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Impact of Climate Change on Agriculture, Fisheries and Livestock Sectors in Kuwait

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Abstract

The issue of limited agricultural land and production, rising food demand, and heavy reliance on imported foods in Kuwait have resulted in pressing concerns regarding food security and equity. Currently, Kuwait heavily relies on imports for over 90% of its food supply, which not only impacts the country's sustainability but also affects other nations. Essential staples like rice, wheat, corn, milk powder, cooking oil, and chicken are particularly vulnerable to recent global price shocks. The consequences of climate change include rising temperatures, warming oceans, increasing incidences of droughts, losses in biodiversity, heightened health risks, and a decline in overall food production. These effects further strain an already stressed ecosystem as Kuwait lacks a comprehensive adaptive strategy that outlines both short-term and long-term action plans/goals to address these challenges. Specifically, within the agricultural, livestock, and fisheries sectors while simultaneously equipping it to handle emergencies or hazardous crises. This paper aims to outline the issues of limited agricultural land and production, rising food demand, and heavy reliance on imported foods, and how Kuwait must prioritize the development and improvement of sustainable agricultural practices and technologies. Furthermore, identifying key stakeholders and their current roles and constraints.

Keywords

Adaptation, Stakeholders, Food Security, Sustainability, Kuwait

1. Introduction

Kuwait is situated within the Middle East bordering Iraq to the west and north, and Saudi Arabia to the south. Kuwait's weather can be characterized as a dry desert climate with extreme summers temperatures reaching up to 50˚C, with short winters and sporadic rainfall. Food security and equity are pressing issues in Kuwait due to limited agricultural land and production, rapid growth in food demand, and the heavy reliance on imported foods (Wheeler, 2015; Alomirah et al., 2010). Currently, Kuwait experiences resource interdependencies both domestically (e.g., the majority of Kuwait's food is imported, more than 90%), and abroad, which, in turn, affects the sustainability of resources in other countries (Siderius et al., 2019; Wheeler, 2015). Especially after recent global price shocks, particularly for staples like rice, wheat, corn, milk powder, cooking oil, and chicken (Wheeler, 2015).

Climate change effects include rising temperatures, warming oceans, increasing drought, biodiversity loss, higher risks of health problems and a decrease in food production further deteriorating an already strained ecosystem. Even though climatic fluctuations and changes have occurred throughout history there are limiting factors that will affect the ability of species and ecosystems to adapt in the future. Future climate change is predicted to happen at a faster rate than earlier natural changes (Brander, 2010). Meanwhile, simultaneous stresses are hindering the resilience of species and ecosystems, including overfishing causing biodiversity loss (including genetic diversity), habitat destruction, pollution, introduced and invasive species, and pathogens (Brander, 2010). Other external factors such as political conflicts, legal environment, economic climate, finances, business structures all play a significant role in resource availability. An example is the wheat shortage due to political conflicts in Ukraine, which has led Kuwait to have a supply shortage and a rise in livestock fodder prices.

To tackle these obstacles and guarantee sustainable food security in the long run, Kuwait must prioritize the adoption of resilient and sustainable agricultural practices. The adverse effects of climate change pose a continuous challenge to various aspects of food systems including supply chains, producers, and farmers. Equity concerns in relation to food production encompass various aspects. Firstly, it involves addressing the wages and working conditions of individuals involved at every step of the food chain, which includes farmers, grocery store workers, and restaurant staff. Secondly, equitable access to resources necessary for food production such as land availability, subsidies, and capital is crucial. Last but equally important is the need to safeguard the environment against pollution associated with food production activities related to air quality degradation, water contamination from pesticide use or other sources, and unpleasant odours (UCI, 2016). Hence, the ability of Kuwait to sustain its growing population and promote fairness will be greatly influenced by how different stakeholders design, structure, and manage food and agricultural systems. In order to ensure the sustainable use of resources, it is imperative that there is a shift towards adopting more environmentally friendly farming practices such as smart farming and technological innovation. This paper aims to explore two main areas: firstly, the potential impacts of climate change on Kuwait's future food security; secondly, identifying key national stakeholders along with their current positions concerning addressing pertinent issues.

2. Climate Change Scenarios

There are several General Circulation Models (GCMs) that are used to predict crop yields under climate change conditions by mid-century (2040-2069) and the end of the 21st century (2071-2100), these include; the Medium-Range Weather Forecasts (ECMWF), 40-year reanalysis (ERA40) and the European Community Hamburg Atmospheric Model (ECHAM5) data using the UK Met Office Regional Climate Model (PRECIS) Providing Regional Climates for Impacts Studies (IPCC, 2000; Ragab & Prudhomme, 2002; Al-Zawad & Aksakal, 2010; Almazroui, 2013; Sharif, 2015; Allbed et al., 2017; Almutawa, 2022a). GCMs are used to simulate the consequences of an increase in atmospheric CO_2 on the mean global climate, both instantaneously with doubling equilibrium CO_2 and time-dependently over several model years with incremental increases in CO_2 concentration (Shackley et al., 1998). The low resolution and significant errors in the simulation of regional feedback in GCMs prevent them from providing detailed regional climate simulations or estimates of future regional climate change (Shackley et al., 1998). Regional errors, however, are not assumed to compromise the validity of the global response to CO_2 (Shackley et al., 1998). According to the Special Report on Emission Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC), the projected effects of climate change will affect global food supplies under different pathways of future socio-economic development (**Table 1**) (Parry et al., 2004; IPCC, 2000). The trajectory of population growth, economic development, and agriculture's response to changing climate conditions will affect the extent of climate change impacts on a global and regional scale (Parry et al., 2004).

Ragab & Prudhomme (2002) using the HadCM2 model predicted that the annual precipitation value set at <50 mm will be reduced by up to 20% depending on the location in Kuwait. Whereas the annual baseline temperature set between 27.5 to 22.5 will increase by 1.25˚C to 1.5˚C by 2050. Coastal areas are expected to experience lower temperature rises in comparison to those inside the region (Ragab & Prudhomme, 2002). Although, according to Dasgupta et al., (2011) under a 1m-SLR (sea level rise), 68.5% of Kuwait's total coastal area is exposed to intensified storm surges affecting 58.7% of the population and more than 50% of the coastal wetlands in Kuwait are likely to be subject to inundation risks. The Middle East and North Africa (MENA) would experience the highest impacts due to SLR affecting 7.9 million people (Dasgupta et al., 2011).

To quantify on a global scale, the impacts of extreme heat stress on maize, spring wheat, and soybean yields resulting from 72 climate change scenarios for the 21st century, Deryng et al. (2014) used the global crop model Predicting Ecosystem Goods And Services Using Scenarios (PEGASUS). It was determined that

Table 1. IPCC Climate change scenarios and description (adapted from IPCC, 2000).

Climate change scenario	Description
A1F1	The emergence of new and more efficient technologies occurs very rapidly when the economy is rapidly growing and the global population peaks by mid-century and falls afterwards. Regional convergence, capacity building, and increased cultural and social interaction are major underlying themes. This is accompanied by a substantial reduction in regional differences in per capita income which is distinguished by being fossil intensive.
A2	The world is very heterogeneous. Self-reliance and the preservation of local identities are the underlying themes. There is a slow convergence of fertility patterns across regions, leading to a continuous increase in the global population. Compared to other storylines, economic development and technological change are largely regionally oriented.
B1	Similarly, to the storyline in A1, convergent societies have the same global population peaking at mid-century and declining thereafter, but with rapid changes in economic structures, with a shift toward a service and information economy, with a reduction in material intensity and a rise in green technologies. There is a focus on global solutions to economic, social, and environmental sustainability, including improved equity, but no additional climate initiatives are being undertaken.
B2	A world based on local solutions to economic, social, and environmental sustainability. It is a world with a continuously increasing global population at a rate lower than A2. This is accompanied by intermediate levels of economic development and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

maize yields would suffer double losses ($\Delta Y = -12.8\% \pm 6.7\%$ versus $-7.0\% \pm 5.3\%$ without Heat Stress at Anthesis (HSA)), reduce projected gains in spring wheat yield by half ($Y = 34.3\% \pm 13.5\%$ versus $72.0\% \pm 10.9\%$ without HSA and in soybean yield by a quarter ($Y = 15.3\% \pm 26.5\%$ versus $20.4\% \pm 22.1\%$ without HSA by the 2080s (relative to the 1980s) under Representative Concentration Pathways 8.5 (RCP 8.5), taking into account CO_2 fertilization effects (Deryng et al., 2014). The various climate model scenarios resulted in differing ranges; soybean produces positive and negative effects, maize generally produces negative effects, and spring wheat generally produces positive effects. In addition, it was determined that drastic climate mitigation policies such as those in RCP 2.6 would avoid more than 80% of global yield losses under RCP 8.5 assuming CO_2 fertilization effects are negligible (Deryng et al., 2014). Whereas, Tebaldi & Lobell (2018) used the Climate Model Intercomparison Project 3 (CMIP3) dataset to extract temperature and precipitation outputs from the historic (20C3M) and assumed the SRES A1B emission scenario and no agricultural adaptation by 2040, estimated expected global changes of +1.6%, −14.1%, −1.8% for wheat, maize, and barley, with 95% probability intervals of (−4.1, +6.7)%, (−28.0, −4.3)%, (−11.0, 6.2)% of current yields, respectively.

Different development paths for global crop yields were analysed by Parry et al., (2004) utilising the HadCM3 GCM using grids of 2" latitude by 2" longitude on four different SRES emissions scenarios (A1FI, A2, B1, and B2). It was estimated that there would be a significant increase in global temperatures, A1FI's scenario predicts the greatest declines in yields both regionally and globally, especially in Africa and parts of Asia with an expected loss of 30% by the 2080s (Parry et al., 2004). Whereas, as a result of regional increases in precipitation that compensate for moderate temperature increases, and the direct effects of high CO_2 concentrations, yield differences between developed and developing countries are the largest under the A2a-c scenarios (Parry et al., 2004). In contrast, under scenarios, B1 and B2, developed and developing countries experience fewer differences in future crop yields, with B2 future crop yield changes slightly more favourable than those of B1 (Parry et al., 2004). The results show that under scenarios of great inequality, there will be considerable increases in prices and hunger risk among poorer nations due to regional differences in crop production will grow greater over time (Parry et al., 2004). The suitability of cropping areas will be altered with low latitudes likely experiencing more water stress from high temperatures and tropical highlands becoming more suitable for cropping (Thornton et al., 2009). As, agriculture in the MENA region primarily takes place in the semi-arid climate zone, either on the coast or in the highlands crop yields are expected to decline by up to 30% with 1.5˚C - 2˚C warming, and by up to 60% with 3˚C - 4˚C warming (Waha et al., 2017; Al-Bakri et al., 2011).

There will also be a shift in fisheries production patterns in the future as species' biodiversity will change as they move to new habitats creating a change in net marine primary production (Merino et al., 2012; Cheung et al., 2009). There is considerable difficulty to assess the magnitude of the impacts, vulnerabilities, and risks on fisheries and aquaculture through controlled experiments due to their open and interconnected ecosystems (Gormley et al., 2015). However, individual species' responses to climate change effects have been examined (Gormley et al., 2015). Climate projections generated using the Geophysical Fluid Dynamics Laboratory of the US National Oceanic and Atmospheric Administration (GFDL's CM 2.1) were applied to three scenarios A1B, B1 and the committed climate change experiment (commit) (Cheung et al., 2009). It is predicted that local extinctions will be common in the tropics, the Southern Ocean, the North Atlantic, the Northeast Pacific coast and in semi-enclosed seas such as the Mediterranean, the Red Sea and the Arabian Gulf (Cheung et al., 2009). Between 2001-2005 and 2040-2060, under the A1B scenario, species distribution range limits are expected to shift poleward by a median of 291 km (25^{th} to 75^{th} percentiles = 61 - 747 km) with 83% of the species (887 spp.) showing a positive poleward shift (Cheung et al., 2009).

Merino et al., (2012) predicted marine fisheries and aquaculture globally to increase by 6% in the potential catches of "large" fish and fishmeal having the potential growth of circa 3.6% under the A1B scenario by 2050. However, on a regional level, low-latitude and tropical regions are expected to decrease production compared to high-latitude countries that are expected to increase production (Merino et al., 2012). According to simulations, fishmeal production and consumption are relatively stable, with fishmeal price increases of −16% to 42% and fish oil price increases of −5% to 50% (Merino et al., 2012). In contrast, high prices (the "Ecological collapse" scenario) could ultimately cause the collapse of small pelagic fisheries that are geographically distant (Merino et al., 2012). Short-term fluctuations are also predicted due to environmental factors such as El Nino and consistent price increases that correspond to the amount of fishmeal utilised in aquaculture. With regards to human population growth, aquaculture could be able to meet human demands in 2050 if it used 80% of the traded fishmeal (a 20% increase from the current value), sustaining a per capita consumption of 17 kilograms/year if the global FIFO ratio (fish-in-fish-out ratio) does not fall below 0.25 (Merino et al., 2012). In the case that fishmeal was exclusively used for aquaculture, the same objective would be accomplished with a lower average technological adaptation (FIFO) of 0.28 (Merino et al., 2012).

Livestock is affected by the climate in different ways: feed-grain availability and price, pasture and forage crop quality and quantity, health, growth, reproduction, and diseases and pests. Although it is likely to fair better than crops against extreme weather events such as heat and drought (Gaughan et al., 2009; Thornton et al., 2009; Chase, 2006; Thomas et al., 2004). The distribution of livestock genotypes as a result of increasing mean temperature that can be tolerated across regions and habitat loss is unknown (Thorton et al., 2009; Thomas et al., 2004). Thomas et al. (2004) predicted that for mid-range climate-warming scenarios (1.8˚C - 2.0˚C and CO_2 increases of 500 - 550 p.p.m.v.) for 2050, 15% - 37% of species will be "committed to extinction". According to Chase (2006), a dairy cow weighing 635 kg and producing 36 kg of milk per day has a 22% higher maintenance energy requirement at 32˚C than it does at 16˚C. Dry matter intake and milk yield are predicted to decrease by 18%, and milk yield decreases by 32% at the same temperature increase (Chase, 2006). Amundson et al. (2005) also found that *Bos taurus* conception rates decline at temperatures above 23.4˚C and at high thermal heat indexes that are equal to or exceed 72.9. It is estimated that pig, beef, and dairy milk production will decline by 1% - 2% by 2050 due to increased heat stress in the USA, alone (Frank et al., 2001). Although, for intensive livestock production systems where some control can be exercised, Rötter and van de Geijn (1999) suggest that the impacts of heat stress may be relatively minor. Extreme weather events can cause animals to suffer morbidity and illness as a result of heat-related illnesses (Gaughan et al., 2009). There are a variety of indirect impacts, including those produced by the effects of climate on the density and distribution of microbes, the distribution of vector-borne diseases, the host's resistance to infections, food and water shortages, and the health impacts of food consumption (Gaughan et al., 2009).

3. Farming Practices in Kuwait

3.1. Agriculture in Kuwait

Of the 1539 km^2 of agricultural land, only 121 km^2 is under cultivation for vegetable crops (PAAFR, 2018; KASA, 2019). Kuwait produces a wide range of crops of which 57 are monitored twice a year (summer and winter) which are organized into seven different categories. From the highest to lowest occupied area, the categories are as follows: fodder (44%), fruiting vegetables (23%), grains (13%), tubers or rooted crops (9%), leafy greens (8%), landscaping and green space (3%) and pulses (1%) (KASA 2019). The majority of the production is under open field occupying 85% of the land compared to protected production systems (greenhouse, shade house, etc.) which total 14.2 km^2. In terms of total production and value cucumbers and tomatoes have the best returns compared to all other crops grown with 9.37 $/sqm and 7.73 $/sqm respectively and the highest production per sqm with 19.2 kg/sqm and 15.8 kg/sqm (**Table 2**). From 2015-2019 both tomatoes and cucumbers saw upward production trends of up 80% and 30% respectively, while the production of alfalfa decreased by 79% while rhodes saw an increase in production (PAAFR, 2019). In terms of self-sufficiency for fruits and vegetables, cucumber and dates are the only crops that exceed 90% self-sufficiency, with overall self-sufficiency for fresh vegetables and fruits at only 43% (Abdullah et al., 2021; PAAFR, 2018).

Growing crops under protected areas can help prolong seasonal changes but requires higher water inputs for irrigation and cooling (Al-Mulla, 2006). However, to reach targets, the 15% of crops grown under protected environments need to substantially increase through efficiency, productivity, and sustainability (Abdullah et al., 2021; Al-Nasser & Bhat, 1998). For Kuwait to achieve high self-sufficiency of 90% for fruits and vegetables, the total area cultivated would need to double which will require higher demands for water, labour and infrastructure. Nevertheless, it is difficult for the country to expand its greenhouse industry as it requires a high investment with a prolonged time frame on the return on investment (Al-Nasser & Bhat, 1998).

Plants have varying critical high and low-temperature thresholds that are dependent on the type of species and cultivars, and with each developmental stage different optimal temperature ranges are required (Thornton et al., 2009). Sowing dates, fertilisation, and crop density need to be adjusted to address climate change's short-term and medium-term effects to maintain similar production rates (del Pozo et al., 2019; Cole et al., 2018; Masud et al., 2017). An increase in heat by just 1% during the winter season can cause a decrease of 1.12% in agriculture production, such values could lower when productivity is at its highest (Alboghdady & El-Hendawy, 2016). However, other effects of climate change may offset these impacts (Gormley et al., 2015; Wiebe et al., 2015). As total biomass of C4 plants such as rhodes, maize and blue panic is only negatively affected when daily mean temperatures rise above 35˚C (Wiebe et al., 2015; Müller & Robertson, 2014).

Müller et al. (2010) estimated that the Middle East carbon fertilisation effects (CFE) will increase by 8.4% normalised to a 100 ppm increase in CO_2 in comparison to Fischer (2009) who estimated an increase of 2.4%. Plants benefit from CO_2 fertilisation because it increases photosynthesis rates while limiting leaf

Table 2. Total area during the winter and summer seasons under protected and open field production, the value ($/sqm) and total quantity produced, and the self-sufficiency of the top three highest produced crops in Kuwait during 2019 (Adopted from PAAFR, 2019, KASA, 2019).

	Total (donum)	%	Protected (donum)		Open Field (Donum)		Value ($/sqm)	Qty (Kg/sqm)	Self Sufficiency (%)
			Summer	Winter	Summer	Winter			
Vegetables Fruits									
Tomato	6899	21%	1016	5086	0	1697	9.37	19.2	65%
Cucumber	6078	19%	3915	2081	82	0	7.73	15.8	98%
Eggplant	4869	15%	1015	1636	0	2218	2.64	8.1	82%
Others	14727	45%	1684	3338	6987	2719	2.23	4.1	-
Total	**32,573**	100%	**7630**	**12,141**	**7069**	**6634**	4.83	10.1	-
Leafy greens									
Lettuce	2610	23%	93	192	0	2325	3.04	4.7	44%
Parsley	1877	16%	91	45	0	1741	1.73	3.5	-
Cabbage	1720	15%	0	58	0	1662	2.69	5.5	45%
Others	5172	45%	430	600	84	4066	1.53	3.1	-
Total	**11,379**	100%	**614**	**895**	**84**	**9794**	2.08	3.9	-
Tubers, Roots, and Bulbs									
Potatoes	7613	61%	65	154	0	7394	2.24	4.6	17%
Onions	1780	14%	0	21	0	1759	2.61	4.0	6%
Fresh Onions	1450	12%	3	35	0	1412	2.24	3.4	-
Others	1685	13%	5	159	0	1611	2.13	3.4	-
Total	**12,528**	100%	**73**	**369**	**0**	**12,176**	2.27	4.2	-
Pulses									
String Beans	896	43%	92	475	0	319	1.53	3.1	-
Cowpea	659	32%	338	247	74	0	1.55	3.2	-
Beans	461	22%	0	1	0	460	1.22	1.5	-
Others	67	3%	12	28	0	37	0.50	1.6	-
Total	**2083**	100%	**442**	**751**	**74**	**816**	1.44	2.7	71%
Grains									
Maize	8824	46%	0	2	8822	0	2.28	2.0	15%
Barley	5533	29%	0	0	0	5533	0.49	1.0	1%
Sorghum	4065	21%	0	5	4060	0	1.17	2.0	90%
Others	594	3%	0	0	0	513	0.44	1.3	-
Total	**19,016**	100%	**0**	**7**	**12,882**	**6046**	1.47	1.7	-
Fodder									
Rhodes	35,620	56%	0	0	13,000	22,620	0.98	5.0	-

Continued

Blue panic	13,431	21%	0	0	2689	10,742	0.00	0.0	-
Alfalfa	12,353	20%	0	0	1841	11,412	1.10	4.8	-
Ohers	1736	3%	0	0	22	1714	7.83	96.1	-
Total	**63,140**	100%	**0**	**0**	**17,552**	**46,488**	0.98	6.4	64%
Final Total	**140,719**		**8759**	**14,163**	**37,661**	**81,954**	**2.15**	**6.2**	42%

transpiration. Increasing CO_2 reduces plant water use, which is also expected to positively impact plant growth when nitrogen is abundant. However, the effect of higher atmospheric CO_2 is still very uncertain owing to many complex interaction mechanisms and it may contribute to the loss of nutritional quality in food and fodder, including protein and micronutrients (Wiebe et al., 2015). However, CO_2 increase could potentially help increase growth of many different vegetables but seasonal shifts due to fluctuating temperatures may alter planting dates.

Nutritional quality can be improved by utilizing different techniques such as; improving crop varieties, biofortified staple crops with zinc and iron, diversifying small-scale production, post-harvest fortification of foods, micronutrient supplementation; plant breeding or genetic approaches to increase micronutrient contents (Dwivedi et al., 2023; Semba et al., 2022; Beddington et al., 2012). Transgenic technology can be a viable solution as it can improve food quality and nutritional content (Verma et al., 2011). Developing cultivars optimised for indoor and vertical farming to solve malnutrition might be the most effective use of genetic engineering (Abdullah et al., 2021; Verma et al., 2011). Genetically Modified Food (GMO) can not only be advantageous towards improving nutritional quality but can also improve; pest resistance, herbicide tolerance, disease resistance, cold tolerance, disease resistance, drought/salinity tolerance, phytoremediation, and pharmaceuticals. However, GMOs can also pose environmental and human health risks (Verma et al., 2011). Other solutions should include better subsidies, insurance, co-ownership as a farming collective sharing costs and equipment, or subsidies and other forms of government intervention would provide farmers with more assurance while accepting risks associated with new production methods.

3.2. Fisheries

A 500-kilometre shoreline along the Arabian Gulf serves as an important piscatorial source for Kuwait (AlHamad, 2006; Carpenter et al., 1997). Despite an average annual catch of around 4000 tons, with the highest recorded catch in 2000 at 5999 tons, the self-sufficiency rate is only 8%, relying heavily on imported fish, which make up 60% of the total fish supply (KASA, 2000-2019; PAAFR, 2018). Yet, the data on fish caught in national reports is underestimated due to unregulated fishing which has resulted in the severe degradation of marine biodiversity due to overfishing (Alsabah, 2021; Alqattan et al., 2020; Al-Abdulrazzak et al., 2015). The effects of overfishing have caused the reduction of fish such as zobaidy (*Pampus argenteus*), suboor (*Tenualosa ilisha*), hamoor (*Epinephelus coioides*), newaiby (*Otolithes ruber*) and hamra (*Lutjanus malabaricus*) with the biggest impact on shrimp (*Penaeus semisulcatus*) stocks (Al-Husaini et al., 2015). Fish population and biodiversity in Kuwaiti Bays are heavily impacted by anthropogenic and recreational undertakings through pollutants from oil-based contaminants, sewage discharge, desalination processes, and natural oxidation-reduction processes (Ali & Chidambaram, 2021; Alqattan & Gray, 2021; Liri et al., 2023). By 2050 the Arabian Gulf may experience an increase of salinity of 2.24 g/l causing fish kill if temperatures continue to rise (Bashitialshaaer et al., 2011; Liri et al., 2023). These sources of pollution pose significant risks to the health and well-being of both the local population and consumers of Kuwaiti fish. In light of these risks and challenges, it is imperative for Kuwait to implement effective strategies and measures to mitigate environmental pollution and ensure the safety of the marine environment.

Fish stocks will be heavily impacted by the effects of climate change and these actions put a vital source of food and income at great risk, as rising salinity and temperature threaten its sustainability (Alqattan & Gray, 2021; EPA, 2019; Wabnitz et al., 2018; Al-Yamani et al., 2017; Asem & Roy, 2010). Changes in physical and biological systems on all continents and most oceans are occurring, with many changes following the expected trajectory of warming temperatures (Thornton et al., 2009; Rosenzweig et al., 2008). The warming of oceans, lakes, and rivers impacts marine and freshwater biological systems (including changes in phenology, migration, species interaction and the composition of communities of algae, plankton, and fish) (Rosenzweig et al., 2008). From 1950-2010 a 0.57˚C increase in sea surface temperature has been observed with a possibility of 0.7˚C every decade (Hereher, 2020; Shirvani et al., 2015). A major issue legislators and researchers face is the lack of research on the impact of climate change in the future and alternative options in the Arabian Gulf (Ben-Hasan & Christensen, 2019). Given the significant emphasis on fisheries as a means of promoting the growth of the "Blue Economy," it is crucial to invest in more research and apply new policies and regulations that can support the sustainability of the fishing industry and address the decline in fish populations (Alqattan & Gray, 2021; Sarwar, 2022). There is a dependence on freshwater fish farms breeding tilapia (*Oreochromis niloticus* or *O. spilurus*) situated in the South (Wafra) and in the North (Abdali) (Kitto & Bechara, 2004). They rely on brackish water that is primarily used for vegetable crop irrigation (Kitto & Bechara, 2004). The biggest drawback of aquaculture is the lack of proper infrastructure, increase in investment and diversifying organisms could be solutions to reducing imported foods but the production has been stagnant with limited growth over the years averaging only 412 tons (PAAFR, 2018). Different projects have been put into motion by the New Kuwait 2035 plan to create model farms to provide know-how and potential of growing high economic valued fish and shrimps aiming to be completed by 2029 (New Kuwait; N.D.). The development of marine trade and tourism has the potential to stimulate economic activities, contributing to sustainable growth and the generation of employment opportunities. Additionally, the marine sector can contribute to energy supply and food security through advancements in offshore renewable energy and marine biotechnology.

3.3. Livestock

The livestock industry in Kuwait mainly focuses on the production of ruminants (cattle, sheep and goats) and poultry. The majority of Kuwait's arable land is used for livestock, but only 15% of the country's red meat demand is met from domestic production (Abdullah et al., 2021). From 2015-2019 the number of sheep and goats saw a steady increase raising from 588,618 to 714,348 and 156,543 to 234,324 but a small increase for the number of cows from, 29,263 to 34,746 (KASA, 2019). The steep increase of ruminants in 2019 decreased the self-sufficiency of fodder from 90% in 2015 to 64% causing a higher dependency on the environment which nearly depleted the natural flora due to overgrazing (PAAFR, 2019; Misak & Abdulhadi, 2022). Livestock fodder quality and quantity will be affected due to climate change both directly and indirectly as atmospheric CO_2 concentrations and temperatures change, which can alter import amounts and availability (Ciscar et al., 2009; Thornton et al., 2009; Hopkins & Del Prado, 2007). Increased heat stress and drought might offset dry matter yields, diminish available drinking water, bring on livestock disease, and alter the length of the grazing season (Thornton et al., 2009; Hopkins & Del Prado, 2007). Countries like Australia which are Kuwait's top sheep importer, supplying more than 56% of the total import of sheep will be facing issues due to climate change causing reduced income for farmers due to environmental stresses (Hughes et al., 2019; Deards & Thompson, 2012; Harle et al., 2007).

Improving the livestock system in Kuwait to provide for future demands will require high investment and modifying feed strategies while reducing demand for imported feed and animals. The use of native plants may be an effective alternative to expensive imported feed (Almutawa, 2022b). Madouh & Al-Sabbagh (2021) identified four potential native forage species to feed livestock (*Cenchrus ciliaris, Cenchrus setigerus, Lasiurus scindicus,* and *Pennisetum divisum*). The use of alternative fodder could reduce the high input of hay rations which amounted to 67,000 tons and bird fodder at 25,000 tons and increase the self-sufficiency rate above 63% for green fodder (PAAFR, 2020-2021). Although Kuwaiti native plants are well-adapted to the abiotic environment, they still have a low biomass production per unit area under extremely low inputs (Madouh & Al-Sabbagh, 2021). The utilisation of conocarpus (*Conocarpus erectus*) a common landscape plant that is widely spread in urban green landscapes has also been identified as fodder (Baroon & Razzque, 2013). Breeding programs within Kuwait are key to having offspring with higher resilience to arid conditions (Razzaque et al., 2009). Countries like Saudi Arabia also see breeding programs using indigenous livestock as one of their climate change adaptation programs (Alsarhan & Zatari, 2022).

The demand for poultry continues to increase with the rising population causing higher imported products due to low self-sufficiency reaching only 20% for meat but 101% for eggs (Al-Nasser et al., 2020; Al-Nasser et al., 2015). In 2018 poultry imports reached 3.2 million birds, local supply can support itself with hatching eggs but requires a large amount of feed like corn and soybean which are purchased from countries such as the United States of America (USA) and India (Alsaffar, 2019; Al-Nasser et al., 2015). Rising temperatures can result in heat stress and disease presence, and with poultry production systems in Kuwait managed just within poultry houses, higher energy demand will be required to maintain a safe living environment (Cole & Desphande, 2019; Ahaotu et al., 2019; Almatawah et al., 2023). To battle the issue of food security KISR have proposed diverse research projects focusing on increasing the added value of poultry to be competitive in the global market, diversifying poultry products to include quails or ducks, and increasing productivity of broilers by reducing feed conversion ratio from 2.0 to 1.4 (Al-Nasser et al., 2020).

3.4. Adaptation

To combat the adverse effects of climate change, adaptation strategies are essential. To maintain governmental efforts to provide agriculture programs and policies, farmers must adjust their strategies to help them adapt to climate change and support sustainable agriculture (Masud et al., 2017). The inability of farmers to adapt to climate change may cause dislocation, social disruption, illness, and even death (Masud et al., 2017). Less than 1.1% of Kuwait's workforce is connected with agricultural activities (PAAFR, 2018; Al-Menaie, 2014). Therefore, there is a heavy reliance on expat farm workers with relatively little to no farming expertise as workers' wages have increased since the pandemic (Al-Nasser & Bhat, 1998). There is also the issue of there being a language barrier or illiteracy among workers which is an obstacle to communication and educating workers. There is also the case of high worker turnover, as farmers do not want to employ farm hands full-time and only seasonally or during labour-intensive short-term jobs to cut overhead costs. Therefore, training competent workers who are consistently on the farm is futile. As well as the fact that farming in Kuwait is new, lacks different generations and has a generational gap. As farming is not considered a viable occupation in Kuwait due to climatic constraints, and many refuse to undertake any manual labour (Alessa, 2017). Furthermore, farmers who do not have an identified successor or those who view farming as a temporary occupation tend to be less inclined to invest in implementing both horizontal and vertical adaptive changes compared to farmers with heirs (Castellano & Moroney, 2018).

There is a lack of widespread understanding and awareness about climate change and greenhouse gases among the farming community in Kuwait. On a larger scale, around 80% of the public associates human unsustainable development with causing climate change, leading to concerns about the quality of life for future generations (Elmi, 2018; Saab, 2009). Some initiatives have been taken to address this lack of awareness and understanding. For example, certain schools in Kuwait, such as Kuwait National English School, have expanded their curriculum to include teachings about climate change and its dangers as it is a part of the "Global Network of Schools addressing Global Challenges" (KNES, n.d.). As well as organizations like the Kuwait Red Crescent Society and the British Council, which conduct workshops to educate the public about climate change and its implications (Kuwait Times, 2022; British Council, 2022). The 2019 "Greening Kuwait" campaign, involving various government sectors, private companies, and volunteers, marked the country's first national effort to restore vegetation in desert areas (UN-Habitat, 2019). As the 2035 National Development Plan progresses, additional campaigns targeting key aspects of the strategy are expected to enhance public awareness.

A gap between local and international knowledge and technology needs to be extensively bridged. A variety of extension activities and services are offered by the International Center for Agricultural Research in the Dry Areas (ICARDA), the Public Authority of Agriculture and Fisheries (PAAFR), the Kuwaiti Farmers Association and the Society of Agricultural Engineers and Environmental Protection Agency (EPA). Growers and producers can gain technical knowledge through extension workers, who can educate them on how to increase their incomes and provide them with research-based information on marketing and processing. Agricultural produce and products also face a problem when it comes to harvest and storage, cold storage and specific packaging for perishable products to ensure higher quality and longer shelf life are unavailable for the majority of the farms in Kuwait. This can be achieved by adapting technology to the food supply chain and harmonizing all the stages of the food industry and placing a more holistic approach through a fork-to-farm (*F2F*) approach (Al-Khateeb et al., 2021). By reforming the current food supply chain and connecting farms to manufacturers, packaging, transportation, distribution, and market-to-customer demand waste can be eliminated, food safety can be improved and reduced, and local food prices can be controlled. This can play a crucial role in maintaining elevated levels of food safety, minimizing the occurrence of food-borne illnesses, safeguarding public health, and effectively managing issues related to food waste and loss (Al-Khateeb et al., 2021; Baig et al., 2017; Alomirah et al., 2010). To accomplish this, one approach is to use a computable general equilibrium model that can assess how the economy reacts to policy changes, technological advancements, and other external factors. This modelling technique takes into account inter-industry connections. Additionally, urban farming practices that prioritize sustainability by implementing farm-to-fork strategies include tracking land-based and aquatic viruses in food production systems (Mahony & van Sinderen, 2022; Abdalla et al., 2022). In addition, the implementation of an e-commerce platform has the potential to reduce food waste. By enabling smarter food chains and utilizing big data for faster creation and value chains with less waste, this solution can be effective (Abdalla et al., 2022; Cole et al., 2018). For instance, in Kuwait, each household generates approximately 1.37 kg of solid waste per person/day, with around 51.1% consisting of foodstuff (Koushki & Al-Khaleefi, 1998). Despite the existence of various adaptive measures to enhance farming practices and food sustainability, challenges still remain. These challenges include limited access to technology and financial resources, inadequate infrastructure for proper waste management, and the need for policy reforms to support sustainable agricultural practices.

1) *Water and energy demands*

Water scarcity is one of the greatest issues faced in Kuwait, which is also threatening the agricultural industry, rapid population growth, improper distribution of water resources, increasing demand for water, hydro-political conditions, deteriorating water quality, low rainfall and high evaporation rates are the primary reasons (Fiaz et al., 2018). The main source of natural water in Kuwait is the Kuwait group and the Dammam aquifers (Al-Maamary et al., 2017; Al-Ruwaih & Almedeij, 2007). Kuwait is one of six GCC six countries (Saudi Arabia, Bahrain, Qatar, UAE, and Oman) that contribute to the recharge of the Dammam aquifer (Al-Maamary et al., 2017). However, it is primarily recharged by direct precipitation at the intake area, the Dammam Dome in Saudi Arabia (Al-Ruwaih & Almedeij, 2007). According to estimates, there is 10.0×10^3 m^3/d (2.2 MIGD) of groundwater flowing to Dammam along the border with Saudi Arabia as a result, groundwater levels have significantly decreased below the average production of 60.01×10^3 m^3/d (13.2 MIGD) of the field (Al-Ruwaih & Almedeij, 2007). In the Dammam aquifer, groundwater salinity increases from 2500 mg/l in the southwest to 10,000 mg/l in the centre (Al-Ruwaih & Almedeij, 2007). In the north and east, salinity abruptly increases to over 150,000 mg/l (Al-Ruwaih & Almedeij, 2007). Rainfall patterns will be altered impacting the availability of water in the regeneration of the aquifers as a result of climate change effects (Al-Maamary et al., 2017). The most reliable source of freshwater is the desalination of seawater across the Arbian Gulf and the Red Sea (Hameed et al., 2019; Al-Ruwaih & Almedeij, 2007). There are a total of six distillation plants have been constructed: Shuwaikh, Shuaiba North, Shuaiba South, Doha East, Doha West, and Az-Zor South with a total distillation capacity of 1.435 million m^3/d (315.6 MIGD) (Al-Ruwaih & Almedeij, 2007). Oil and natural gas are essential for the operation of power plants as a result, Kuwait may be unable to meet its electricity and desalinated water needs due to increased electricity and desalinated water demands which could be met through the application of solar energy (Al-Maamary et al., 2017). Finally, a crucial source of agricultural production involves the utilization of treated wastewater, with recycled water accounting for 19% of the total water consumed within the agricultural sector (Aleisa, 2019).

Electricity consumption per capita is twice as high as or higher than the world average in Kuwait (Waha et al., 2017). Around 68% of the electricity load is used for residential purposes (private residences, investment buildings (with apartments, predominantly inhabited by foreigners) and public housing (Hertog, 2020). Regardless of the Kuwaiti authority's intention to increase energy supplies, there is a need to rethink the energy policy and subsidies since fossil fuels will still be used (Al-Maamary et al., 2017). As climate change will harm water supply and management systems, increasing their resilience is a mandatory adaptation step. An increase in electricity and desalinated water tariffs to curb usage has been ineffective, a s access to water is considered a fundamental right, there is strong political opposition towards eliminating or reducing water subsidies (Aljamal et al., 2022). A partial increase was made in 2017, however, it affected mainly customers in the public sector, where water and electricity prices are now close to the cost of production (Hertog, 2020). With, the average Organization for Economic Cooperation and Development (OECD) price level for water in 2017 was ($15) in comparison to the government tariff ($13), industrial and agriculture ($4) and agricultural and industrial (producers ($2.5) (KD/1000 imp gal) (Hertog, 2020). Since Kuwait has an average of 80% clear skies throughout the year, its solar energy potential is among the best in the world (Reiche, 2010). A SWOT analysis on the utilisation of solar energy in Kuwait was analysed with strengths focusing on the long-term sustainability and potential, while two weaknesses identified mentioned poor planning leading to postponed projects and limited investment towards renewable energy (Al-Fadhli & Al-Habaibeh, 2020).

2) *Subsidies*

Governmental bodies and collective associations also support the agricultural sector directly and indirectly by providing specific subsidies. The Public Authority of Agriculture and Fisheries (PAAFR) provide; direct subsidies in the form of purchasing farmer's produce and subsidizing production costs based on the amount produces (fruit and vegetable, however, herbs are not included) that are then placed for auction in the Sulabiyah marketplace (Al-Forda), which is open for purchase to various distributors. PAAFR has allocated different budgets for subsidies within the different agriculture sectors. Subsidies for plant production, fodder, fisheries, cows, palm trees and other subsidies. The largest budget allocated to fodders is approximately $35 million per year and the second biggest was plant production at $22 million between 2020-2021 (PAAFR, 2019-2020). As well as over the years PAAFR has sporadically distributed free land for agriculture, aquaculture, livestock, and stables. Indirectly PAAFR provides pesticides and pesticides management services, and agricultural machinery for rent for a nominal fee. As well as free courses and seminars are provided covering livestock and agricultural production. Additionally, nursery plants are for sale in the growing season at a nominal fee once a year. PAAF, also offers laboratory services (soil and water analysis and insect, pest and disease identification and control), inoculation, vaccination services and livestock fodder with some being free and some for a nominal fee. The Ministry of Electricity and Water offers subsidies to farmers, providing water at a rate of $4 per 1000 imperial gallons and electricity for active farms at a cost of $0.01 per kilowatt-hour (MEW, 2017).

Some societies and associations support the agricultural sector in Kuwait through the Ministry of Social Affairs and Labor (MSAL); the Society of Agricultural Engineers offers free courses and seminars, and they also cover expenses for Kuwaiti agricultural engineers that are members for knowledge development (travel expenses to exhibitions, conventions and lectures). The Kuwaiti Farmers Association provides a space for distributing and selling produce (food markets and subsidies for diesel fuel).

3) *Stakeholders*

To be able to address this food equity and security by the mid and end of the 21st century there is first a need to create a climate change adaptation strategy. Currently, there is no national climate change adaptation plan that outlines stakeholders' goals, responsibilities and time frame to achieve those goals (**Table 3**). To ensure the sustainability of these food sources to reduce compounding stresses in the future. The adaptation plan should include a framework to assess the impact resulting from climate change and weather shocks on food security (Karfakis et al., 2012). Stakeholders within food production, process, and regulation are key to maintaining food security. Currently, the difficulties faced by stakeholders involved; a lack of communication with one another, no follow-through, late deadlines, lack of transparency, and nepotism (Al Mulla, 2022). Also, there is inefficient collaboration, and integration between the research, NGOs, private companies, governmental institutions and farmers association groups concerning climate change adaptation in all sectors to raise awareness and empower local communities to propose solutions. To improve governance frameworks and capacities, key stakeholders should participate in identifying and measuring these shared risks. Therefore, when risk management and mitigation cannot be performed by one sector alone, incentives for joint action might be proposed.

4. Conclusion

Formulating targeted adaptation strategies and policies is extremely difficult as it is hard to quantify emission values driving climate change effects. Nonetheless, Kuwait needs to develop an adaptation and development plan with various scenarios to address any issues faced regarding food accessibility and security due to climate change with a sense of urgency. A climate change adaptation plan needs to outline long-term and short-term action plans and goals by mid and end of the 21st century. Any adaptation strategy should involve or include community action to enable local participation towards a shared collective societal responsibility. Furthermore, an adaptive strategy capable of handling emergencies and hazardous crises is absent. To ensure basic nutritional needs are met healthy and sustainable eating habits are sustained. These targets can be expected to be met through the reduction of food waste and loss, improving existing infrastructural plans, and trade and subsidy policies towards improving current agricultural practices.

Table 3. Current Stakeholder roles towards the agricultural, fisheries and livestock sectors in Kuwait.

Stakeholder	Organisation Type	Current Role
Public Authority of Agriculture and Fisheries (PAAF)	Government	• Provide subsidies for farmers directly in and indirectly in the form of (fertilisers, pesticides, services, vaccination, laboratory analysis, extension services etc). • Participate in drafting, implementing, and enforcing food laws, regulations and food standards. • Agriculture import/export Regulations.
Ministry of Commerce (MOC)	Government	• Participate in drafting, implementing, and enforcing food laws, regulations and food standards (Alomirah et al., 2010).
Ministry of Health (MOH)	Government	• Participate in drafting, implementing, and enforcing food laws, regulations and food standards (Alomirah et al., 2010). • Preparation, anticipation, and prevention of health issues related to climate change (EPA, 2019).
Ministry of Electricity and Water (MEW)	Government	• Data collection. • Monitoring and evaluating networks. • Construction of new wells (EPA, 2019). • Technical assistance and training and education in the sector (EPA, 2019). • Subsidised electricity and water.
Kuwait Municipality (KM)	Government	• Participate in drafting, implementing, and enforcing food laws, regulations and food standards (Alomirah et al., 2010).
Kuwait Institute of Scientific Research (KISR)	Government/ Private	• Participate in research services and projects (also collaborations with the UN, PAAF, PAI, KU and EPA). • Education and technical training.
Kuwait University (KU)	Government	• Research services and projects. • Education and technical training.
Public Authority of Industry	Government	• Standardization Committee
Public Authority for Applied Education and Training (PAAET)	Government	• Education and technical training.
Kuwait Environmental Protection Agency (KEPA)	Government	• Education and technical training. • Laboratory analysis, extension services.
Kuwait Foundation for the Advancement of Science (KFAS)	Private NGO	• Funds research institutions, scientists and projects, mainly Kuwait University and KISR.
United Nations (UN)/Food and Agriculture Organization of the United Nations (FAO)	NGO	• Kyoto agreement -Primarily concerned with mitigating climate change by reducing carbon dioxide (CO_2) emissions and sequestering it from the atmosphere (Reiche, 2010; UNFCCC, 2009; Bättig et al., 2008; Behnassi et al., 2019). • Habitat III (Food security and strengthening of urban-rural linkages for sustainable urban development (FAO, 2017).
Arab Forum for Environment and Development (AFED)	NGO	• Periodical report on the state of the environment and natural resources in the Middle East. • Discuss regional reports on environmental matters and investigate their impact on the process of sustainable development in the Middle East.

Continued

		• Work with the business community in the Arab world to develop corporate Environmental Responsibility Programs, adopt sustainable practices and move towards cleaner production technologies. • Cooperating with the media and the advertising sectors to promote environmental awareness. • Working with educational institutions on scientific research. • Supporting networking of NGOs active in the domain of environment and development and coordinating joint programs.
Council of Arab Ministers Responsible for the Environment (CAMRE)	NGO	• 2004/2005 Arab Environmental action program. • Desertification Combat to increase the arable lands and to enhance the nomadic environment. • Specify guidelines to regulate trading in genetically engineered products and living organisms in the Arab region. • Seminar on water resource integrated management. • Awareness-raising seminar on means of facing the depletion of natural resources and wildlife. • Promote the concept of cleaner production and to establish national centres for cleaner production. • complete establishing a descriptive (qualitative) and statistical database.
Joint Committee on Environment and Development in the Arab Region (JCEDAR)	NGO	• Follow up on all the actions and meetings of the UN International Convention for Combating Desertification and the International Convention on Biodiversity. • Establish an Arab bank for genetic plant species in the Arab region. • Test the indicators of desertification in a selected number of countries. • Specify guidelines to regulate trading in genetically engineered products and living organisms in the Arab region. • Hold seminars on the complementary activities that integrate the three international environmental agreements (desertification combat, biodiversity and climatic changes). • Organize a training course on means of preparing projects for the rehabilitation of the degraded land to be presented to the donation organizations. • Hold a practical seminar on case studies of rehabilitation of degraded lands. • Call for a meeting of national contact (liaison) offices of the International Convention on Biodiversity to address the actual implementation of strategies and action plans for the aquatic biodiversity in the Arab region. • Organize an awareness-raising seminar on means of facing the depletion of natural resources and wildlife, accompanied by reviewing case studies of some countries e.g. Somalia. • Hold a seminar on water resource integrated management (JCEDAR, 2003).
Center of Environment and Development for Arab Region and Europe (CEDARE)	NGO	• Provide accredited training, rehabilitation and education programmes.
Gulf Cooperation Council (GCC)	NGO	• GCC Unified Customs Law and Single Customs Tariff" (UCL)-five per cent on almost all imported foods and a single-entry point policy, a unified guide for controls on imported food (Alomirah et al., 2010).

Continued

		• Working towards updating food laws, creating unified standards and conformity assessment systems that are consistent with international, regional and national needs (Alomirah et al., 2010).
Kuwait Farmers Federation (KFF)	NGO	• Subsidies for diesel. • Technical and educational support for members.
Poultry Breeders Cooperative Association	NGO	• Technical and educational support for members.
Society of Agricultural Engineers	NGO	• Technical and educational support for members.
Union of Productive Societies	NGO	• Technical and educational support for members.
Kuwaiti Federation of Livestock Breeders	NGO	• Technical and educational support for members.
Union of all cow breeders and fresh milk producers	NGO	• Technical and educational support for members.
Kuwait Beekeepers Association	NGO	• Technical and educational support for members.
World Health Organization (WHO)	NGO	• Technical and educational support for members.
World Bank	NGO	• Strategic advisory services program (generator and connector of development knowledge).

Monitoring programs should also be placed to track targets and the progress of these actions, with a contingency plan if these plans do not progress accordingly. The ability for stakeholders to cooperate will be key to maintaining a safe future for all the residents living in Kuwait.

Author Contributions

All authors contributed to the conception and design. Material preparation, data collection and analysis were performed by Athari Abdulaziz Almutawa and Abdulrahman Alfraih. The first draft of the manuscript was written by both authors who commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Abdalla, Z., El-Ramady, H., Omara, A. E.-D., Elsakhawy, T., Bayoumi, Y., Shalaby, T., & Prokisch, J. (2022). From Farm-to-Fork: A pictorial Mini Review on Nano-Farming of Vegetables. *Environment, Biodiversity and Soil Security, 6,* 149-163. https://doi.org/10.21608/jenvbs.2022.145977.1180

Abdullah, M. J., Zhang, Z., & Matsubae, K. (2021). Potential for Food Self-Sufficiency Improvements through Indoor and Vertical Farming in the Gulf Cooperation Council: Challenges and Opportunities from the Case of Kuwait. *Sustainability (Switzerland),* *13,* Article No. 12553. https://doi.org/10.3390/su132212553

Ahaotu, E. O., De los Ríos, P., Ibe, L. C., & Singh, R. R. (2019). Climate Change in Poultry Production System—A Review. *Acta Scientific Agriculture, 3,* 113-117. https://doi.org/10.31080/ASAG.2019.03.0617

Al Mulla, M. S. (2022). Nepotism and Corruption: A Descriptive and Analytical Study in the Reality of Kuwaiti Society. In *Corruption-New Insights*. IntechOpen.

Al-Abdulrazzak, D., Zeller, D., Belhabib, D., Tesfamichael, D., & Pauly, D. (2015). Total Marine Fisheries Catches in the Persian/Arabian Gulf from 1950 to 2010. *Regional Studies in Marine Science, 2,* 28-34. https://doi.org/10.1016/j.rsma.2015.08.003

Al-Bakri, J., Suleiman, A., Abdulla, F., & Ayad, J. (2011). Potential Impact of Climate Change on Rainfed Agriculture of a Semi-Arid Basin in Jordan. *Physics and Chemistry of the Earth, Parts A/B/C, 36,* 125-134. https://doi.org/10.1016/j.pce.2010.06.001

Alboghdady, M., & El-Hendawy, S. E. (2016). Economic Impacts of Climate Change and Variability on Agricultural Production in the Middle East and North Africa Region. *International Journal of Climate Change Strategies and Management, 8,* 463-472. https://doi.org/10.1108/IJCCSM-07-2015-0100

Aleisa, E. (2019). Analysis on Reclamation and Reuse of Wastewater in Kuwait. *Journal of Engineering Research, 7,* 1-27.

Alessa, S. Y. (2017). *The Manpower Problem in Kuwait* (Vol. 5). Routledge. https://doi.org/10.4324/9781315159706

Al-Fadhli, H. M., & Al-Habaibeh, A. (2020). SWOT Analysis for the Current and Future Utilisation of Solar Energy Technologies in Kuwait. In *The 12th International Conference on Applied Energy*.

AlHamad, N. (2006). *Nutrition Country Profile State of Kuwait*. https://www.fao.org/3/aq040e/aq040e.pdf

Al-Husaini, M., Bishop, J. M., Al-Foudari, H. M., & Al-Baz, A. F. (2015). A Review of the Status and Development of Kuwait's Fisheries. *Marine Pollution Bulletin, 100,* 597-606. https://doi.org/10.1016/j.marpolbul.2015.07.053

Ali, A., & Chidambaram, S. (2021). Assessment of Trace Inorganic Contaminates in Water and Sediment to Address Its Impact on Common Fish Varieties along Kuwait Bay. *Environmental Geochemistry and Health, 43,* 855-883. https://doi.org/10.1007/s10653-020-00559-6

Aljamal, A., Speece, M., & Bagnied, M. (2022). Understanding Resistance to Reductions in Water Subsidies in Kuwait. *Local Environment, 27,* 97-111. https://doi.org/10.1080/13549839.2021.2002287

Al-Khateeb, S. A., Hussain, A., Lange, S., Almutari, M. M., & Schneider, F. (2021). Battling Food Losses and Waste in Saudi Arabia: Mobilizing Regional Efforts and Blending Indigenous Knowledge to Address Global Food Security Challenges. *Sustainability (Switzerland), 13,* Article No. 8402. https://doi.org/10.3390/su13158402

Allbed, A., Kumar, L., & Shabani, F. (2017). Climate Change Impacts on Date Palm Cultivation in Saudi Arabia. *Journal of Agricultural Science, 155,* 1203-1218. https://doi.org/10.1017/S0021859617000260

Al-Maamary, H. M. S., Kazem, H. A., & Chaichan, M. T. (2017). Climate Change: The Game Changer in the Gulf Cooperation Council Region. *Renewable and Sustainable Energy Reviews, 76,* 555-576. https://doi.org/10.1016/j.rser.2017.03.048

Almatawah, Q. A., Al-Khalaifah, H. S., Aldameer, A. S., Ali, A. K., Benhaji, A. H., & Varghese, J. S. (2023). Microbiological Indoor and Outdoor Air Quality in Chicken Fattening Houses. *Journal of Environmental and Public Health, 2023,* Article ID: 3512328.

https://doi.org/10.1155/2023/3512328

Almazroui, M. (2013). Simulation of Present and Future Climate of Saudi Arabia Using a Regional Climate Model (PRECIS). *International Journal of Climatology, 33,* 2247-2259. https://doi.org/10.1002/joc.3721

Al-Menaie, H. S. (2014). Prospects of Agriculture in the State of Kuwait-Constraints and Opportunities. In *Environmental Cost and Face of Agriculture in the Gulf Cooperation Council Countries: Fostering Agriculture in the Context of Climate Change* (pp. 43-59). Springer International Publishing. https://doi.org/10.1007/978-3-319-05768-2_3

Al-Mulla, Y. A. (2006). Cooling Greenhouses in the Arabian Peninsula. *International Symposium on Greenhouse Cooling, 719,* 499-506. https://doi.org/10.17660/ActaHortic.2006.719.57

Almutawa, A. A. (2022a). Date Production in the Al-Hassa Region, Saudi Arabia in the Face of Climate Change. *Journal of Water and Climate Change, 13,* 2627-2647. https://doi.org/10.2166/wcc.2022.461

Almutawa, A. A. (2022b). Native and Xeric Plant Recommendations for Urban Landscapes in Kuwait. *Technology in Horticulture, 2,* Article No. 7. https://doi.org/10.48130/TIH-2022-0007

Al-Nasser, A. Y., & Bhat, N. R. (1998, February). Protected Agriculture in the State of Kuwait. In *Proceedings of the Workshop on Protected Agriculture in the Arabian Peninsula, Doha (Qatar)* (pp. 15-18).

Al-Nasser, A., Al-Khalaifah, H., Khalil, F., & Al-Mansour, H. (2020). Poultry Industry in the Gulf Cooperation Council with Emphasis on Kuwait. *World's Poultry Science Journal, 76,* 577-589. https://doi.org/10.1080/00439339.2020.1782802

Al-Nasser, A., Al-Khlaifa, H., Al-Bahouh, M., Khalil, F., Boareki, M., & Ragheb, G. (2015). Challenges Facing Poultry Production in Kuwait. *World's Poultry Science Journal, 71,* 339-348.

Alomirah, H. F., Al-Zenki, S. F., Sawaya, W. N., Jabsheh, F., Husain, A. J., Al-Mazeedi, H. M., & Jukes, D. (2010). Assessment of the Food Control System in the State of Kuwait. *Food Control, 21,* 496-504. https://doi.org/10.1016/j.foodcont.2009.07.015

Alqattan, M. E. A., & Gray, T. S. (2021). Marine Pollution in Kuwait and Its Impacts on Fish-Stock Decline in Kuwaiti Waters: Reviewing the Kuwaiti Government's Policies and Practices. *Frontiers in Sustainability, 2,* Article ID: 667822. https://doi.org/10.3389/frsus.2021.667822

Alqattan, M. E., Gray, T. S., & Stead, S. M. (2020). The Illegal, Unreported and Unregulated Fishing in Kuwait: Problems and Solutions. *Marine Policy, 116,* 103775. https://doi.org/10.1016/j.marpol.2019.103775

Al-Ruwaih, F. M., & Almedeij, J. (2007). The Future Sustainability of Water Supply in Kuwait. *Water International, 32,* 604-617. https://doi.org/10.1080/02508060.2007.9709692

Alsabah, N. (2021). Effects of Overfishing on Kuwait Bay. *International Journal of Engineering Science, 10,* 1-5.

Alsaffar, A. E. (2019). Broiler Breeder Research in Kuwait. In *International Seminar on Tropical Animal Production.*

Alsarhan, A., & Zatari, T. (2022). *Fourth National Communication of the Kingdom of Saudi Arabia.* https://unfccc.int/sites/default/files/resource/7123846_Saudi%20Arabia-NC4-1-Fourth%20National%20Communication%20NC4%20Kingdom%20of%20Saudi%20Arabia%20March%202022.pdf

Al-Yamani, F., Yamamoto, T., Al-Said, T., & Alghunaim, A. (2017). Dynamic Hydrographic Variations in Northwestern Arabian Gulf over the Past Three Decades: Temporal Shifts and Trends Derived from Long-Term Monitoring Data. *Marine Pollution Bulletin, 122,* 488-499. https://doi.org/10.1016/j.marpolbul.2017.06.056

Al-Zawad, F. M., & Aksakal, A. (2010). Impacts of Climate Change on Water Resources in Saudi Arabia. In I. Dincer, *et al.* (Eds.), *Global Warming* (pp. 511-523). Springer. https://doi.org/10.1007/978-1-4419-1017-2_33

Amundson, J. L., Mader, T. L., Rasby, R. J., & Hu, Q. S. (2005). Temperature and Temperature-Humidity Index Effects on Pregnancy Rate in Beef Cattle. In *Proceedings of 17th International Congress on Biometeorology*.

Baig, M. B., Straquadine, G. S., & Aldosari, F. O. (2017). Revisiting Extension Systems in Saudi Arabia: Emerging Reasons and Realities. *Journal of Experimental Biology and Agricultural Sciences, 5,* 160-164. https://doi.org/10.18006/2017.5(Spl-1-SAFSAW).S160.S164

Baroon, Z., & Razzaque, M. A. (2013). Observations on Silage Making of Landscape Conocarpus Browse Residues as Feed Ingredient in Kuwait. *International Journal of Sustainable Development and Planning, 8,* 362-379. https://doi.org/10.2495/SDP-V8-N3-362-379

Bashitialshaaer, R. A., Persson, K. M., & Aljaradin, M. (2011). Estimated Future Salinity in the Arabian Gulf, the Mediterranean Sea and the Red Sea Consequences of Brine Discharge from Desalination. *International Journal of Academic Research, 3,* 133-140.

Bättig, M. B., Brander, S., & Imboden, D. M. (2008). Measuring Countries' Cooperation within the International Climate Change Regime. *Environmental Science & Policy, 11,* 478-489. https://doi.org/10.1016/j.envsci.2008.04.003

Beddington, J. R., Asaduzzaman, M., Fernandez, A. B., Clark, M. E., Guillou, M., Jahn, M. M., & Nobre, C. A. (2012). *Achieving Food Security in the Face of Climate Change: Final Report from the Commission on Sustainable Agriculture and Climate Change*.

Behnassi, M., Pollmann, O., Gupta, H., & Studies, R. C. (2019). *Climate Change, Food Security and Natural Resource Management*. Springer. https://doi.org/10.1007/978-3-319-97091-2

Ben-Hasan, A., & Christensen, V. (2019). Vulnerability of the Marine Ecosystem to Climate Change Impacts in the Arabian Gulf—An Urgent Need for More Research. *Global Ecology and Conservation*, *17,* e00556. https://doi.org/10.1016/j.gecco.2019.e00556

Brander, K. (2010). Impacts of Climate Change on Fisheries. *Journal of Marine Systems, 79,* 389-402. https://doi.org/10.1016/j.jmarsys.2008.12.015

British Council. (2022). *Kuwait Climate Change Champions: Supporting Young People to Create a Greener, More Sustainable World*. British Council. https://www.britishcouncil.com.kw/en/kuwait-climate-change-champions-supporting-young-people-create-greener-more-sustainable-world

Carpenter, K. E., Krupp, F., & Jones, D. A. (1997). *Living Marine Resources of Kuwait, Eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates*. Food & Agriculture Org.

Chase, L. E. (2006). *Climate Change Impacts on Dairy Cattle. Fact Sheet, Climate Change and Agriculture: Promoting Practical and Profitable Responses*.

Cheung, W. W., Lam, V. W., Sarmiento, J. L., Kearney, K., Watson, R., & Pauly, D. (2009). Projecting Global Marine Biodiversity Impacts under Climate Change Scenarios. *Fish and Fisheries, 10,* 235-251. https://doi.org/10.1111/j.1467-2979.2008.00315.x

Ciscar, J. C., Iglesias, A., Feyen, L., Goodess, C. M., Szabó, L., Christensen, O. B., & Soria, A. (2009). *Climate Change Impacts in Europe*. Final Report of the PESETA Research

Project.

Cole, J., & Desphande, J. (2019). Poultry Farming, Climate Change, and Drivers of Antimicrobial Resistance in India. *The Lancet Planetary Health, 3,* e494-e495. https://doi.org/10.1016/S2542-5196(19)30236-0

Cole, M. B., Augustin, M. A., Robertson, M. J., & Manners, J. M. (2018). The Science of Food Security. *NPJ Science of Food, 2,* 1-8. https://doi.org/10.1038/s41538-018-0021-9

Dasgupta, S., Laplante, B., Murray, S., & Wheeler, D. (2011). Exposure of Developing Countries to Sea-Level Rise and Storm Surges. *Climatic Change, 106,* 567-579. https://doi.org/10.1007/s10584-010-9959-6

Deards, B., & Thompson, N. (2012). Competition in Australia's Live Sheep Export Markets. *Agricultural Commodities, 2,* 88-90.

del Pozo, A., Brunel-Saldias, N., Engler, A., Ortega-Farias, S., Acevedo-Opazo, C., Lobos, G. A., & Molina-Montenegro, M. A. (2019). Climate Change Impacts and Adaptation Strategies of Agriculture in Mediterranean-Climate Regions (MCRs). *Sustainability (Switzerland), 11,* Article No. 2769. https://doi.org/10.3390/su11102769

Deryng, D., Conway, D., Ramankutty, N., Price, J., & Warren, R. (2014). Global Crop Yield Response to Extreme Heat Stress under Multiple Climate Change Futures. *Environmental Research Letters, 9,* Article ID: 034011. https://doi.org/10.1088/1748-9326/9/3/034011

Dwivedi, S., Garcia Oliveira, A. L., Govindaraj, M., & Ortiz, R. (2023). Biofortification to Avoid Malnutrition in Humans in a Changing Climate: Enhancing Micronutrient Bioavailability in Seed, Tuber, and Storage Roots. *Frontiers in Plant Science, 14,* Article ID: 1119148. https://doi.org/10.3389/fpls.2023.1119148

Elmi, A. A. (2018). Risks to Critical Environmental Resources and Public Wellbeing from Climate Change in the Eyes of Public Opinion in Kuwait. *Environmental Progress & Sustainable Energy, 37,* 232-239. https://doi.org/10.1002/ep.12662

EPA (2019). *Kuwait National Adaptation Plan 2019-2030.* https://unfccc.int/sites/default/files/resource/Kuwait-NAP-2019-2030.pdf

FAO (2017). *The Future of Food and Agriculture: Trends and Challenges* (Vol. 296). https://www.fao.org/3/i6583e/i6583e.pdf

Fiaz, S., Ali, M., & Owis, F. (2018). Achieving Food Security in the Kingdom of Saudi Arabia through Innovation: Potential Role of Agricultural Extension. *Journal of the Saudi Society of Agricultural Sciences, 17,* 365-375. https://doi.org/10.1016/j.jssas.2016.09.001

Fischer, G. (2009). How do Climate Change and Bioenergy Alter the Long-Term Outlook for Food, Agriculture and Resource Availability. *Expert Meeting on How to Feed the World, 2050.*

Frank, K. L., Mader, T. L., Harrington, J. A., Hahn, G. L., & Davis, M. S. (2001). Climate Change Effects on Livestock Production in the Great Plains. In *Livestock Environment VI, Proceedings of the 6th International Symposium 2001* (p. 351). American Society of Agricultural and Biological Engineers.

Gaughan, J., Lacetera, N., Valtorta, S. E., Khalifa, H. H., Hahn, L., & Mader, T. (2009). Response of Domestic Animals to Climate Challenges. In K. L. Ebi, I. Burton, & G. R. McGregor (Eds.), *Biometeorology for Adaptation to Climate Variability and Change* (pp. 131-170). Springer. https://doi.org/10.1007/978-1-4020-8921-3_7

Gormley, K. S., Hull, A. D., Porter, J. S., Bell, M. C., & Sanderson, W. G. (2015). Adaptive Management, International Co-Operation and Planning for Marine Conservation Hotspots in a Changing Climate. *Marine Policy, 53,* 54-66. https://doi.org/10.1016/j.marpol.2014.11.017

Hameed, M., Moradkhani, H., Ahmadalipour, A., Moftakhari, H., Abbaszadeh, P., & Alipour, A. (2019). A Review of the 21st Century Challenges in the Food-Energy-Water Security in the Middle East. *Water (Switzerland), 11,* Article No. 682. https://doi.org/10.3390/w11040682

Harle, K. J., Howden, S. M., Hunt, L. P., & Dunlop, M. (2007). The Potential Impact of Climate Change on the Australian Wool Industry by 2030. *Agricultural Systems, 93,* 61-89. https://doi.org/10.1016/j.agsy.2006.04.003

Hereher, M. E. (2020). Assessment of Climate Change Impacts on Sea Surface Temperatures and Sea Level Rise—The Arabian Gulf. *Climate, 8,* Article No. 50. https://doi.org/10.3390/cli8040050

Hertog, S. (2020). *Reforming Wealth Distribution in Kuwait: Estimating Costs and Impacts* (pp. 1-76). LSE Middle East Centre Kuwait Programme Paper Series 28. http://eprints.lse.ac.uk/105564/2/Reforming_WealthDistribution__in_Kuwait_New.pdf

Hopkins, A., & Del Prado, A. (2007). Implications of Climate Change for Grassland in Europe: Impacts, Adaptations and Mitigation Options: A Review. *Grass and Forage Science, 62,* 118-126. https://doi.org/10.1111/j.1365-2494.2007.00575.x

Hughes, N., Galeano, D., & Hatfield-Dodds, S. (2019). The Effects of Drought and Climate Variability on Australian Farms. *ABARES Insights, 6,* Article No. 11.

IPCC (2000). *Special Report on Emissions Scenarios.*

JCEDAR (2003). *Report and Decisions of the 4th Session of JCEDAR.* https://sustainabledevelopment.un.org/content/documents/WestAsiaRimReport.pdf

Karfakis, P., Lipper, L., & Smulders, M. (2012). The Assessment of the Socioeconomic Impacts of Climate Change at Household Level and Policy Implications. In *Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Proceedings of a Joint FAO/OECD Workshop* (pp. 133-150). Food and Agriculture Organization of the United Nations (FAO).

KASA (Various Dates). State of Kuwait, Central Statistical Office, Annual Statistical Abstract. In D. Held, & K. Ulrichsen (Eds.), *The Transformation of the Gulf: Politics, Economics and the Global Order*. Routledge.

Kitto, M., & Bechara, G. P. (2004). Business Aquaculture in Kuwait—Challenges and Solutions. *World Aquaculture, 35,* 58-60.

Koushki, P. A., & Al-Khaleefi, A. L. (1998). An Analysis of Household Solid Waste in Kuwait: Magnitude, Type, and Forecasting Models. *Journal of the Air and Waste Management Association, 48,* 256-263. https://doi.org/10.1080/10473289.1998.10463678

Kuwait National English School (KNES) (n.d.). *The UNESCO Climate Change Initiative.* https://knes.edu.kw/the-unesco-climate-change-initiative.php

Kuwait Times. (2022, December 8). Kuwait Red Crescent Society: Important to Raise Climate Change Awareness. *Kuwait Times*. https://www.kuwaittimes.com/krcs-important-to-raise-climate-change-awareness/

Liri, H., AlKandary, D. S., & Al-Awadhi, J. M. (2023). Evaluation of Seawater Quality of Kuwait Bay Using Physio-Chemical Parameters. *Kuwait Journal of Science, 50,* 1-18. https://doi.org/10.48129/kjs.16319

Madouh, T. A., & Al-Sabbagh, T. A. (2021). Nutritional Quality and Adaptation of Several Native Plant Species of Kuwait to the Farming System As Potential Livestock Feed. *International Journal of Earth & Environmental Sciences, 2,* 1-8.

Mahony, J., & van Sinderen, D. (2022). Virome Studies of Food Production Systems: Time for "Farm to Fork" Analyses. *Current Opinion in Biotechnology, 73,* 22-27. https://doi.org/10.1016/j.copbio.2021.06.014

Masud, M. M., Azam, M. N., Mohiuddin, M., Banna, H., Akhtar, R., Alam, A. S. A. F., & Begum, H. (2017). Adaptation Barriers and Strategies towards Climate Change: Challenges in the Agricultural Sector. *Journal of Cleaner Production, 156,* 698-706. https://doi.org/10.1016/j.jclepro.2017.04.060

Merino, G., Barange, M., Blanchard, J. L., Harle, J., Holmes, R., Allen, I., & Rodwell, L. D. (2012). Can Marine Fisheries and Aquaculture Meet Fish Demand from a Growing Human Population in a Changing Climate? *Global Environmental Change, 22,* 795-806. https://doi.org/10.1016/j.gloenvcha.2012.03.003

Ministry of Electricity and Water MEW (2017). http://portal.mew.gov.kw/files/documents/2017-28-tariff.pdf

Misak, R., & Abdulhadi, A. (2022). Geo- and Environmental Hazard Studies in Kuwait. *The Geology of Kuwait,* 171. https://doi.org/10.1007/978-3-031-16727-0_8

Müller, C., & Robertson, R. D. (2014). Projecting Future Crop Productivity for Global Economic Modeling. *Agricultural Economics, 45,* 37-50. https://doi.org/10.1111/agec.12088

Müller, C., Bondeau, A., Popp, A., Waha, K., & Fader, M. (2010). *Climate Change Impacts on Agricultural Yields*.

Omar Asem, S., & Roy, W. Y. (2010). Biodiversity and Climate Change in Kuwait. *International Journal of Climate Change Strategies and Management, 2,* 68-83. https://doi.org/10.1108/17568691011020265

Parry, M. L., Rosenzweig, C., Iglesias, A., Livermore, M., & Fischer, G. (2004). Effects of Climate Change on Global Food Production under SRES Emissions and Socio-Economic Scenarios. *Global Environmental Change, 14,* 53-67. https://doi.org/10.1016/j.gloenvcha.2003.10.008

Public Authority for Agriculture and Fish Resources (PAAFR) (Various Dates). *Annual Statistical Bulletin*.

Ragab, R., & Prudhomme, C. (2002). Climate Change and Water Resources Management in Arid and Semi-Arid Regions: Prospective and Challenges for the 21st Century. *Biosystems Engineering, 81,* 3-34. https://doi.org/10.1006/bioe.2001.0013

Razzaque, M. A., Mohammed, S. A., Al-Mutawa, T., & Bedair, M. (2009). Growth, Reproduction and Milk Yield of Holstein Friesian Heifers Born and Adapted in Kuwait. *Pakistan Journal of Nutrition, 8,* 1159-1163. https://doi.org/10.3923/pjn.2009.1159.1163

Reiche, D. (2010). Energy Policies of Gulf Cooperation Council (GCC) Countries-Possibilities and Limitations of Ecological Modernization in Rentier States. *Energy Policy, 38,* 2395-2403. https://doi.org/10.1016/j.enpol.2009.12.031

Rosenzweig, C., Karoly, D., Vicarelli, M., Neofotis, P., Wu, Q., Casassa, G., & Imeson, A. (2008). Attributing Physical and Biological Impacts to Anthropogenic Climate Change. *Nature, 453,* 353-357. https://doi.org/10.1038/nature06937

Rötter, R., & van de Geijn, S. C. (1999). Climate Change Effects on Plant Growth, Crop Yield and Livestock. *Climatic Change, 43,* 651-681. https://doi.org/10.1023/A:1005541132734

Saab, N. (2009). Arab Public Opinion and Climate Change. *Arab Environment: Climate Change,* 1.

Sarwar, S. (2022). Impact of Energy Intensity, Green Economy and Blue Economy to Achieve Sustainable Economic Growth in GCC Countries: Does Saudi Vision 2030 Matters to GCC Countries. *Renewable Energy, 191,* 30-46. https://doi.org/10.1016/j.renene.2022.03.122

Semba, R. D., Askari, S., Gibson, S., Bloem, M. W., & Kraemer, K. (2022). The Potential

Impact of Climate Change on the Micronutrient-Rich Food Supply. *Advances in Nutrition, 13,* 80-100. https://doi.org/10.1093/advances/nmab104

Shackley, S., Young, P., Parkinson, S., & Wynne, B. (1998). Uncertainty, Complexity and Concepts of Good Science in Climate Change Modelling: Are GCMs the Best Tools? *Climatic Change, 38,* 159-205. https://doi.org/10.1023/A:1005310109968

Shirvani, A., Nazemosadat, S., & Kahya, E. (2015). Analyses of the Persian Gulf Sea Surface Temperature: Prediction and Detection of Climate Change Signals. *Arabian Journal of Geosciences, 8,* 2121-2130. https://doi.org/10.1007/s12517-014-1278-1

Siderius, C., Conway, D., Yassine, M., Murken, L., & Lostis, P. L. (2019). Characterising the Water-Energy-Food Nexus in Kuwait and the Gulf Region. *Environmental Research Letters, 15,* Article ID: 094024. https://doi.org/10.1088/1748-9326/ab8a86

Som Castellano, R. L., & Moroney, J. (2018). Farming Adaptations in the Face of Climate Change. *Renewable Agriculture and Food Systems, 33,* 206-211. https://doi.org/10.1017/S174217051700076X

Tebaldi, C., & Lobell, D. (2018). Estimated Impacts of Emission Reductions on Wheat and Maize Crops. *Climatic Change, 146,* 533-545. https://doi.org/10.1007/s10584-015-1537-5

Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., & Williams, S. E. (2004). Extinction Risk from Climate Change. *Nature, 427,* 145-148. https://doi.org/10.1038/nature02121

Thornton, P. K., van de Steeg, J., Notenbaert, A., & Herrero, M. (2009). The Impacts of Climate Change on Livestock and Livestock Systems in Developing Countries: A Review of What We Know and What We Need to Know. *Agricultural Systems, 101,* 113-127. https://doi.org/10.1016/j.agsy.2009.05.002

UN-Habitat. (2019, November 6). *Greening Kuwait: A Campaign to Address Impacts of Sand Storms and Climate Change through Planting 100,000 Trees in Kuwait.* https://unhabitat.org/news/06-nov-2019/greening-kuwait-a-campaign-to-address-impacts-of-sand-storms-and-climate-change

University of California, Irvine School of Law (UCI). (2016, March 12). *Establishing Equity in our Food System. UCI Law.* https://www.law.uci.edu/events/food-equity/2016/

Verma, C., Nanda, S., Singh, R. K., Singh, R. B., & Mishra, S. (2011). A Review on Impacts of Genetically Modified Food on Human Health. *Open Nutraceuticals Journal, 4,* 3-11. https://doi.org/10.2174/1876396001104010003

Wabnitz, C. C., Lam, V. W., Reygondeau, G., Teh, L. C., Al-Abdulrazzak, D., Khalfallah, M., & Cheung, W. W. (2018). Climate Change Impacts on Marine Biodiversity, Fisheries and Society in the Arabian Gulf. *PLOS ONE, 13,* e0194537. https://doi.org/10.1371/journal.pone.0194537

Waha, K., Krummenauer, L., Adams, S., Aich, V., Baarsch, F., Coumou, D., & Schleussner, C. F. (2017). Climate Change Impacts in the Middle East and Northern Africa (MENA) Region and Their Implications for Vulnerable Population Groups. *Regional Environmental Change, 17,* 1623-1638. https://doi.org/10.1007/s10113-017-1144-2

Wheeler, D. L. (2015). Food Security, Obesity, and the Politics of Resource Strain in Kuwait. *World Medical and Health Policy, 7,* 255-277. https://doi.org/10.1002/wmh3.153

Wiebe, K., Lotze-Campen, H., Sands, R., Tabeau, A., Van Der Mensbrugghe, D., Biewald, A., & Willenbockel, D. (2015). Climate Change Impacts on Agriculture in 2050 under a Range of Plausible Socioeconomic and Emissions Scenarios. *Environmental Research Letters, 10,* Article ID: 085010. https://doi.org/10.1088/1748-9326/10/8/085010