To understand the water flows embedded in international trade, as well as the water intensity of a food item, the water footprint concept was developed as a tool to quantify all the direct and indirect water requirements of a (food) product (Hoekstra et al. 2011). The water footprint measures humanity's appropriation of fresh water in volumes of water consumed and/or polluted.

Arid countries generally have higher food imports than exports. This may still be fine in the overall trade balance if other sectors compensate for this. Nevertheless, it implies that national agricultural production in a water-limited system always depends on food import policies. If the subsidies are substantial, it may be a reason for producers to close their business. However, in cases where they grow what is not being imported, they may be stimulated.

Giving this interdependency between food production and water systems, achieving United Nations Sustainable Development Goals (SDGs) 2 (zero hunger) and 6 (clean water and sanitation) requires a careful balance between the objectives for water and food (Mulligan et al. 2020). This article addresses the following key issues:

- How do the food system and the water system in an arid country interact, and what are the trends that affect them?
- What are key food system compartments, drivers and outcomes/trade-offs in an arid, net food-importing country?
- If we take the "water footprint" perspective on board, how does this influence trade-offs between the food system outcomes?

The article explores the role of water in the food system by focusing on Egypt, an arid country where fresh water from the Nile is a prerequisite for producing food. To cope with its increasing population's demand for (healthy) food, the country is facing a fundamental dilemma: either allocate its scarce fresh water resources to food production more efficiently to have a high self-sufficiency rate, or rely on food imports and offer them at a subsidized price to the consumer, to reach the entire population.

In the next section, an overview of the food system in Egypt is presented using a food system analysis approach. Data on water and food for Egypt and trends between 1997 and 2017 can also be found. Then in section 3, food system compartments, drivers and outcomes are discussed. Compartments cover the production–consumption chain. The environmental driver "water availability" and the socio-political driver "food subsidies" are contrasted here. The outcomes provide appreciations of health/nutrition, sustainability and inclusiveness. Finally, in section 4, the water footprint concept is used to challenge the food system outcomes when seeing water in food products as a by-product without value. This concept is then used to appreciate two important food products in Egypt: wheat and poultry. The ambition is that the paper holds promise for food system thinking in a wider range of arid, strongly food-importing regions.

2. Trends in food and water systems development

Egypt's population grew by 47 per cent (from 66 million to 97 million people) between 1997 and 2017. This growth is continuing, and in 2050 it is expected that the population will number 151 million people (FAO 2017b). In addition, Egypt experienced growth in gross domestic product (GDP) from US$1,200 per capita in 1997 to US$3,500 in 2017, due to several economic reforms attracting foreign investments, although this growth is not experienced by all its inhabitants. This implies an unequal distribution of wealth. It should also be noted that economic wealth is not equally distributed among the population, as revealed in a World Bank study on inequality in Egypt (Verme et al. 2014). Table 1 shows major socio-economic and food- and water-related indicators and their trends between 1997 and 2017.

Table 1
Main water and food characteristics of Egypt

	1997	*2007*	*2017*
Population (millions)	66	79	97
GDP per capita (US$1,000s)	1.2	1.6	3.5
Renewable water resources (m^3 per capita)	869	723	589
Area under cultivation (% of total land)	3.2	3.5	3.7
Undernourishment (% of population)	5.2	4.8	4.5
Severe food insecurity (% of population)			10
Adult obesity (% of population 18+ years)	21	25	31
Sugar and sweetener supply (kg/capita/year)	30	26	27
Vegetables supply (kg/capita/year)	175	224	159
Fruits supply (kg/capita/year)	88	107	103
Cereals supply (kg/capita/year)	254	244	262
Fish supply (kg/capita/year)	10	18	23
Meat supply (kg/capita/year)	21	28	26

Source: Galal (2002); FAO (2020).

The combination of a growing population and GDP with unequal distribution of wealth causes food security risks. Moreover, there is little arable land in Egypt – mainly limited to the Nile Valley and Delta, as well as a few oases and some arable land in the desert. The total arable area is below 4 per cent of the territory and has hardly increased over the years, mainly due to the lack of fresh water (Index Mundi 2020). Most of these arable lands are now equipped for irrigation (FAO 2020b). Except for a small region along the Mediterranean coast, all crops are irrigated with Nile River water, regulated upstream by the Aswan reservoir as the most important fresh water source. From this reservoir, Egypt receives an annual amount of 55.5 km^3 of water, according to the Sudan-Egypt Waters Agreement of 1959. Even though Egypt managed to increase agricultural crop production significantly from 1980 to 2017 (FAO 2017b), water availability per person decreased from 869 m^3/capita/year in 1997 to 589 m^3/capita/year in 2017 (table 1). In summary, the population growth, growth of GDP and unequal division of wealth, in combination with a scarcity of arable land and fresh water, will cause serious food security risks in the future.

From a nutrition perspective, Egypt experiences undernourishment rates of between 4.5 and 5.2 per cent, with a decreasing trend since 1997. On the other hand, the country has a high rate of adult obesity throughout the population, with an increasing trend from 24.6 per cent in 2007 to 31.1 per cent in 2016 (Statista 2020). The latter can be explained by a major shift in Egyptian food consumption from 1990 to 2017, with an increased amount of calories, a sustained increase in (processed) meat and fish consumption, and no reduction in cereal intake (table 1). Thus, dietary patterns have changed over time, which could explain the growing rates of obesity.

Food security is an issue in Egypt, as population numbers are growing, while there is limited scope to expand the area of arable land. In response to this issue, the country relies on substantial food imports to meet domestic food demand. Figure 1 shows an overview of trade for some major Egyptian food items.

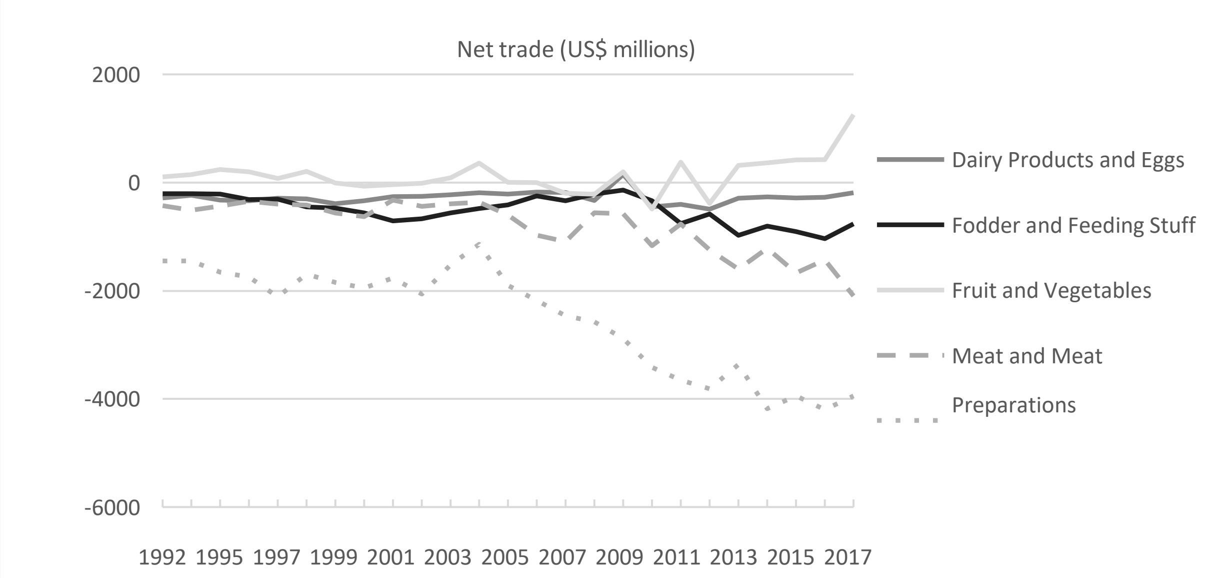

Figure 2: Net trade of major food items in Egypt

Source: FAO (2017b).

Egypt is traditionally a net importing country (figure 2), with agricultural commodities representing more than 25 per cent of total imports (WTO 2020). With respect to food, Egypt imports about 40 per cent of its food needs annually and is the largest importer of wheat in the world (FAO 2017b). The other main imported crops include maize and soybean. The import of meat-based products has also increased over the last decades due to changes in the dietary habits of the Egyptian population, particularly in relation to a gradual increase in chicken consumption. On the other hand, Egypt is also exporting high-value food commodities, including fruits and vegetables such as citrus, potatoes, onions, grapes, pomegranates, garlic, mangoes, strawberries, beans, guava, cucumbers, peppers and aubergines. Table 2 presents an overview of agricultural imports and exports, and shows that the gap in value between them has been growing over time. Thus, Egypt is becoming increasingly dependent on other countries to meet its domestic food demand. This gap is likely to increase as population and GDP rise.

Table 2

Trade in Egypt

	1990-1994	*1995-1999*	*2000-2004*	*2010-2014*	*2014-2019*
Average agricultural imports per year (US$ millions)	2,642	3,583	3,249	13,943	13,053
Average agricultural exports per year (US$ millions	426	531	832	4,292	4,716

Source: FAO (2017b).

3. Food system characterization

The food system approach (Glopan 2016; IFAD 2020, as shown in figure 1) is applied to show the connection with the water system. Water is the main driver of food systems in Egypt, as it is an input to agricultural production. The quantity and quality of water and its availability over time (scarcity) are important conditions that make agricultural production possible and productive. Water is also a political and economic driver, as it is a public good to be managed. In the Nile Delta, water availability is not only subjected to biophysical and environmental conditions, but also to an agreement between Egypt and the upstream countries. In a water-scarce context, where and how the water is used is conditional on the decisions of policymakers. Water is also a demographic driver in the sense that a growing population means growing water demand, for drinking, sanitation, health and agriculture. In the component "distribution and storage," water is used for cleaning products before marketing. Further, any loss of product (bad storage) translates into a loss of water (which cannot be used for other purposes). As such, water is a primary driver that (in)directly affects all components of the food system.

3.1 Food system categories

As in other countries, multiple food systems coexist in Egypt and include:

- The traditional food system
- The transitional food system
- The modern or high-tech food system.

The characterization of the three food systems is based on the typologies as defined by the High Level Panel of Experts (HLPE 2017), the food system description of Egypt provided by Broek and Boerrichter (2014), and personal communication with Ir. K. Roest, food and water specialist in Egypt (2020).

Traditional food system

This food system is mainly represented by smallholder farmers and comprised 62 per cent of the population in 2018 (Armanius 2018). The average annual income between 2005 and 2018 was EGP 27,922 (± US$1,800) (CEIC 2018). Unemployment reached 11.4 per cent in 2018, with more than three quarters of the jobless aged 15-29 (IFAD 2019). This implies that parts of the population live under the US$1.25/day poverty line. In this food system, the producers and consumers are basically the same people. Agricultural production is mostly for own and/or family consumption, as the areas of land are too small to grow crops commercially: the average farm size is 1-3 feddan (0.42-1.26 ha). Farmers own their own livestock (cows, buffalo, sheep, goats, chickens) for milk and meat, and grow wheat, vegetables and maize for home consumption. Food is not distributed outside the region, and is usually directly prepared and consumed. There is little trade, and mechanization is rarely used. People living in this food system often rely on a second job (e.g. in the construction sector) to add to their family income. They usually come from rural areas.

Transitional food system

People in this food system are farmers with generally higher incomes (>US$1,500/year) and accounted for around 24 per cent of the total population in Egypt in 2018 (Armanius 2018). As in traditional food systems, farmers produce food mainly for own consumption. However, they also have the possibility to grow cash crops such as vegetables and cotton that can be traded on markets. Farm sizes are 3-20 feddan (1.26-8.40 ha), and there is moderate to good access to domestic markets through middlemen, which allows for food trade. Thus, the food system contains people from cities who purchase domestically produced food items on markets or as street food. It contains mostly unprocessed food items.

Modern or high-tech food system

This food system includes farming systems commonly located in the desert area near oases which produce large volumes of agricultural products, use patented variety crops (citrus fruits, vegetables), have well-organized supply chains and use foreign knowledge by hiring international consultants and experts. This food system is characterized by a dependency on imports from both a production and a consumption perspective. On the production side, imports are in the form of agrochemicals, services and equipment to cultivate food, while on the consumption side, diets are significantly based on imported (semi-)processed food. Income levels are high, even up to European standards. Around 13 per cent of the Egyptian population live in this food system. Besides the farmers, this food system also includes the wealthier people in large cities (e.g. Cairo) who purchase (processed) foods from supermarkets that are stocked with high-quality food items.

3.2 Food system drivers

Multiple drivers affect the food system in Egypt, including governance, the availability and quality of natural resources, population growth, changing consumer preferences, the availability of techniques and infrastructure, and climate change (Bene et al. 2019). It is obvious that one of the most important food system drivers in Egypt is water for domestic food production, due to limited rainwater, scarce groundwater resources and a fixed amount of surface water inputs from the Nile River. The second most important driver is food subsidies. This is a policy decision to make food available at affordable prices within the context of population growth and urbanization (demographic driver); it will be assessed further.

Water availability and quality

The quantity and quality of water, and its availability over time (scarcity), are important conditions making agricultural production in Egypt possible and thriving. However, the country is dealing with severe water scarcity, as can be observed in its national water balance (Omar and Moussa 2016) in table 3.

Table 3
Egypt water balance
(Billions of cubic metres – BCM)

Water inflow Egypt	*BCM/year*
Nile River	55.5
Rainfall	1.6
Non-renewable groundwater from desert	2.4
Shallow groundwater	6.5
Total water inflow	66.0
Water requirements by all sectors	79.5

Source: Omar and Moussa (2016).

Egypt requires more water (79.5 BCM/year) than the available renewable resources (63.6 BCM/year). Thanks to the recycling of drainage water from the Nile and the introduction of modern and more efficient technologies for irrigation, the country is able to cope with a water shortage of 13.5 BCM/year, but the water shortage is likely to deteriorate as the population and economy grow. This foreseen socio-economic transformation has implications for food demand and for dietary patterns of the population. In general, people living in urban areas with higher income levels consume higher-quality and more water-intensive foods such as meat, milk and eggs (Ecker et al. 2016). Water scarcity is a strong limiting factor for food production now and will be in the future for Egypt, and self-sufficient production of food in the current situation is not possible.

Food subsidies

Egypt has a long history of subsidizing food to promote social equity and political stability. Started in the 1940s, the food subsidy programme was expanded in the 1950s and 1960s (by the socialist Nasser regime) to provide basic commodities at subsidized prices to all Egyptians. The main subsidized food items include wheat, sugar and cooking oil, which are also the food items most imported by Egypt. During the 2008 global food price crisis, the country sought to address the problem of bread distribution and leakage in two ways: through the mass production of bread using military bakeries and by allowing local distribution outlets to administer the sale of bread. After the 2011 revolution, food subsidy costs represented about 25 per cent of total public expenditure. The system was perceived to be poorly targeted, with 88 per cent of Egyptian households having access to a ration card allowing purchases of food at subsidized prices.

Food subsidies are regarded as an important safety net for poor people, guaranteeing the availability of affordable staple crops, helping to reduce malnutrition and infant mortality, mitigating the adverse effects of recent economic reform and structural adjustment, and preventing riots and disturbances within society. On the other hand, it is suggested that subsidization of these general energy-intensive food items contributes to the country-wide obesity problem (Asfaw 2006a). Obesity rates among women in Egypt, for instance, show a continuous rising trend (figure 3).

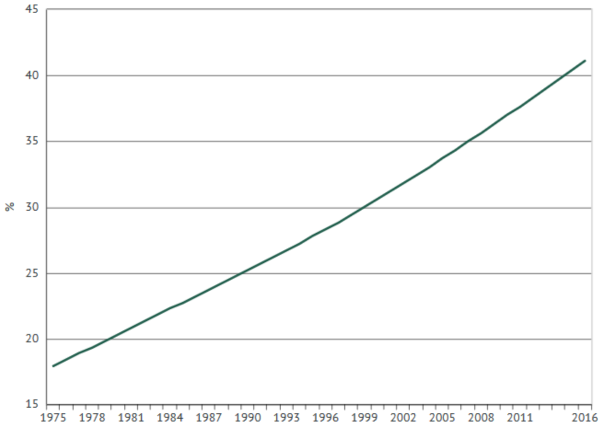

Figure 3: Obesity trends for women in Egypt, 1975-2016

Source: KNOEMA (2020).

3.3 Food system outcomes

This section presents the main characteristics of the three food systems in Egypt through descriptions of the socio-economic and environmental outcomes of the food system (see figure 1), which include nutrition and healthy diets, sustainability and resilience (through sustainable water use and climate resilience), and inclusiveness (through employment and income generation).

Nutrition and healthy diets

As shown earlier, diets in Egypt are currently changing towards more meat, fish, wheat, sugars and oil/fats, with significant effects on the population's nutritional status. About 31 per cent of all people aged 18 years or older are overweight (Statista 2020). The change in diets towards these food items has also been associated with food subsidies on wheat and oil products (Asfaw 2006b). At the same time, some people in the country are undernourished. The national prevalence of under-5 stunting was, for example, 21 per cent in 2014 (UNICEF 2020). This number is highest in urbanized areas, mainly due to low household incomes. Both under- and overnutrition (through excess consumption of calories) are widespread throughout the country and visible in all three Egyptian food systems. This implies that unhealthy food products are available and purchased at restaurants, modern supermarkets, and even informal markets in the poorest regions of Egypt. However, more research is required with respect to linkages between food subsidies and diets, food availability and food choices.

The diet of the Egyptian population will also have a large influence on the water resources required to produce their food, and vice versa. The water footprint concept, as presented earlier, enables us to analyse the water-related sustainability of Egyptian consumption behaviours and to assess the potential environmental consequences of the different pathways for the country's food system transformation.

Traditionally, meat-based diets are linked with a higher water footprint than vegetable-rich diets, since livestock products generally have a larger water footprint than crop products, both per kg and per calorie (Hoekstra 2014). The introduction of more healthy or sustainable diets – even those containing meat – implies the need for a larger reduction of the water footprint (Vanham et al. 2013, 2018).

However, this reduction in the total water footprint should be carefully considered. Contrary to popular belief, foods of animal origin mainly contribute to the green component of the water footprint, whereas fruits, nuts and oils contribute more to the blue component, since they are usually grown under irrigation (Harries et al. 2020). The socio-economic component also has a large influence on diet and, therefore, on its water footprint. The blue water footprint of urban populations in Egypt per capita is roughly 20 per cent higher than that of rural households (696 vs 597 m^3/capita/year), mainly due to the higher consumption of livestock-based and processed food products (Wahba et al. 2018).

Although it is difficult to establish a clear linear relationship between healthy diets and water, a more balanced diet, which integrates nutritional and environmental considerations, could decrease the environmental burden in an efficient way (Tompa et al. 2020). By introducing the water footprint as a complementary tool to develop national food-based dietary guidelines, water-scarce countries could reduce their internal blue water consumption while meeting their nutrition requirements (Mirzaie-Nodoushan et al. 2020).

Sustainability and climate resilience

Sustainable water use

The three identified food systems in Egypt are all using water unsustainably. The traditional and transitional food systems mainly rely on Nile water, which is used for the irrigation of agricultural lands either via direct canal irrigation or indirectly through (shallow) groundwater. Although various programmes have been initiated to increase irrigation efficiency, the irrigation practices in these food systems are still mainly based on inefficient traditional/conventional techniques, leading to excess water use by the agricultural production sector (Amer et al. 2017). Moreover, the traditional and transitional food systems also include the cultivation of water-intensive crops such as rice, sugar cane and bananas. These food systems need to deal with highly polluted water, as vast amounts of untreated waste- and sewage water are discharged into the water system. This is putting additional pressure on the availability of fresh water resources. Water treatment is not widely implemented, while the availability of desalinated water is lacking due to the high cost. There is a general lack of understanding and low public awareness of saving water and preventing water pollution throughout these food systems (ibid.). The modern food system does not rely on the polluted surface water sources, but mainly uses fossil groundwater reserves from deep aquifers to produce food that meets international food safety standards, which is not sustainable in the long term. From a consumer perspective, the modern food system value chain is particularly focused on export. As such, food and thus (virtual) water are exported out of the country.

Climate resilience

Climate change is a serious threat to Egypt, due to rising temperatures and sea levels, risks associated with coastal erosion, flooding and salinity intrusion, and decreased rainfall (ibid.). It will have three main consequences: (i) changes in the climatic conditions in upstream areas will affect fresh water; (ii) local environmental conditions in the delta itself may change, which could have an impact on crop growth and productivity; (iii) and the delta is very vulnerable to a sea level rise, resulting in problems such as coastal erosion, enhanced flood risk and saltwater intrusion.

The primary source of fresh water in the Nile Basin is the Blue Nile, originating in the Ethiopian Highlands. Projections of changes in rainfall in this area are inconsistent. In an ensemble of regional climate models, changes in annual rainfall in the Blue Nile Basin range from a 15 per cent decrease to a 10 per cent increase by mid-century, affecting water availability in Egypt (Conway 2017; Taye et al. 2020). Similar to this, the impacts on the winter rainfall of the coastal region of the Nile Delta, averaging around 200 mm/year, is still unclear. Some models project an increase in heavy rainfall events, and there is some evidence that severe rainfall events have been increasing in recent years, with notable events in October and November 2015, October 2016 and April 2018, leading to casualties and crop losses due to flooding (Fawaz and Soliman 2016). Temperature rise is another relevant issue to consider, with most of the models agreeing on a rise of around 2º C. Higher temperatures can have widespread impacts, causing more frequent heat extremes, higher evaporation rates and negative impacts on, for example, wheat yields (Fawaz and Soliman 2016; Ali et al. 2020). How these climatic changes will affect agriculture in Egypt is, therefore, uncertain. However, year-to-year variability is also expected to increase, with significant consequences for the reliability of water resources (Jevrejeva et al. 2014; Siam and Eltahir 2017).

Climate change will also affect global sea levels. While the best estimate for global mean sea level rise is well below 1 m, higher rates associated with significant melting of the Greenland and Antarctic ice sheets cannot be ruled out, with an estimated upper limit of 1.9 m (Jevrejeva et al. 2017). High rates of sea level rise will have major impacts on large cities such as Alexandria and Port-Said, but will also increase saltwater intrusion in the coastal Nile Delta Aquifer. A recent study found that, on its own, groundwater extraction has a greater impact on the salinization of the Nile Delta Aquifer than sea level rise, but the two factors combined cause the largest reduction in fresh groundwater resources (Mabrouk et al. 2018).

The traditional food system is not very resilient to these repercussions of climate change. In general, this food system can be described as a natural food environment where people are dependent on land, water and other resources which are locally available. Water availability and soil salinity are, for example, two important parameters that decide what food is grown and consumed in this food system. Changes in the environmental conditions of the agricultural system (e.g. water availability and soil quality) due to climate change may have a severe impact, especially since mechanization, technology and knowledge on mitigation measures is often lacking.

The transitional food system has more opportunities to address the effects of climate change through the use of equipment, techniques and additives. Adaptation options to reduce vulnerability to sea level rise include beach nourishment and installing breakwaters. Another important adaptation measure is spatial planning. Future developments have to take sea level rise into account. Also, improving coastal zone management can significantly reduce the vulnerability of the coast to future climate change.

The modern food system is characterized as a system with a high level of control, and, therefore, greater resilience to climate change. This system can be described as a fully fledged man-made environment with modernized retail. Moreover, there are sufficient technologies and knowledge within this system to find solutions to problems that may occur due to climate change. In addition, it could be argued that this food system entails the international trade of food to make it more resilient to the effects of climate change in Egypt. However, the actual effects of climate change on crop yields, cultivation transitions and farmer incomes of all food systems need to be further investigated.

Market inclusiveness

Smallholder farmers play a crucial role in food systems, both as the suppliers of food but also as its main consumers. This is especially the case in Egypt, as around 24 million people (or around a quarter of the population) are involved in agriculture for their livelihood (FAO 2020a). In the traditional food system in the country, the smallholder farmers are both the producer and the main consumer of food, with little interaction with the broader market. There is little added value to the agricultural products produced, which hampers growth in family income and the national economy at large. As such, inclusivity of the traditional food system is ranked as poor, particularly with respect to smallholder farmers in food value chains, and young people.

The transitional food system is more dynamic from a market perspective, as relationships between producers and markets exist, and prices are negotiated based on personal economic goals. The markets are more complex, as they include input providers (e.g. fertilizers, mechanization equipment), shopkeepers, traders and processors, and generate more added value to food and, thus, economic growth for both young and elderly people. The modern food system is judged as the system with the highest level of market inclusivity. These markets are well developed, consist of complex value chains, including certification of products, and use high-tech equipment and (international) services to maximize agricultural yields and income. The modern Egyptian food system value chains produce high-quality food that meets international standards with respect to food safety. They also provide a decent income for farmers as well as for its service providers, and generate jobs for both low/moderately and highly educated people (Broek and Boerrichter 2014).

An overview of the food system outcomes for the three identified food systems in Egypt is presented in figure 4, based on a qualitative expert judgement from the authors.

Based on the description of the nutrition and health outcomes of the Egyptian food systems, which reveals that cheap and unhealthy food is consumed by all groups of people, leading to a situation of increasing obesity, the nutrition and healthy diets score is set at 2 (poor) for all food systems.

For climate resilience in the traditional food system, changes in the system due to climate change may have a severe impact, as mechanization, technology and knowledge on mitigation measures are often lacking. This food system is, therefore, particularly vulnerable to climate change and given a score of 1 (very poor). A slightly higher score of 3 (moderate) is given to the transitional food system, as it offers more opportunities to address climate change. The modern food system is characterized as highly resilient to climate change (a score of 5).

There is little market inclusiveness in Egypt's traditional food system; therefore, it is given a score of 1. The market dynamics of the transitional food system in Egypt is given a score of 3, although more research is required with respect to the actual functioning of the market and its value chains. The modern Egyptian food system value chains produce high-quality food that meets international standards with respect to food safety, with complex value chains providing multiple employment opportunities and providing a decent income for both farmers and its service providers. It is, therefore, considered inclusive and given a score of 5. It should, however, be noted that more research with respect to gender inclusiveness is required.

Water is the main limiting factor in the optimal functioning of food systems in Egypt. The country's three identified food systems are, however, all using the water system unsustainably. Although improvements in efficient water use have been initiated, overall sustainable water use is given a score of 2 (poor) for both the traditional and transitional food systems, as there is still scope to further develop modern irrigation techniques and water reuse. The modern food system mainly uses ancient groundwater reserves from deep aquifers, which is not sustainable over the long term. From a consumer perspective, food (and thus virtual water) is exported. Overall, sustainable water use by the modern food system in Egypt is given a score of 1 (very poor).

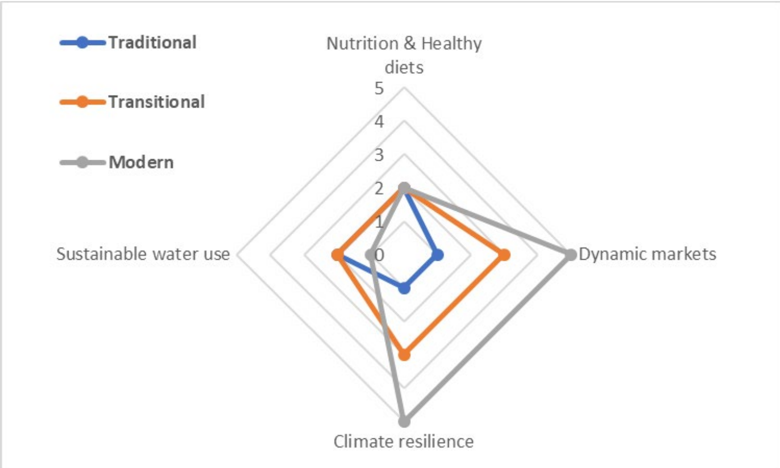

Figure 4: Food systems' performance based on four socio-economic and environmental parameters.

A score of 0 is regarded as poor; a score of 5 as very good. Scoring has been done by the expert judgement of the authors. In this context, it should be noted that additional research is required to quantify the food system outcomes through stakeholder consultations in Egypt.

4. Linking water and food systems using water footprint analysis as a tool: The examples of wheat and poultry in the Egyptian food system

The role of water in the Egyptian national food system can be quantified using the water footprint approach (Hoekstra et al 2011). This section includes a short description of the concept and how it can be used to quantify the interaction between water and food. Egypt's water footprint is also described, and two relevant examples are presented. These examples show the interaction between the water and food systems in Egypt and which pathways result in increased food system outcomes that generate maximum value with respect to socio-economic and environmental parameters. Both examples are extremely important in the Egyptian food system. While they represent a substantial part of the Egyptian diet, they also have a wide implication for the water system due to their large water demand. It should, however, be noted that transition pathways generate synergies and/or trade-offs between food system outcomes.

The water footprint indicator provides relevant insights into the water gap, now and in the future, for decision makers regarding foreseen or desired food system transitions. It measures the amount of water required to produce each of the goods and services used by humans, considering the whole production chain and all the direct and indirect water flows involved (Hoekstra et al. 2011). The water footprint also differentiates the origin of the water, considering green water as the water coming from rainfall, stored in the soil and used directly by plants and crops, and blue water as the water applied through irrigation (either from surface or groundwater sources). Since agriculture is by far the largest water consumer, accounting for more than 99 per cent of the fresh water resources used (considering both the green and blue components), the water footprint of a country has a clear link to its food system. This could be explained by the fact that to produce 1 kg of cereals, around 1,650 L of water is required, or to produce 1 kg of chicken meat, more than 4,300 L of water is required (Mekonnen and Hoekstra 2011).

From a national perspective, the water footprint can be calculated from both a production and a consumption perspective. The first one will focus on measuring the fresh water consumed by the national economic sectors, while the second will focus on the products consumed by the population. By importing and exporting products, countries are de facto importing and exporting water – the so-called virtual water flows – and, therefore, externalizing or internalizing the water-related impacts of the food system.

4.1 Water footprint in Egypt

Egypt uses around 80 per cent of its fresh water resources for food production (FAO 2016). However, as the country is unable to produce all the food demanded by its growing population, it imports a large quantity of agriproducts, thus importing water. Based on this information, the water footprint of food consumption in Egypt has been established at around 70 km^3/year (green and blue water). More than 35 per cent comes from outside the country, thanks to the import of agricultural products (Mekonnen and Hoekstra 2011). By doing this, Egypt is not only importing the water embedded in those products – also called virtual water – but, moreover, is saving precious resources for other purposes, such as the production of high-added-value products for export. In this sense, around 8 km^3/year of fresh water is used by Egypt to produce agricultural products for export (figure 5).

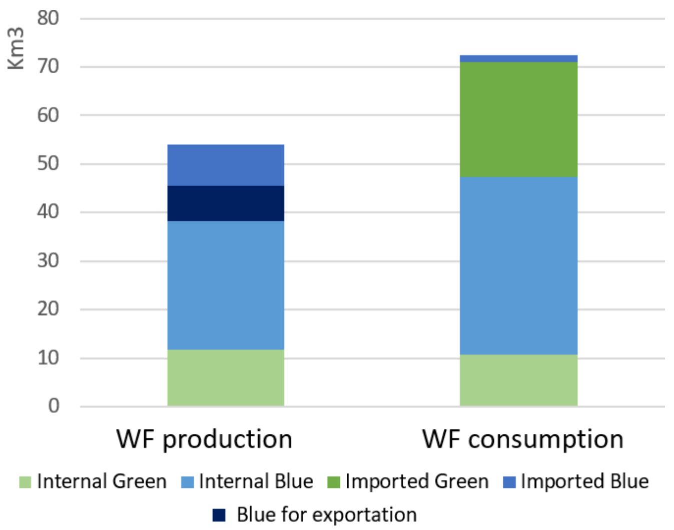

Figure 5: Water footprint of food production and consumption in Egypt

Source: Own elaboration from data extracted from Mekonnen and Hoekstra (2011).

The water footprint also provides information related to the water “gap” for food production, now and in the future. The expected increase in population, together with the potential effects of climate change on water availability, leads to changes in the potential water gap for food production. Thus, Abdelkader and colleagues (2018) developed a modelling framework to assess the future water gap in Egypt. They modelled several scenarios considering different rates of population growth, increases in water availability by reuse and desalinization, increases in irrigation efficiency, and agricultural expansion. They found that while water availability will remain almost constant, the growth of water demand, for municipal use (drinking water, sanitation, industrial use) and especially for food production, will increase to almost 100 km^3/year by 2050 (Abdelkader et al. 2018) (figure 6).

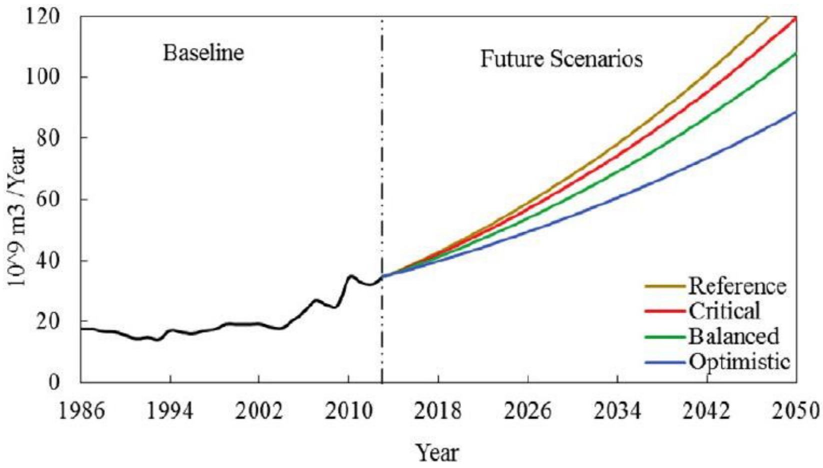

Figure 6: Current and projected water gap according to some scenarios

Source: Abdelkader et al. (2018).

4.2 Wheat

Wheat is one of the most essential ingredients in the Egyptian diet, representing around 30 per cent of average daily calorific intake, estimated at 3,160 Kcal (FAO 2018b). Wheat represents almost 10 per cent of the total value of agricultural production, and about 20 per cent of all agricultural imports to Egypt. The predominance of wheat in Egyptian dietary habits comes from both cultural and political factors. *Baladi* bread, mainly made with wheat flour, has been produced since the times of ancient Egypt and is considered a staple at Egyptian tables, from breakfast to dinner and for all social classes. The price of *baladi* bread has been highly subsidized since the early 1970s, where a food security policy came into force to make wheat more affordable for the population, causing a rise in its consumption from 80 kg/capita to the current 146 kg/capita per year (McGill 2015). This figure has been fairly stable over the last 20 years and is independent from income growth. However, with a growing population, the total national consumption of wheat has increased drastically since the mid-20th century, from 2.5 million tonnes in the early 1960s to more than 19 million tonnes in 2018 (Index Mundi 2020).

To cope with the exponential demand for wheat, and as by far the largest importer of the product globally, with a self-sufficiency rate of around 45 per cent (FAO 2018), the Egyptian government established an import policy and is heavily involved in the wheat value chain. The Egyptian government is the major purchaser of domestic wheat, and the General Authority for Supply Commodities (GASC) alone is the world's biggest wheat purchaser (McGill 2020). Thus, of the 19 million tonnes consumed yearly in Egypt, almost 9 million tonnes are produced in the country, either for direct consumption by the farmers (or used as seed and feed) or purchased by the government. The remaining 10 million tonnes are imported by the government (4.3 million tonnes) and by the private sector (5.7 million tonnes).

Unlike water-abundant regions of the world, the production of wheat in Egypt depends exclusively on irrigation and, therefore, has a large blue component. Although the water footprint of 1 kg of wheat from Egypt is lower than that of the largest world producers, such as China or Russia, in the latter, the blue component is minimal, since wheat is usually grown under rainfed conditions. Thus, the total water footprint of wheat production in Egypt is calculated as 1,100 m^3, with blue water comprising more than 80 per cent (Mekonnen and Hoekstra 2011).

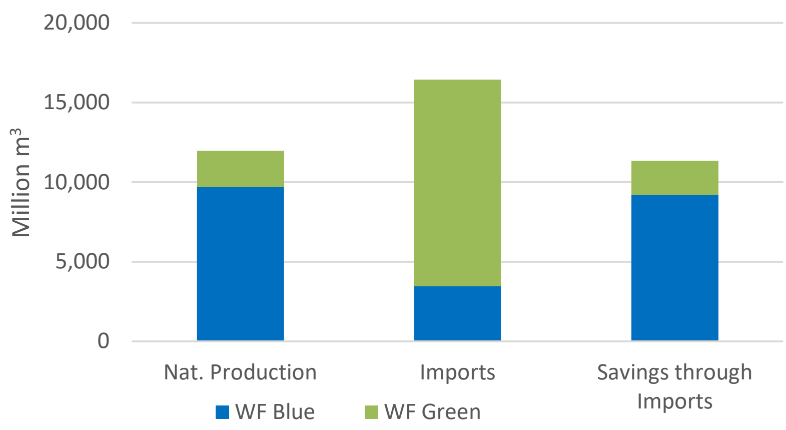

Figure 7: Water footprint of wheat consumption in Egypt (million m^3/year) (2011-2014).

Source: Own elaboration based on data from McGill (2020) and Mekonnen and Hoekstra (2011).

In total, to produce 9 million tonnes of domestic wheat, Egypt requires almost 10 km^3/year of blue water (figure 7). If all the wheat consumed by Egypt were produced nationally, the total fresh water resources required would be around 18 km^3/year. Due to its wheat imports, Egypt is saving around 9 km^3/year of its national fresh water resources, which can be used in other sectors with higher added value, such as fruit production for international markets.

Coping with growing demand

In line with population growth, demand for wheat in Egypt will also increase. By 2050, it is expected to grow from the current 19 million tonnes to more than 40 million tonnes, while domestic production will reach a maximum of 14.5 million tonnes in the most favourable scenario (Kandagatla and Almas 2020). If climate change increases the demand for water for wheat by 9 per cent in the Nile Delta and by 18 per cent in both Middle and Upper Egypt (Ouda et al. 2015), the country's aspirations to increase its self-sufficiency in the near future will be jeopardized. The following strategies, implemented at different levels of the Egyptian wheat value chain, may be considered to cope with the above situation:

- Production side: Increase the productivity of wheat and increase the area under irrigation.
- Distribution side: Reduce the waste of wheat during processing, storage and distribution.
- Consumption side: Diversify dietary habits to reduce dependence on wheat.
- Governmental side: Reduce the direct or indirect subsidies to wheat production and consumption, making the whole value chain more efficient.
- Rely on importation: Guarantee the supply of wheat through imports from water-abundant regions.

Potential transition pathways: Increasing domestic production while coping with climate change

According to the Agricultural Development Strategy 2030, Egypt aims to increase its self-sufficiency in wheat from the current 45-50 per cent to 81 per cent. To achieve this, two principal approaches can be taken:

- Reduce the water footprint of wheat by increasing yields and making more efficient use of the water (more crops per drops)
- Increase the area under irrigation by making more land and non-conventional water resources available.

According to Ouda and Zohry (2017), the use of modern farming techniques, such as the cultivation of wheat on raised beds, irrigating wheat with sprinklers or intercropping with other crops such as tomato, cotton or sugar beet, could reduce the wheat production-consumption gap by more than 20 per cent. However, according to Asseng et al. (2018), the ongoing programme to increase the irrigated land area in parallel with the strategies for crop intensification will not be enough to achieve the goal of self-sufficiency in the near future, which will cause an increase in water demand of up to 20-29 km^3.

Saving water by improving wheat storage

The Egyptian government operates all large-scale inland storage by using a system of traditional flat storage called *shona*. This system is completely inefficient, causing significant qualitative and quantitative losses from exposure to weather and pests. Although there are no official statistics, the losses at the *shona* are estimated to be in the range of 10-20 per cent, while the silos technology, mainly used by the private sector, has losses of less than 2 per cent (McGill 2020). Considering those figures and the storage capacity of both the government and the private sector, the annual waste of wheat is estimated at around 450 MT. If this figure is translated into water volumes, more than 0.4 km^3 of blue water is lost every year (0.5 per cent of the total Egyptian withdrawal). While a silo storage system is marginally more expensive than the basic *shona* system, the water savings from reduced losses by investing in modern storage facilities would compensate several times for the additional cost, with an estimated cost of US$0.006/$m^3$ saved. This would be US$2.4 million/year in absolute terms.

Promoting less water-intensive products

By assessing the effects of dietary change on national water consumption, a country can design new diets with lower water-related implications while meeting its nutrition requirements (Mirzaie- Nodoushan 2020). The water footprint should also be considered a driver when food-based dietary guidelines are developed, to boost the consumption of less water-intensive food products among the population. To achieve this, nutritional water productivity should be taken into consideration, as should where the water is coming from, to minimize the impacts of diets on national resources.

Making smart subsidies

The Egyptian government, through the universal subsidy of *baladi* bread, is heavily involved at every level of the wheat value chain. The subsidy scheme covers wheat production, procurement, flour milling and bakery production, either by direct or indirect subsidies. For example, the price offered by the government to national producers has usually been set above the world price, to encourage domestic production, reduce imports and improve the balance of payments (Coelli 2010). However, this causes a high rate of leakage in the system, as economic incentives are misaligned, forcing the government to procure more wheat than would have been needed, even at the subsidized price (Kassim et al. 2018). The government has already undertaken some measures to shift food subsidies towards the end of the supply chain to reduce inefficiencies. By turning bakeries and groceries into market competitors, they have an incentive to improve their efficiency and effectiveness, reducing the leakage of flour to the black market (Abdalla and Al-Shawarby 2017).

Water allocation policy

If Egypt fails to achieve its self-sufficiency aspirations for wheat (Asseng et al. 2018), it will need to keep relying on wheat importation. By doing this, it is saving a large amount of its fresh water resources via virtual water flows. However, this policy makes the country vulnerable to international market fluctuations. Smart decisions on water allocations are needed, supporting farmers to make the transition to higher-added-value crops while keeping a safety degree of self-sufficiency. Food self-sufficiency may also be achieved from an economic perspective to allocate agricultural water to high-value cash crops. The income of these crops can be used to compensate for food imports (e.g. wheat), to bring food import expenditures and food export income into balance.

4.3 Poultry demand in Egypt

Due to population growth, economic development and associated dietary changes, the demand for poultry and other livestock products is increasing. As a result, poultry demand in Egypt is likely to rise by an immense 1,100 per cent from 100,000 tons in 2015 to 11,000,000 tons in 2050 (FAO 2017b).

Synergies and trade-offs in food systems

Stimulating poultry consumption is considered positive from a nutrition and health perspective if consumed appropriately, as it provides a main source of protein. Awareness-raising programmes on healthy poultry-related dishes may, however, be required, as most of the current chicken meat is consumed as fast food, a significant obstacle to a healthy diet. A growth in domestic poultry production will also be beneficial from an employment perspective, as it generates jobs in production, processing and logistics (e.g. cool transportation). This is especially relevant considering the large unemployment numbers in Egypt and would be seen as positive from a market dynamic perspective.

On the other hand, the main trade-off from increasing domestic poultry production would be in the field of climate change and sustainable water use. Chicken production results in more greenhouse gas emissions than vegetable production. Moreover, poultry and its associated products have a larger water footprint than most vegetable crops: 1 kg of chicken meat requires 4,325 L of water, while 1 kg of vegetables requires 322 L (Water Footprint Network 2020). From a water perspective, this is a serious concern, as Egypt is already a water-stressed country. Increasing the size of the poultry sector would put additional pressure on the limited water sources. Table 4 provides an overview of expected green and blue water use by poultry (products) in Egypt based on expected growth in poultry demand (FAO 2017a).

Table 4
Water footprint of poultry and egg production 2010-2050, based on expected growth in poultry demand in Egypt

		Million m^3 from Egypt		
		2010	*2030*	*2050*
Poultry	Green water	1,984	7,001	24,365
	Blue Water	2,198	1,233	2,606
Eggs	Green water	444	1,233	2,606
	Blue water	513	1,425	3,011

Source: Own calculations, based on Mekonnen and Hoekstra (2010) and FAO (2017a).

Taking into consideration the effects of climate change and the worldwide action to reduce greenhouse gas emissions (the Paris Agreement), a large expansion of the poultry industry is not going to help achieve this goal. Thus, from a climate and water perspective, the discouragement of poultry consumption would be more beneficial. However, more research is required to assess and compare the effects of other protein sources (e.g. fish) on climate and water use, to define the best protein food source or transition pathway without compromising environmental goals.

Overall, the strategy of increasing poultry within Egypt's food systems depends on the value that government and private stakeholders in the country place on nutrition, employment and environmental outcomes. This can be achieved through multi-criteria analysis techniques, for instance.

5. Conclusions and recommendations

This paper used a food systems approach to analyse the trends, characteristics, drivers and outcomes of food systems in a country in a semi-arid region that were built up mainly relying on water resources. As such, Egypt is a clear example of a country where the scarcity of available water, combined with increased population and climate change, has important bearings on the food system now and in the future.

The two major drivers of the food systems analysed are the application of a food subsidy system and water availability. The analysis shows how an increasing population and a subsidized food policy to make food cheaply available to all are combined with a shortage of available water. The dependency on food imports, especially for some of the main staples, may be an area of concern with respect to food self-sufficiency. The food system outcomes reveal that there is scope to further improve nutrition and health and to enhance sustainable water use.

The use of the water footprint indicator provides relevant insights into the water-related impacts of Egyptian food systems and the potential pathways to follow. Only through a smart combination of the drivers of water availability and food policies will Egypt be able to cope with the expected water (and food) gap in future. This can be done by importing crops from water-abundant regions, increasing the efficiency of water use to produce more crops with the same amount of water though modern irrigation techniques, or by popularizing less water-intensive and healthier diets among the population.

After a detailed analysis of the wheat and poultry systems, where future changes are expected, it only becomes clearer that the current food systems in Egypt have a direct connection with water. Any pathway to transform these systems will have strong implications for water resources and, in turn, will be limited by its availability. By subsidizing food, Egypt is making cheap food items accessible to the whole population. Where and how this food is produced – either at the expense of scarce national water resources or by importation, underwritten by the national budget – is a crucial decision to make. In the context of population growth, the country's aspiration to become a more self-sufficient country in the future by expanding agricultural lands or by increasing water efficiency will be jeopardized by the fact that water availability will be difficult to increase. Smart water allocation decisions are required to decide whether the water resources available are used to produce high-added-value crops for exportation or, for instance, they are allocated for the domestic production of some of the basic food basket items (i.e. cereals and livestock).

References

Abdalla, M. and Al-Shawarby, S. (eds.). 2017. The Tamween food subsidy system in Egypt: evolution and recent implementation reforms, 107-150.

Abdelkader, A. et al. 2018. National water, food, and trade modeling framework: The case of Egypt. *Science of the total environment* 639: 485-496.

Ali, M.G.M. et al. 2020. Climate change impact and adaptation on wheat yield, water use and water use efficiency at North Nile Delta. *Frontiers of Earth Science* 1-15.

Amer, M.H., El Hafez, S.A.A. and El Ghany, M.B.A. 2017. *Water saving in irrigated agriculture in Egypt (case studies and lessons learned)*. Lambert Academic Publishing. ISBN: 978-620-2-02402-0, 188 pp.

Arslan, A. et al. 2020. *Rural Development Report 2021: Framework for the Analysis and Assessment of Food Systems Transformations*. Rome: IFAD.

Armanius, D.M. 2018. *World without poverty*. New York: United Nations Department of Economic and Social Affairs.

Asfaw, A. 2006a. Do Government Food Price Policies Affect the Prevalence of Obesity? Empirical Evidence from Egypt. *World Development* 35(4): 687-701. doi:10.1016/j.worlddev.2006.05.005.

Asfaw, A. 2006b. The role of food price policy in determining the prevalence of obesity: Evidence from Egypt. *Review of Agricultural Economics* 28(3): 305-312.

Asseng, S. et al. 2018. Can Egypt become self-sufficient in wheat? *Environmental Research Letters* 13(9): 094012.

Béné, C. et al. 2019. Understanding food systems drivers: A critical review of the literature. *Global Food Security* 23: 149-159. doi: 10.1016/j.gfs.2019.04.009.

CEIC. 2018. Egypt Average Household Income: Value 2005-2018. CEIC. https://www.ceicdata.com/en/egypt/average-household-income/average-household-income-value.

Coelli, T. 2010. The Cost Efficiency in the Production and Distribution of Subsidized Bread in Egypt.

Washington, D.C.: World Bank.

Conway, D. 2017. Water resources: Future Nile river flows. *Nature Climate Change* 7(5) : 319-320. https://www.nature.com/articles/nclimate3285.

de Fraiture, C. et al. 2007. Looking ahead to 2050: scenarios of alternative investment approaches. In *Water for Food, Water for Life*. (No. 612-2016-40591). London: Earthscan, and Colombo: International Water Management Institute.

Ecker, O. et al. 2016. *Nutrition and economic development: Exploring Egypt's exceptionalism and the role of food subsidies*. Washington, D.C.: International Food Policy Research Institute.

Falkenmark, M. 2013. Growing water scarcity in agriculture: future challenge to global water security. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 371(2002): 20120410.

FAO. 2016. FAO's Global Information System on Water and Agriculture – Country profile Egypt. Food and Agriculture Organization of the United Nations, 16 December. http://www.fao.org/aquastat/en/countries-and-basins/country-profiles/country/EGY.

FAO. 2017a. Africa Sustainable Livestock 2050 – Country Brief Egypt. *FAO Animal Production and Health Report*, No. I7312EN/1/05.17. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2017b. FAOSTAT. Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/#data.QC.

FAO. 2018a. *The future of food and agriculture—Alternative pathways to 2050*. Rome: Food and Agriculture Organization of the United Nations.

FAO. 2018b. FAOSTAT, Wheat Production Statistics. Food and Agriculture Organization of the United Nations. www.fao.org/faostat/en/#data/TP.

FAO 2020a. AQUASTAT Main Database. Food and Agriculture Organization of the United Nations, 31 March. http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en.

FAO. 2020b. Egypt at a glance. Food and Agriculture Organization of the United Nations. http://www.fao.org/egypt/our-office/egypt-at-a-glance/en/.

Fawaz, M.M. and Soliman, S.A. 2016. The potential scenarios of the impacts of climate change on Egyptian resources and agricultural plant production. *Open Journal of Applied Sciences* 6.04(2016): 270.

Galal, O.M. 2002. The nutrition transition in Egypt: obesity, undernutrition and the food consumption context. *Public Health Nutrition* 5(1A): 141-148. doi: 10.1079/PHN2001286.

Glopan. 2016. *Food systems and diets: Facing the challenges of the 21st century*. London: Global Panel on Agriculture and Food Systems for Nutrition. http://glopan.org/sites/default/files/ForesightReport.pdf/.

Harris, F. et al. 2020. The Water Footprint of Diets: A Global Systematic Review and Meta-analysis. *Advances in Nutrition* 11(2): 375-386.

HLPE. 2017. *Nutrition and food systems*. Rome: High Level Panel of Experts of the Committee on World Food Security.

Hoekstra, A.Y. 2014. Sustainable, efficient, and equitable water use: The three pillars under wise freshwater allocation. *WIREs Water* 1: 31-40.

Hoekstra, A.Y. et al. 2011. The water footprint assessment manual: Setting the global standard. London: Routledge.

IFAD. 2019. *Investing in rural people in Egypt*. Rome: IFAD. https://www.ifad.org/documents/38714170/40865296/Investing+in+rural+people+in+Egypt/24dc8bdb-

2d70-4802-9771-f52122fb3c40.

IFAD. 2020. Food systems – transforming food systems for all. IFAD. https://www.ifad.org/en/food-systems.

Index Mundi. 2020. Egypt Wheat Domestic Consumption by Year. Indexmundi.

https://www.indexmundi.com/agriculture/?country=eg&commodity=wheat&graph=domestic-consumption.

Jevrejeva, S., Grinsted, A. and Moore, J.C. 2014. Upper limit for sea level projections by 2100. *Environmental Research Letters* 9(10): 104008.

https://iopscience.iop.org/article/10.1088/1748-9326/9/10/104008/pdf

Kassim, Y. et al. 2018. *An agricultural policy review of Egypt: First steps towards a new strategy*, volume 11. Washington, D.C.: International Food Policy Research Institute.

Kandagatla, R. and Almas, L.K. 2020. *Egypt's Reliance on Imported Wheat: Concerns, Challenges and Opportunities*. Canyon: West Texas A&M University. https://wtamu-ir.tdl.org/bitstream/handle/11310/295/21_Dr.%20Lal%20K.%20Almas.pdf?sequence=1.

KNOEMA. 2020. Food balance sheets. KNOEMA. https://knoema.com/FAOFBS2017/food-balance-sheets?country=1000550-egypt.

Mabrouk, M. et al. 2018. Impacts of sea level rise and groundwater extraction scenarios on fresh groundwater resources in the Nile Delta Governorates, Egypt. *Water* 10(11): 1690. https://www.mdpi.com/2073-4441/10/11/1690/htm.

McGill, J. et al. 2015. Egypt: Wheat sector review. *Country Highlights*, No. 21. Rome: Food and Agriculture Organization of the United Nations.

Mekonnen, M.M. and Hoekstra, A.Y. 2010. The green, blue and grey water footprint of crops and derived crop products. *Value of Water Research Report Series*, No. 47. Delft: UNESCO-IHE Institute for Water Education. http://www.waterfootprint.org/Reports/Report47-WaterFootprintCrops-Vol1.pdf.

Mekonnen, M. M. and Hoekstra, A.Y. 2011. National water footprint accounts: the green, blue and grey water footprint of production and consumption, volume 1: Main Report. *Value of Water Research Report Series*, No. 50. Delft: UNESCO-IHE Institute for Water Education.

Mulligan, M. et al. 2020. Mapping nature's contribution to SDG 6 and implications for other SDGs at policy relevant scales. *Remote Sensing of Environment* 239(220): 111671. https://doi.org/10.1016/j.rse.2020.111671.

Omar, M.E.M. and Moussa, A. 2016. Water management in Egypt for facing the future challenges. *Journal of Advanced Research* 7: 403-412.

Ouda, S.A. and Zohry, A.E.H. 2017. Crops intensification to reduce wheat gap in Egypt. In *Future of Food Gaps in Egypt*, 37-56. Cham: Springer.

Ouda, S.A., Noreldin, T. and Abd El-Latif, K. 2015. Water requirements for wheat and maize under climate change in North Nile Delta. *Spanish Journal of Agricultural Research* 13(1): 1-7.

Oweis, T. 2018. *Water management for sustainable agriculture*. Cambridge: Burleigh Dodds Science Publishing Limited.

Siam, M.S. and Eltahir, E.A. 2017. Climate change enhances interannual variability of the Nile river flow.

Nature Climate Change 7(5): 350-354. https://www.nature.com/articles/nclimate3273.

Statista. 2020. Prevalence of obesity in the adult population aged 18 years and older in Egypt from 2007 to 2016. Statista. https://www.statista.com/statistics/979509/egypt-prevalence-of-obesity-adult-population-aged-18-years-and-older/.

Taye, M.T., Moges, S.A. and Block, P. 2020. Evaluation of the CMIP5 Climate Model for Precipitation Projections over the Upper Blue Nile Basin. In *Climate Variability and Change in Africa*, 25-35. Cham: Springer. https://link.springer.com/chapter/10.1007/978-3-030-31543-6_4.

Tompa, O. et al. 2020. Is the Sustainable Choice a Healthy Choice?—Water Footprint Consequence of Changing Dietary Patterns. *Nutrients* 12: 2578.

UNICEF. 2020. Nutrition. United Nations Children's Fund. https://www.unicef.org/egypt/nutrition.

van den Broek, W. and Boerrigter, H. 2014. Metropolitan food supply: case study Cairo: a quick scan study to enhance fresh food supply and minimize postharvest losses. *Wageningen UR Food and Biobased Research Report*, No. 1466. Wageningen: Wageningen University and Research.

Vanham, D., Mekonnen, M.M. and Hoekstra, A.Y. 2013. The water footprint of the EU for different diets.

Ecological indicators 32: 1-8.

Vanham, D. et al. 2018. The water footprint of different diets within European sub-national geographical entities. *Nature Sustainability* 1(9): 518-525.

Verme, P. et al. 2014. Inside Inequality in the Arab Republic of Egypt – facts across People, Time and Space. Washington, D.C.: World Bank, 155 pp.

Wahba, S.M., Scott, K. and Steinberger, J.K. 2018. Analyzing Egypt's water footprint based on trade balance and expenditure inequality. *Journal of Cleaner Production* 198: 1526-1535.

Water Footprint Network. 2020. Water footprint of crop and animal products: a comparison. Water Footprint Network. https://waterfootprint.org/en/water-footprint/product-water-footprint/water-footprint-crop-and-animal-products/.

WTO. 2020. World Trade Profiles. World Trade Organization. https://www.wto.org/english/thewto_e/countries_e/egypt_e.htm.

Personal communication: Ir. K. Roest, food and water specialist in Egypt (2020).

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