Research on World Agricultural Economy
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RESEARCH ARTICLE

Prospects on Agricultural Development in Kuwait, An Overview

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ABSTRACT

High Gross Domestic Product (GDP) countries in the Arabian Peninsula, such as the State of Kuwait, invest billions of dollars annually for developing the agricultural sector to counter harsh climatic conditions, poor soil fertility, and scarcity of irrigation water. With the increase in population, these countries must increase agricultural production to meet rising demands and reduce reliance on food imports, which currently constitute about 90% of the total food demand in Kuwait. This study provides an overview of the agricultural sector in Kuwait to assess the current status of agricultural development and provide recommendations for improvement, considering key factors such as economic constraints, climate change and food security. An intensive literature review was carried out with an assessment of available data at local institutions. Despite the challenges over the past two decades, agricultural areas have been expanding by 38%. The number of holdings increased by 300% in 2017/18. Large subsidies are granted by the government amounting to KD 26 million in 2019/20. However, the agricultural sector's contribution to GDP did not exceed 0.6% over the past decade with little indication of a significant growth trend in the future. To enhance local food production, Kuwait must adopt sustainable agricultural technologies and reduce the demand on land reclamation for irrigation purposes. The future outlook of the agricultural sector, however, is not clear under the current business as usual. Strategic planning for resilient agricultural development may consider sustainable farming technology systems with renewable energy, such as vertical and smart farming systems. This will boost agricultural production for social sustainability and environmental benefits such as reducing the demand

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ARTICLE INFO
Received: 8 August 2024 | Revised: 5 September 2024 | Accepted: 6 September 2024 | Published Online: 16 October 2024
DOI: https://doi.org/10.36956/rwae.v5i4.1165

CITATION
Omar Asem, S., 2024. Prospects on Agricultural Development in Kuwait, An Overview. Research on World Agricultural Economy. 5(4): 189–202. DOI: https://doi.org/10.36956/rwae.v5i4.1165

on land, water, electricity, and chemical usage. Future research is needed to assess the economic sustainability of large-scale advanced technology farming systems considering climate change, energy demand and food security.
Keywords: Agricultural Holdings; Subsidies; Self-Sufficiency; Vertical Farming; Climate Change; Smart Farms; Land-Use Mapping

1. Introduction

Located in the Northeastern region of the Arabian Peninsula, the State of Kuwait is among the hottest countries in the world [1]. It experiences extremely elevated temperatures during summer, frequent dust storms, short mild winters, intense sunlight, low humidity, and dry conditions. The daily maximum temperature averages 45 °C in July, but temperatures as high as 51 °C are common. Rainfall is light averaging 110 mm annually, occurring between November and April. The average evaporation rate fluctuates between 21 $mm \cdot d^{-1}$ in July and 3 $mm \cdot d^{-1}$ in January. The prevailing winds blow from the north-west and the south-east directions. The surface of Kuwait is a level to undulating desert plains, occasionally interrupted by low hills, scraps and wadis. The landscape is controlled by the presence of duricrust (locally known as "gatch"), or hard layers formed at the surface [2].

Soil and water are the most essential resources for successful agricultural development. Extensive fertile soil coupled with quality water supplies encourages efficient agricultural production with minimal effort. However, because of its geography and climate constraints, Kuwait lacks an abundance of these resources. Fresh water is primarily sourced from desalination plants and mostly consumed for domestic needs. Of the total groundwater withdrawn annually, 54% (114 million m^3 per year) [3] is allocated for agricultural use. Groundwater is typically high in salinity and usually desalinated by Reverse Osmosis (RO) units in local farms to produce fresh water for irrigation purposes. Additionally, recycling municipal wastewater has proven effective for greenery landscaping, afforestation projects, and irrigated forage production farms.

Since the discovery of oil in the 1940s, land-use has become much more intensive with the increase of population reaching more than 4.2 million people in 2022 [4]. The increased demand for food was met through imports, which constituted about 45% of the GDP in 2019 [4], and it is deemed necessary to adopt a policy of increasing self-sufficiency in at least some food requirements.

In response to these challenges, the Public Authority for Agriculture and Fish Resources (PAAFR) operates as the sole official entity in the State of Kuwait responsible for agricultural development. The Kuwait Farmers Federation (KFF) serves as the vital link between PAAFR and the Kuwait's farmers. It was established in 1974 to foster dialogue and operations between farmers and agricultural support services. An Agricultural Master Plan (1995–2015) was developed [5] to guide the development of sustainable agriculture. In 1999, the State of Kuwait conducted a soil survey project to provide essential information for delineating suitable arable land for irrigated agriculture and to allocate agricultural zones based on soil characteristics [2]. Aligned with Kuwait's Vision 2035, efforts are underway to develop agricultural production, thus contributing to food security and sustainable development goals (SDGs). However, an assessment of the current status of the agricultural sector is necessary for monitoring progress towards achieving Kuwait's Vision 2035, considering influential factors such as economic constraints, climate change and food security.

This overview presents a case study on agricultural development in the arid lands of Kuwait. It provides information on agricultural progress over time, the implications of climate change on productivity as well as presenting some solutions to environmental challenges and food security. Moreover, recommendations are presented to promote agricultural technology with sustainable alternative energy sources to enhance agricultural production while reducing demand on land, water and energy. The insights offered could be used for future planning to improve agricultural production in time. Other agricultural areas in similar arid areas such as Qatar, Bahrain and United Arab Emirates (UAE) may ben-

efit from adopting similar recommendations presented in this overview.

2. Material and Methods

Information on arable land use in Kuwait was compiled from the soil survey conducted by the Kuwait Institute for Scientific Research (KISR) in the year 1999 for the State of Kuwait[2]. The survey classified the types of soils and their potential for irrigated agriculture. The study was conducted in two scales: a reconnaissance survey (1:100,000) and a semi detailed scale (1:25,000) for 200,000 ha selected based on the reconnaissance survey. Available digital maps were used, which were developed for identifying soil types and their distribution by using Geographic Information System (GIS) technology, following USDA soil guidelines and classifications according to the Keys to Soil Taxonomy, 1994[6].

Maps on land-use, which were developed at scale 1:100,000[2, 7] showing land-uses categories were also used in the area assessment. The soil survey data on land-use at this scale divides the country into 9 map units[7]. Only three map units are presented in this manuscript including northern, southern and central areas of Kuwait, in which agricultural areas are shown.

To assess land use changes in agricultural areas over decades, recent satellite imageries were developed using Google Earth maps attributed to Landsat/Copernicus, Data SIO, NOAA, U.S. Navy, NGA, GEBCO, Airbus, and CNES/Airbus. The selected imagery, dated 1/1/2021[8], was used to develop polygons for estimating area sizes. These images were then compared to the soil land-use maps reported in 1999. A ground truthing was conducted in January 2024 to designate the agricultural farm locations in the north, central and south of Kuwait.

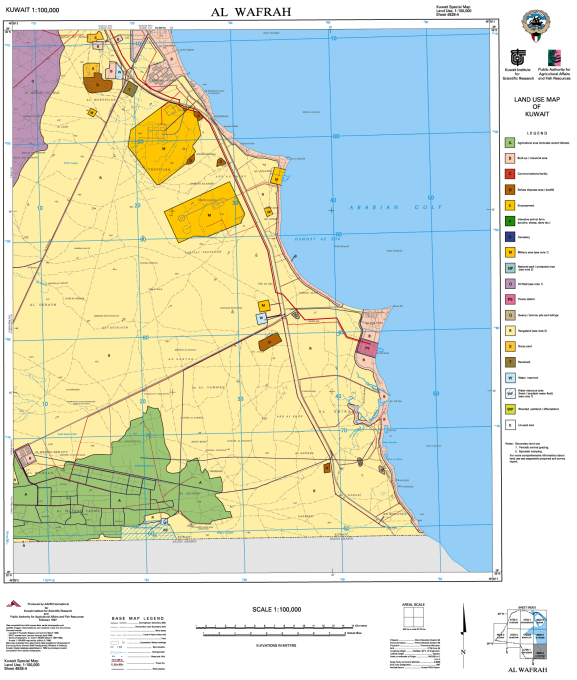
Data on number of holdings was obtained from PAAFR[9] and Kuwait Annual Agriculture Statistics of Central Statistical Bureau, and the State of Kuwait, for the year 2019[10]. The latest information provided in this report is from 2018/2019. More recent information was gathered from different electronic databases, such as the World Bank Databank and the FAO Database[11]. Additionally, in-depth literature search was conducted on electronic databases such as Scopus, Science Direct, Sciamgo Journal & Country Rank (SJR), and NSTIC Portal e-library at KISR. The literature search focused on arid lands, regional gulf countries such as Saudi Arabia and the the United Arab Emirates, and the impact of climate change on agriculture and food security. Articles were selected without time constraints, and relevant reports were identified and reviewed to extract pertinent information for this study.

During the preparation of this work the author used Microsoft Word Editor to improve and edit the manuscript. After using this tool/ service, the author reviewed and refined the content as needed and takes full responsibility for the content of the publication.

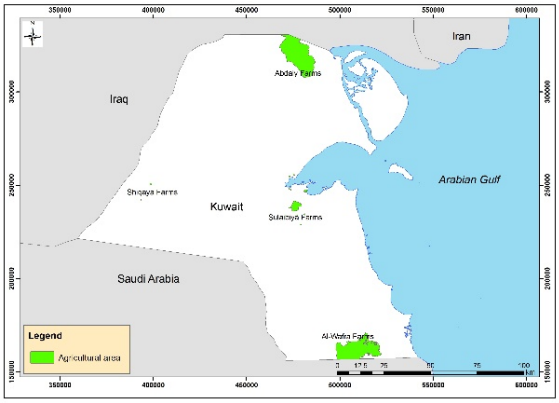
3. Results

3.1. Position of the Arable Lands

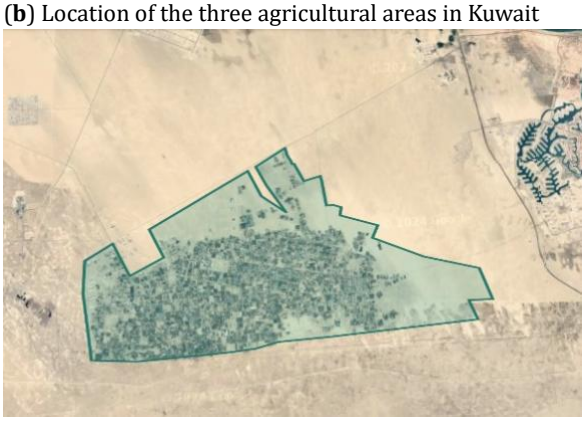
Land-use mapping of the state of Kuwait was compiled at a scale of 1:100,000. The percentage area of agricultural areas was estimated at 46,061 ha (2.70% of the total area)[2, 7, 12]. Three main areas are categorized as agricultural areas. These areas include Al-Wafra (**Figure 1**), Al-Abdali (**Figure 2**), and in the center of Kuwait at Al-Sulaybia and Kabd (**Figure 3**)[2, 8, 12]. These areas include open fields and greenhouse cultivation, tree plantations, nurseries, and large uncultivated areas. Google Earth Engine 2021 indicated an expansion of the three areas from 1999, totaling 63,607 ha in 2024 (3.57% of the total country area) (**Table 1**). Data analysis showed a strong correlation between 1999 and 2021 data as shown in (**Figure 4**), with an R^2 value = 0.8853, indicating that Google Earth can be a reliable tool for future assessment and that all areas have increased in size with a total of 38% over this period.



(**a**) Al-Wafra area in the south of Kuwait [2].



(**b**) Location of the three agricultural areas in Kuwait



(**c**) Al-Wafra area boundaries (Map data Google © 2021 [8]. Landsat/Copernicus, Data SIO, NOAA, U.S. Navy, NGA, GEBCO; Airbus, CNES/Airbus.

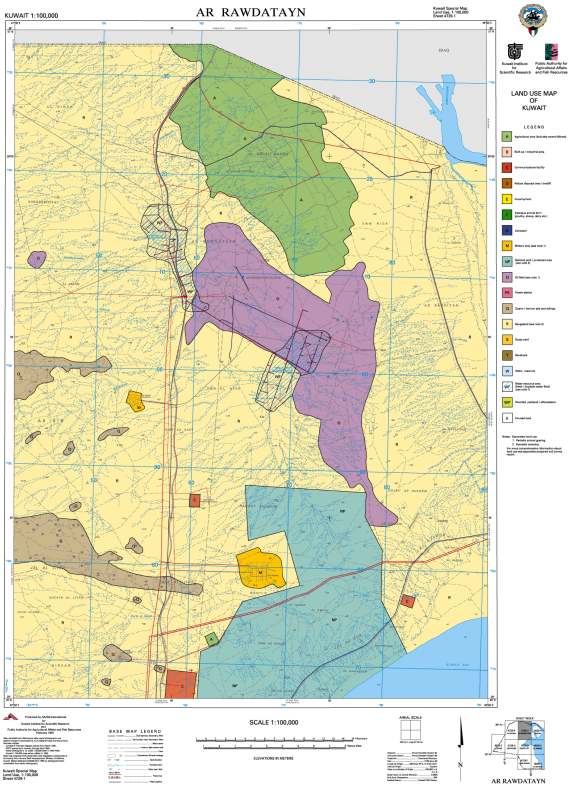
Figure 1. Land-use map showing Al-Sulaibiya and Kabd agricultural area in the southwest of Kuwait City in 1999 highlighted in light green in the left map [2], and in 2021 (Map data Google © 2021 [8]) in the right map.

Table 1. Agricultural areas in Kuwait in 1999 [2] and 2021 [8] in ha.

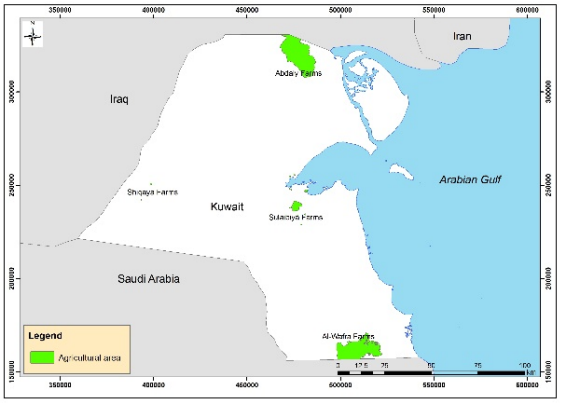
Agricultural Area	1999	2021	% Change
Al-Wafra	16,397	27,825	69.7
Al-Abdalli	24,719	30,090	21.7
Al-Sulaibiya & Kabd	4,945	5,692	15.1
Total	46,061	63,607	38.0

3.2. Agricultural Holdings

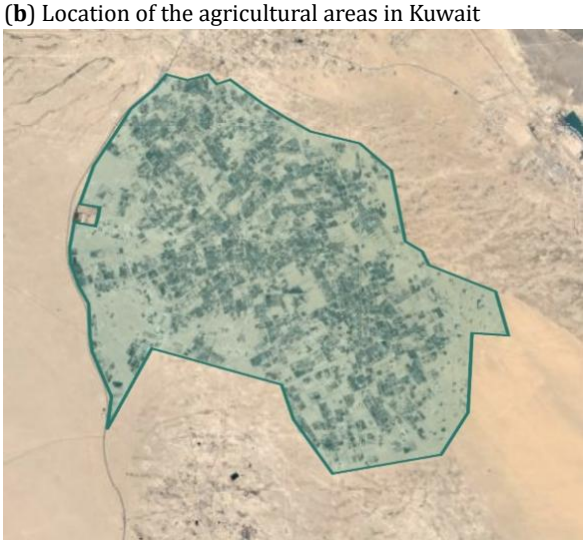
There is a significant increase (300.4%) in the number of holdings between FY 2016/17 and 2017/18 in the three agricultural areas Al-Wafra, Al-Abdali and Al-Sulaibiya as shown in **Table 2**. Assessment of each area from the available data [9] shows that Al-Wafra area hosts the largest number of holdings specialized in crops and vegetable production. In Al-Abdali area, there is a diverse range of activities, including crop cultivation, vegetable farming, and livestock production (cattle and poultry). Al-Sulaibiya agricultural area has a smaller number of holdings (1,839 holdings in 2017/18) that are specialized in all the above-mentioned types of productions in addition to sheep and goats. The number of holdings in Al-Sulaibiya increased rapidly in 2017/18 specializing both in forage production and livestock. The Kabd area has the largest specialized number of holdings in sheep and goats' production (3,005 holdings in 2017/18) [9]. The number of holdings that increased significantly in 2017/18 are those that produce forage, crops, and vegetables in Al-Sulaibiya, AL-Wafra and Abdali. There is a poor correlation between the two fiscal years, with R^2 = 0.0977 (**Figure 5**). The comparison shows that all areas have increased in the number of holdings, except for the Kabd area where it showed a decline of 13.1%. These figures, however, require updating to accurately reflect the current expansion in agricultural areas.



(**a**) Al-Abdali area in the north of Kuwait [2].



(**b**) Location of the agricultural areas in Kuwait



(**c**) Al-Abdali area boundaries (Map data Google © 2021 [8]. Landsat/Copernicus, Data SIO, NOAA, U.S. Navy, NGA, GEBCO; Airbus, CNES/Airbus.

Figure 2. Land-use map showing the Al-Abdali area in the north of Kuwait in 1999 (highlighted in green in the left map) [2], and in 2021 (Map data Google © 2021 [8]) in the lower right map.

Table 2. Number of holdings in agricultural areas in Kuwait [10].

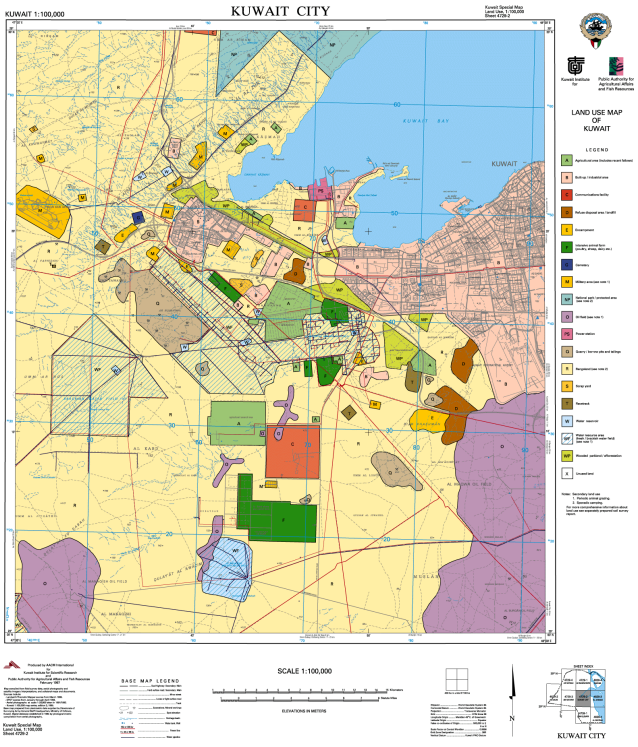
Agricultural Area	2016/17	2017/18	% Change
Al-Wafra	1,904	14,366	654.5
Al-Abdalli	1,950	12,037	517.2
Al-Sulaibiya	101	1,839	1,721
Kabd	3,460	3,005	−13.1
Others	618	918	48.5
Total	8,033	32,165	300.4

4. Discussion

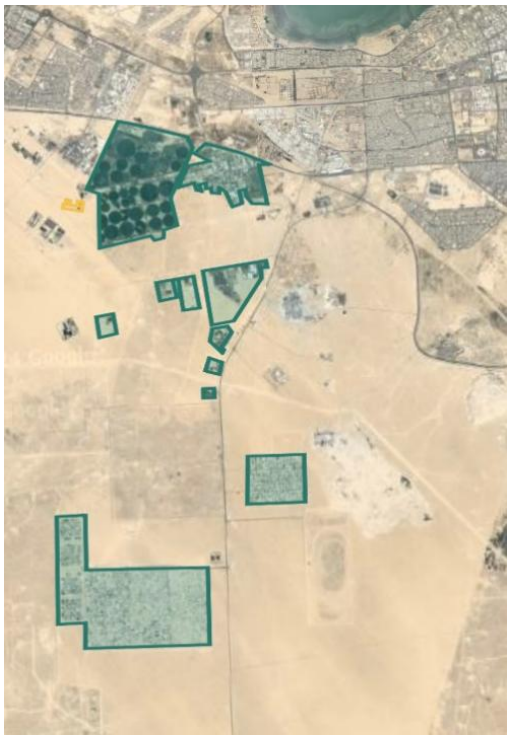
4.1. Developed Agricultural Areas

The land-use maps in **Figures 1–3** show the primary agricultural areas in Kuwait (Al-Wafra, Al-Abdali, Al-Sulaibiya and Kabd). The maps are presented in 1999 and 22 years later, in 2021. The areas were estimated for each agricultural area and presented in **Table 1** and **Figure 6**. Although Al-Abdali area was the largest agricultural area in both years however, Al-Wafra area showed the highest expansion over time (69.6%). This could be attributed to its location being at the border with the Kingdom of Saudi Arabia and its soil type which is mostly Torripsamment with good drainage [13, 14]. Overall, the total expansion of the agricultural areas in Kuwait was estimated at 38%, which covered about 3% of the total land area of Kuwait. **Figure 6** shows the changes in area size for each agricultural area between the two years. These changes in agricultural areas were also reported in the years 2000, 2013 and 2022 by using Normalized Difference Vegetation Index (NDVI) to delineate actual cultivated areas and exclude non-cultivated lands within

the agricultural areas[15]. This study showed a significant increase in the cultivated areas from 5.2 km^2 (520 ha) to 72.2 km^2 in Al-Abdali and 4.5 km^2 (7,220 ha) to 74.5 km^2 (7,450 ha) in Al-Wafra, an increase to almost similar extent in both farming areas[15]. In 1999, the total actual cultivated land with crops and vegetables, both in open fields and greenhouses, was 65.827 km^2 (6,582.7 ha)[9], which is about 14.29 % of the total areas suitable for irrigated agriculture as shown in **Table 1** for the same year. It is worth noting that the annual agricultural services and support offered by the Government of Kuwait such as training, utilities, pesticides, and livestock vaccination are the same across all areas. However, the areas in the center of Kuwait are more specialized in livestock production and irrigated forage production owned by the private sector.



(**a**) Al-Sulaiybia and Kabd agricultural area in the southwest of Kuwait City[2].



(**b**) Boundaries of agricultural areas in Al-Sulaibya and Kabd areas. (Map data Google © 2021[8]. Landsat/ Copernicus, Data SIO, NOAA, U.S. Navy, NGA, GEBCO; Airbus, CNES/Airbus.

Figure 3. Land-use map showing Al-Sulaibiya and Kabd agricultural area in the southwest of Kuwait City in 1999 highlighted in light green in the left map[2], and in 2021 (Map data Google © 2021[8]) in the right map.

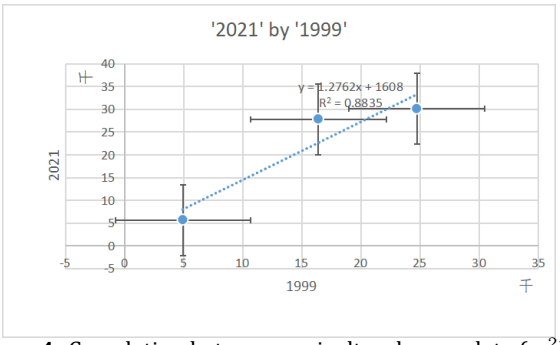


Figure 4. Correlation between agricultural areas data (m^2) in Kuwait in 1999 and 2021.

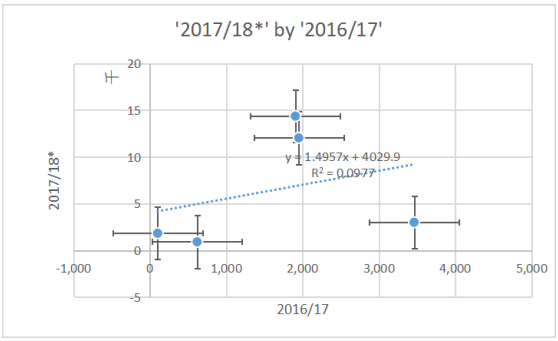


Figure 5. Correlation in the number of holdings between 2016/17 and 2017/18 in four agricultural areas.

PAAFR is the responsible authority for agricultural land leasing and designation. The farms are different in sizes between 5 ha to 150 ha. Most of the recently established farms are purchased from the previous owners, who would most of the time divide the farm into smaller areas (5–10 ha) and sell them to other users. The price is high, averaging between 12–15 USD per m^2. The outcome of this assessment contradicts the findings of Kaitharah [16], who reported that arable land in Kuwait is declining at a rate of 1% per annum. However, it is necessary to estimate areas that are active in producing crops. Farms are increasingly diversifying their use, dedicating portions to ornamental plant production, and public recreation. However, data on this action is currently unavailable and needs further investigation by the concerned authorities.

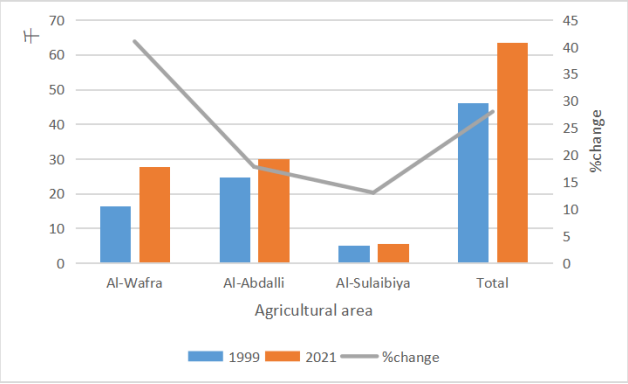


Figure 6. Percentage increase in Agricultural areas in Kuwait in two years (1999) and (2021) [2, 8].

4.2. Agricultural Holdings

The number of farm holdings in Kuwait is presented in **Table 2** and **Figure 7**. In 2016/17, the Kabd area showed the highest number of holdings; however, they were utilized as paddocks for livestock production. In 2017/18, a drastic change in number of holdings was reported by PAAFR [10], which could be attributed to subdivision of larger size holdings (150 ha) into smaller ones and selling them to other users or it could be due to improvements in PAAFR census procedures and information technology. The difference in the number of holdings is significantly larger in fiscal year 2017/18 showing a rapid development with a total of 300.4% increase. While Al-Sulaibiya, Al-Wafra and Al-Abdali areas showed a significant increase in the number of holdings. These holdings are specialized in crop and vegetable production (85% of the total types of productions) however, Al-Sulaibiya showed an increased percentage of holdings focused on sheep and goat' production amounting to 11% of the total. Poultry and cattle production each accounted for 2%. Conversely, a decline in the number of holdings up to 13.1% was observed in the Kabd area, attributed to control of land use for urban and industrial developments.

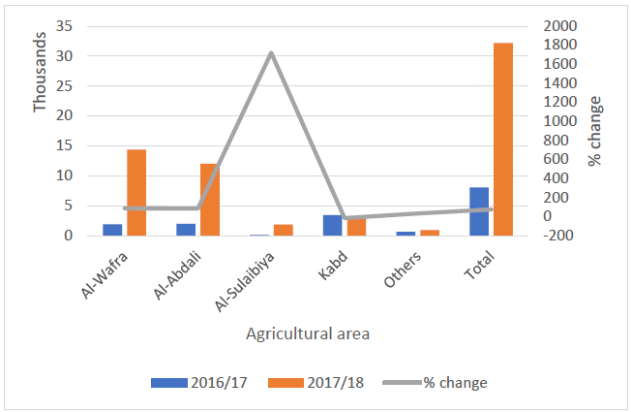


Figure 7. Percentage of change in the number of holdings in two fiscal years [10].

4.3. Economic Overview

To encourage production of commodities under harsh climatic conditions, necessitating the establishment of protected agricultural facilities, electrical power sources, roads, machinery, labor, irrigation systems, water desalination units, fertilizer, pesticides, as well as advanced technologies such as smart and vertical farming, the government of Kuwait represented by PAAFR provides generous annual subsidies to producers. Subsidies expenditures pertain to fruitful palms, fisheries, plant production, milk and cows. Other governmental subsidies pertain to energy, water, construction services, pest control, research, roads, veterinary and laboratory services etc. [17]. The expenditure on subsidies has been continuous over the years, however, it fluctuated annually as shown in **Table 3**. In 2019/20, the total subsidy expenditure amounted to about KD 26 million [9]. The expenditure on fodders was the highest among all subsidies covering on average 42% of the total average subsidies (about KD 10 million). Jabsheh, Behbehani and Abdulmalek [17] recommended restructuring

agricultural subsidies in Kuwait to address several challenges, such as, specifing target products, benchmarking resources based on productivity for each commodity produced, using indirect subsidies as primary target to increase productivity, introducing modern farming techniques and technology for the agricultural sector, and eliminating subsidies on products where the subsidy exceeds 50% of production cost. Abdullah, Zhang and Matsubae [18] noted that support from the government could promote planting schemes that target varieties of produce necessary to address the country's critical self-sufficiency deficit, while expanding research into optimizing cultivars through indoor and vertical farming applications.

Changes in plant production in Tons for the years 2015–2019 are shown in **Figure 8** for diverse types of crops. Production of cropped area (shown as fodder in **Figure 8**) includes pulses, cereals and green fodder such as Alfalfa. Vegetables are increasing every year, such as tomato, cucumber, eggplant, pepper, pumpkin, okra and strawberries, most of which are produced in protected environments.

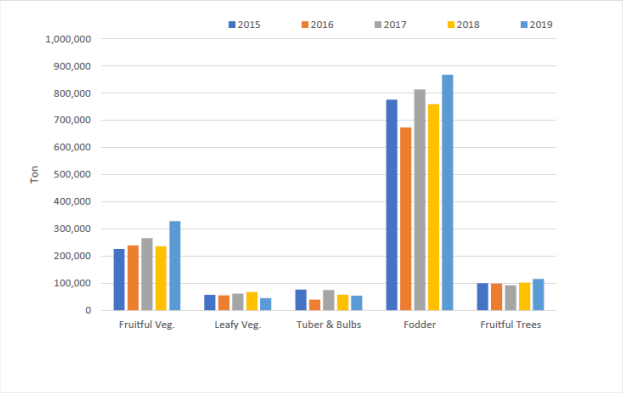


Figure 8. Five-years crop production in Kuwait (Tons) [10].

The self-sufficiency percentage of green fodder showed values that exceeded 90% in both 2015 and 2016 (**Figure 9**); whereas eggs exceeded 100% self-sufficiency percentage. In 2019, red meat was 21%, poultry meat reached 31% and cow's milk amounted to 20% [9, 11]. The self-sufficiency rates for fresh fish and shrimp were 7% and 10% respectively. Local companies are also engaged in the production of eggs and poultry meat such as Naief, and KUPCO.

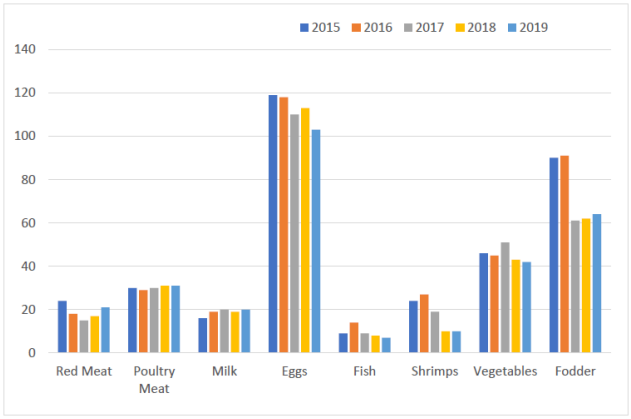


Figure 9. Development of self-sufficiency percent of main agricultural production in Kuwait (2015–2019) [9].

The agricultural sector's contribution to GDP is less than 1% [4], and for almost a decade it never exceeded 0.6% of the GDP. The trend, however, is slightly increasing over time (**Figure 10**). This humble contribution of the agricultural sector to the GDP percentage is due to the harsh climatic conditions, limited resources for agricultural production, and other constraints relating to fluctuation in the market prices for food and oil. Despite these challenges, the country remains committed to providing subsidies to local producers to promote agricultural production.

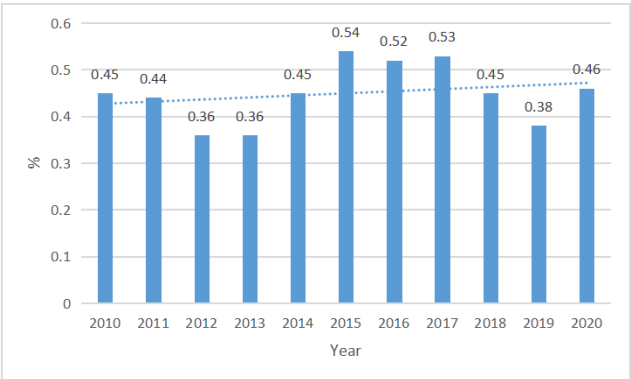


Figure 10. Agriculture contribution to the Gross Domestic Production (GDP) (% of GDP in a decade (2010–2020) [4].

4.4. Food Security

Food security means access to enough food by all people always for an active and healthy life and becoming more effective for economic development. The World Bank and FAO estimated that about 800 million people in the developing world lack access to the necessary food for such a life. Making food security the highest

Table 3. Total government subsidies for the period 2017/18 and 2019/20 (in KD) [9].

Subsidy Type	2017/18		2019/20		Average	
	Amount (KD)	%	Amount (KD)	%	Amount (KD)	%
Plant production	7,189,471	28	8,826,784	34	8,008,128	31%
Fodders	11,718,303	46	9,899,854	38	10,809,079	42%
Fisheries	499,868	2	499,851	2	499,860	2%
Milk and cows	4,200,000	17	5,137,138	20	4,668,569	18%
Palm trees	1,127,304	4	882,276	3	1,004,790	4%
Other	704,922	3	804,099	3	754,511	3%
Total	25,439,868	100	26,050,002	100	25,744,935	100%

political priority is a prerequisite for hunger eradication and mitigating environmental degradation. Food security for developing countries could be improved by increased investment and policy reforms [19, 20]. However, it should be noted that local agricultural production encouraged by self-sufficiency policy in developing countries, for example in the Middle East and North Africa, has been analyzed by Larson (2013) [21], and the findings suggest that trade-based food security policies have no significant effect on the sustainability of water resources, while the costs of policies based on self-sufficiency for water resources are high. Therefore, food security strategies in developing countries should consider alternative approaches beyond self-sufficiency.

By creating an enabling environment for improving food security and nutrition involves sustainable agricultural practices, adequate investments, better policies, legal frameworks, stakeholder participation and institutional reforms to promote and sustain progress. Policy makers and governments are developing strategic investment plans for food security in some developing countries [22, 23].

Some key threats relating to food security in Kuwait include disruption to global supplies through climatic events in producing regions; natural disaster or geopolitical instability disrupting supply chains; uncertain impact of climate change on global food supplies; price volatility in global markets and the development of nutrition-related diseases within the population.

In 2022, Kuwait was ranked 65.2 [24] on the Global Food Security Environment Index, where a score of 100 represents the best conditions [24]. The scoring includes four categories: affordability, availability, quality and safety, as well as sustainability. Kuwait scored the lowest among the GCC States, except in the availability Index, where it scored 62.9 [24].

In addressing food security issues, the Kuwait Ministry of Commerce and Industry issued several recommendations to develop an integrated strategy for food and water security. These recommendations are highlighted as follows [22]: investment in and ownership of agricultural land in countries of fertile regions; diversification of import sources; achievements of self-sufficiency and integrated agricultural economic cycle; management of water resources system; increase financial support for food security companies; control food prices; cooperation with international expertise, and development of integrated national strategy for food and water.

4.5. Climate Change

Climate change has severe impacts on agricultural development and food security, particularly in arid lands like Kuwait [25]. At local production level, it impacts irrigation water availability, sand movement and groundwater quality and quantity. With the increase of temperature, outdoor field plantation becomes increasingly challenging, especially during the late spring and summer months. Demand for irrigation water to irrigate crops intensifies, further affecting groundwater quality and quantity. Kuwait is addressing climate change in response to these threats. It has enacted regulations to reduce greenhouse gas emissions and promote the use of alternative energy sources. Reducing carbon emissions can help to slow the rate of climate change. Application of solar energy and wind energy technologies have been successfully demonstrated in Al-Shegaya area, southwest of Kuwait. The project demonstrated three technologies: Photovoltaics (PV), Concentrating Solar

Power (CSP) and Wind Energy. The Al-Shegaya project, currently producing 70 MW of power, serves the Ministry of Electricity and Water and Renewable Energy. A similar project could be developed in the agricultural areas to provide electricity support to advanced agricultural systems such as vertical farms that require consistent energy supply year-round. For example, it can provide 180 w per m^2 in vertical farm using LED lamps to grow lettuce (about 78 kwh per month) or 342 w per m^2 for growing strawberries (125 kwh per month). Installing solar panels on the roof of vertical farms or on the ground will allow renewable energy to partially power operations. The Ministry of Electricity and Water and Renewable Energy may also consider developing a pilot plant for solar power supply to produce 10–20 MW in each agricultural area to supply them with energy and reduce demand on electicity.

Climate change will impact sand mobility in areas along the sand strip from north to south, especially Al-Wafra, Al-Sulaibiya and Kabd areas. These areas are vulnerable to sand encroachments and every summer sand accumulates along roads, farms and buildings [26]. Road maintenance is expensive, but sand is used for leveling farms and industrial development. While wind breakers and afforestation projects have been initiated in many parts of the country, due to uncontrolled grazing, much of the land has been eroded and became more severe to wind erosion. Solutions such as erecting compound fences, using palm reed fences, growing rows of trees [27], spraying sand fixative material, mulching, using green mats, or applying diluted phosphoric acid can help mitigate sand mobility [28]. To reduce the impact of grazing a recent study on forage production utilizing native vegetation in Kuwait showed that native grass species provide dry matter under drought conditions and are suited for a complementary role with other forages in full season forage systems in Kuwait. The study recommends that farmers may integrate native forages in the dry matter cropping for flexibility and diversity in their farming systems [29].

With the increase in temperature and evapotranspiration, soil salinity will increase at the soil surface, which limits crop production in the open fields. Moreover, using brackish/saline water with varying salinity levels in farms exacerbates the problem, leading to sever soil degradation [30–33].

4.6. Future Perspective

Kuwait's GDP was 43,233.5 USD per capita in 2022. The contribution of agriculture is minor to the GDP (0.6%). Since oil is still the dominant sector, the prospect of significantly increasing this share does not look promising. The agriculture sector in Kuwait headed by PAAFR is supported by the government to encourage local production. Despite government support for local production, significant growth in agriculture seems unlikely. However, considering the expected increase in population size and the corresponding rise in food demand, it is recommended to make a strategic shift in the agricultural system to be able to address several challenges relating to climate change impact, rising food demand, energy and water needs, land reclamation, species tolerance to extreme weather conditions, import prices, and restructuring subsidies. The trend in the future contribution of agriculture to the GDP per capita is low and the government of Kuwait needs to restructure the agricultural sector to increase its contribution efficiently and sustainably to the GDP. One alternative solution is the adoption of sustainable vertical farming systems and the use of recycled wastewater for irrigating agricultural crops and landscaping [15]. For Kuwait, to achieve 100% self-sufficiency scenario in key crops like tomato, potato, green pepper, carrot, lettuce, and cabbage requires significant expansion of the total area for open field by 43 km^2, protected field 31 km^2, indoor farm 15 km^2 and vertical farm 0.089 km^2 [18]. The study concluded that expanding open field cultivation to accommodate increase in self-sufficiency is not a viable option. With a small area of arable land in Kuwait for vegetable crops (121 km^2) it is not recommended to expand open field agriculture by 159% to reach the target of 100% self-sufficiency for these crops [18]. Moreover, the study concluded that Controlled Environment Agriculture (CEA) systems utilized in indoor and vertical farming have crucial benefit of employing soilless culture, thus bypassing the need for occupying Kuwait's scarce arable land [18]. Soil management practices including smart agriculture, regenerated practices, and adapta-

tion to climate change impacts in the context of Kuwait's conditions are also recommended for open field farming [15, 16].

Kuwait collaborates with other Gulf Cooperation Council (GCC) countries to promote sustainable food security practices. In 1999, the trade exchange size in agricultural and livestock products between Kuwait and GCC countries exceeded KD 259 thousand, with Saudi Arabia contributing 59%, the UAE 31%, Bahrain 3.2%, Qatar 6.3%, and Oman 0.9%. There is a potential for enhancing the trade exchange size with the increase in agricultural productivity over time. To better address future challenges, Kuwait needs to conduct research on climate change impacts on agriculture, the water-energy-food nexus as well as in-depth studies on latest applications and technologies used in agriculture that commensurate with the natural conditions in the GCC States [15]. It is also necessary to conduct analysis of the feasibility of current policies related to food considering climatic changes and fluctuations in oil prices. Transitioning towards a green economy and supporting investment in the low-risk agriculture sectors in developing countries with ample agricultural lands are potential strategies for supporting food supply in the long-term. Coordination, research, and strategic policy adjustments are crucial for Kuwait to effectively navigate future food security challenges.

5. Conclusions

The land-use maps developed in this study by using Google Earth revealed a significant expansion of agricultural designated areas in the north, south and central parts of Kuwait. The number of holdings has notably increased allowing the public to establish new farms with generous support from the government. However, more data is needed to assess the actual number of farms that are active in agricultural production. Currently, the only available data sources are those provided by PAAFR [9] and the Central Statistical Bureau [10]. This data needs updating and thorough review by the concerned authorities.

The fluctuations in food and oil prices impact the annual subsidies and consequently agricultural production. However, the government is expected to continue subsidizing agricultural production with conditions relating to the amount of annual production. While egg self-sufficiency has exceeded 100%, other products remain below 50%, except for green fodder, which surpasses 80%. Achieving 100% self-sufficiency in vegetable production across all crops through expanded open field farming by designating more lands seems unlikely [18]. Although promotion of local food systems may not be economically feasible for local producers and some producers may profit more from international supplies [19], it may be more feasible for the government to optimize land productivity and promote more sustainable and advanced CEA systems for resilient agricultural production. The CEA system provides indoor-controlled conditions and efficient use of water and nutrients. These systems employ hydroponic or aeroponic irrigation with high water use efficiency. Several smart farms are established at small scales in Kuwait in collaboration with international companies, such as Pure Harvest, Green Life, and Keight. These farms have shown good potential for mass production of green leaves with high market value. Additionally, some local farmers successfully produced mushrooms in controlled environments with local experience [16]. Kuwait can benefit from these advanced farming systems by expanding their development at a larger scale.

Achieving food security requires strategic planning and regional collaboration, particularly in the face of climate change impacts [25], which affect irrigation water availability, sand movement, and groundwater quality and quantity as well as food products prices [25]. To reduce pressure on electric power provided with subsidy by the government, alternative solar energy systems are recommended to be established at a pilot-scale in each agricultural area with initial phase providing 10–20 MW for each area. Advanced CEA systems would offer viable solutions to agricultural constraints and climate change impacts. Further scientific research and innovation are essential to advance agricultural production, evaluate proven technologies and their cost effectiveness, and mitigate climate change's impact on food and agriculture. Additionally, analyzing the feasibility of current food-related policies, including subsidies, con-

sidering climatic changes and oil price fluctuations, is imperative. In this respect, specific research titles are suggested as follows:

- Energy requirements for large-scale advanced agricultural systems development
- Evaluation of the efficiency of solar energy units as alternative energy solutions for smart farming systems
- Economic assessment of sustainable farming system for local producers
- Water consumption in advanced technology agricultural systems
- Assessment of CO_2 emission from smart farming systems and potential mitigation solutions
- Exploring alternative solutions and incentives for food subsidies control and reduction
- Market value of local production versus international imported food
- Diversity in food commodities suitable for local production
- Encouragement of Small and Medium Enterprise (SME) agricultural producers to contribute to food security

Author Contributions

The author contributed to the conceptualization, literature review, data analysis and interpretation, writing, revising and responding to comments from reviewers and editors.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data Availability Statement

Data on agricultural holdings, self-sufficiently, crop production, and subsidies that support results and analysis in this article are cited for public availability including links to publicly archived datasets. Data on agricultural areas by soil survey are available from the corresponding author upon reasonable request and with permission from Kuwait Institute for Scientific Research (KISR). Agricultural area mapping by using Google Earth are publicly available following the link in the citation.

Acknowledgement

I would like to express my appreciation to Kuwait Institute for Scientific Research (KISR) for their publication approval, support and encouragement. I am also grateful to Sheikh Shreaz and Jose Kaitharah for reviewing and editing the manuscript before submission.

Conflict of Interest

The author has no conflict of interest to report.

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