Sustainable Agriculture Research; Vol. 13, No. 2; 2024
ISSN 1927-050X E-ISSN 1927-0518
Published by Canadian Center of Science and Education

# Assessing Sustainability Performance at Farm Level in the Kingdom of Bahrain

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Received: July 8, 2024 Accepted: August 12, 2024 Online Published: August 20, 2024

doi:10.5539/sar.v13n2p68 URL: https://doi.org/10.5539/sar.v13n2p68

**Abstract**

Crop production in Bahrain is facing many challenges that may undermine farm's sustainability. Farmers are an important player and assessing farm's sustainability to identify performance gaps is essential. This study aims to measures farm sustainability in Bahrain using Response-Inducing Sustainability Evaluation (RISE) tool accompanied by field visit observations. The assessment was carried out on 29 farms and applied on 8 themes. The study contributed by configuring RISE's regional data to match Bahrain's conditions through the adjustment of some evaluation functions. The application of RISE showed that the average score of the 29 farms was (63 points) which indicates the requirement of additional improvement. Farms fared well in five themes (quality of life, water use, working conditions, soil use, and farm management). Whereas it performed low in three themes (Material Use, Biodiversity & Economic viability). Quality of life theme received the highest score (76 points), while biodiversity was the lowest (34 points). RISE application was successful; however, land tenure needs to be considered to improve local sustainability. Despite the presence of lands that are classified as agriculture but unexploited, it is suggested to encourage landowners exploiting the lands or rent them out to other farmers. In addition, the development of good agricultural practises guidelines is vital.

**Keywords:** agriculture, farms, indicators, sustainability, sustainable agriculture

## 1. Introduction

Extensive food production associated with the substantial use of fertilizers, pesticides and water has caused a considerable environmental menace (Pretty et al., 2011; X. Wang, 2022). The impacts generated from agricultural production piqued the interest of researchers in the field of sustainability. The assessment of agricultural sustainability is a critical tool for fostering the idea of sustainable agricultural systems, as it incorporates the principles of sustainability into agricultural policy preparation and decision-making (Talukder & Blay-Palmer, 2017; Santiago-Brown et al., 2015; Zhang et al., 2022). A variety of evaluation tools, including Environmental Impact Assessment (EIA), Sustainability Standards with Principles, Criteria and Indicators (PC&I), Life Cycle Assessment (LCA) and Cost-Benefit Analysis (CBA) have been proposed over the years for the sustainability assessment of production systems. Many of these evaluations, though, relied primarily on the components of environmental sustainability (Werf & Petit, 2002) and a very little, however, concentrated on evaluating the three pillars of sustainability (environmental, economic and social) for individual farm-level (Bhushan & Rai, 2004; Marchand et al., 2014). Up to now, an increasing number of sustainability systems, indicator-based evaluation methodologies for the assessment of agricultural sustainability have been developed (Ali & Perna, 2021). In most cases, however, the use of current and well-established sustainability measurement approaches and tools such as Multi-Criteria Decision Analysis (MCDA), Sustainability Assessment of Food and Agriculture Systems (SAFA), the IDEA method (Indicateurs de Durabilité des Exploitations Agricoles), Monitoring Tool for Integrated Farm Sustainability (MOTIFS), a component- based framework for the European Union (SAEMETH) and the Response-Inducing Sustainability Evaluation model (RISE) necessitated a wide range of indicators, which increased the time required for data collection, planning, and analysis (Dantsis et al., 2010; Zulfiqar & Thapa, 2017). Response-Inducing Sustainability Evaluation tool (RISE) is an indicator-based system used to evaluate the agricultural performance at farm level holistically. It was created by the School of Agricultural, Forest, and Food Sciences (HAFL) at Bern University of Applied Sciences in Switzerland and was

used in many countries (Grenz et al., 2016). RISE has been reviewed and tested successfully on a variety of farms in different countries with different environmental and climatic conditions (Mutyasira et al., 2018; Alaoui et al., 2022; Coteur et al., 2020; Cruz et al., 2018b; de Olde, 2017; De Olde et al., 2016; Gaviglio et al., 2016; Grenz et al., 2009; Heredia-R et al., 2020; de Olde et al., 2016; Miller et al., 2020; Nouri et al., 2017; Talukder & Blay-Palmer, 2017; Urutyan & Thalmann, 2011).

The crop production in Bahrain is hampered by many challenges such as scarcity of local natural resources, as evidenced by water scarcity, lack of rainfall, high temperatures, soil and water salinities, scarcity of arable agricultural land, in addition to challenges concerning the transfer and adaptation of modern agricultural technologies, investment, policies and labour shortage in agriculture. Moreover, the production of grains and other agricultural goods in Bahrain is virtually non-existent, which is one factor that contributes to the country's high level of reliance on imported food to satisfy consumer demand. Domestic agricultural production is insufficient to meet the needs of a growing population, which necessitates the development of a food security strategy that addresses the four fundamental aspects of food security: the availability of food; its accessibility; its capacity to be utilized; and the stability of the food supply. There are challenges for local producers in the form of price competition with imported food supplies, and as a result, there are restricted prospects for marketing certain items. Additionally, while an agriculture master plan is critical, there is a shortage of relevant data and information, as well as times when data and information are outdated and thorough efforts are required to produce and maintain up-to-date agricultural statistics so that informed decisions can be made. The Information and eGovernment Authority platform is a tool that contains many data, but information on the agricultural sector is missing. A powerful information tool is the AgroBh platform which was launched in May, 2022 by the National Initiative for Agricultural Development (NIAD). Agricultural sector is considered one of the most significant industries in Bahrain. Understanding the concept of sustainability at farms is now indispensable and timely. The government aims for a sustainable, productive farming industry that implements clean and environmentally friendly practices to provide consumers with high-quality products. Therefore, it is important for farmers to cope with this objective and implement agricultural practices that guarantee sustainability without causing harm to the environment. The purpose of this research was to determine the state of the agricultural sustainability in Bahrain and to measure agricultural sustainability at farm-level using Response-Inducing Sustainability Evaluation (RISE).

### *1.1 The Bahrain Crop Production Sector*

According to the database of registered farms in the Ministry of Municipalities Affairs and Agriculture in 2020, only 355 of the 685 registered farms are currently engaged in the process of cultivating crops. However, only 47 farms (14%) are listed on AgroBH platform which indicates that those 47 farms are the most operating in the market or independent, the remaining 86% of active farms are either dependent farms or they sell directly to consumers or producing for personal use (AgroBH, 2022). The crop production in Bahrain combines traditional agriculture, protected agriculture, and hydroponic production. The main crops are dates and 61 different varieties of vegetables and fruits that are grown commercially, including 18 different kinds of leafy greens, 29 varieties of vegetables, and 14 varieties of fruits.

## 2. Method

Analyses were conducted to measure the agricultural sustainability at farm-level and calculate the average score for Bahrain. A list of 176 farms was obtained from Ministry of Municipalities affairs and Agriculture. A criterion was put forward to consider a farm to be suitable for this study, it included the following: the farm was operational, the farmer was selling the produced crops in the market, the farmer was willing to provide information and access to his farm, the farmer was willing to spend about 4 to 6 hours answering the questionnaire, the farmer was managing the day-to-day operations of the farm or was knowledgeable about all farming practices and activities. Other farms were excluded when the owner could not be reached after three attempts on various days, in addition to those who were contacted and refrained to participate. Following the criteria, only 29 farms were rendered suitable, with 19 of them having both crops and livestock.

### *2.1 Field Data Collection*

Primary data were also collected through in-person interviews and site visits to farms from the month of December 2021 to June 2022, which served as the basis for this research. The first step was to take a quick tour in the farm. This allowed to have an understanding of various aspects of farming, the surrounding environment, the irrigation system used and water storage, the storage and application of pesticides, and common practices of farming activities through direct observations. Following the tour, the interview with the farmer was conducted and polled with many questions built in RISE. In each farm, the interview took about 4 to 6 hours, depending on

farm size, farm activities, and farmer's knowledge. Additionally, experts from were consulted from the Ministry of Municipalities Affairs and Agriculture, the School of Agricultural, Forest, and Food Sciences (HAFL) at Bern University of Applied Sciences in Switzerland and other local agricultural experts. Research papers were viewed to understand Bahrain's context such as (Al-Zubari et al., 2018; Bani, 2020; Bannari et al., 2017; Elagib & Addin Abdu, 1997; Sattout, 2016), Google Earth (satellite images captured in 2022) was used to extract additional information related to farm land size, pesticides, agricultural inputs, ecological features, and derived precise information from official web databases.

*2.2 Regional Data (Indicator's Configuration)*

Due to the diversity of agricultural production conditions around the world, indicators must first be adjusted to the regional conditions. With the available information obtained, the present work contributed to the setting up of the regional data in RISE to match Bahrain's conditions. The regional adjustments were made to some of the RISE evaluation functions (reference values) to best fit the characteristics of the farms in Bahrain as shown in Table 1. The data was obtained from various sources such as local official websites, international official websites, New LocClim software, researched papers, and the assistance received from the School of Agricultural, Forest, and Food Sciences (HAFL) at Bern University of Applied Sciences in Switzerland. Some regional data could not be found, thus necessitating the utilization of the default values integrated within RISE 3.0.

Table 1. The regional adjustments made in RISE

| **Modified to Regional** | **Inputted Data** | **Source** |
|---|---|---|
| Mean Annual Temperature | 28.4 | Meteorological Directorate under Ministry of Transportation and Telecommunications in Bahrain |
| Moisture Index | -97 | New LocClim application developed by FAO and the Bern University of Applied Sciences in Switzerland |
| $ET_0$ | Average last 10 years | CropWat 8.0 application developed by FAO using Penman Monteith method for the calculation of ET0 and Bahrain official actual weather data |
| Number of working hours per week | 48 Hrs | Bahrain Labour Law - Article 51 |
| Maximum number of working hours per week | 60 Hrs | Bahrain labour law - Article 53 |
| Maximum number of working days per week | 6 Days | Bahrain labour law - Article 57 |
| High Crop Yields | Values differ depending on crops | Calculated using the Maximum yield data received from top crop producers in Bahrain |
| Low Crop Yields | Values differ depending on crops | Calculated using the Minimum yield data received from top crop producers in Bahrain |
| Regional Crop Yields | Values differ depending on crops | Calculated using the regional yield data received from top crop producers in Bahrain |
| Soil pH level | pH between 7.1 and 8.6 | (Bannari et al., 2017) |
| Climate Zone | Subtropical dry | FAO, 2012 https://www.fao.org/forestry/fra/80298/en/ |
| Humidity Zone | Dry (Potential evapotranspiration > rainfall) | FAO, 1989 https://www.fao.org/3/t0122e/t0122e00.htm#Contents |

## 3. Results and Discussion

A face-to-face interview and field visit was conducted for 29 farms in different areas of Bahrain during December 2021 to June 2022.

*3.1 RISE Score*

The average score for the 29 farms was successfully calculated using RISE. The score of each theme was

presented in the polygon illustrated in Figure 1. The theme of "Animal Husbandry" was excluded because it was irrelevant to the current assessment since the focus was on crop production. In addition, the "Energy & Climate" theme was not computed due to the inability to precisely determine the agricultural energy density for Bahrain. Such data must be entered in the regional section to be able to calculate this theme; and the failure to do so resulted in an error message that disabled the software from calculating the final score of such farm and therefore calculating the average score for Bahrain.

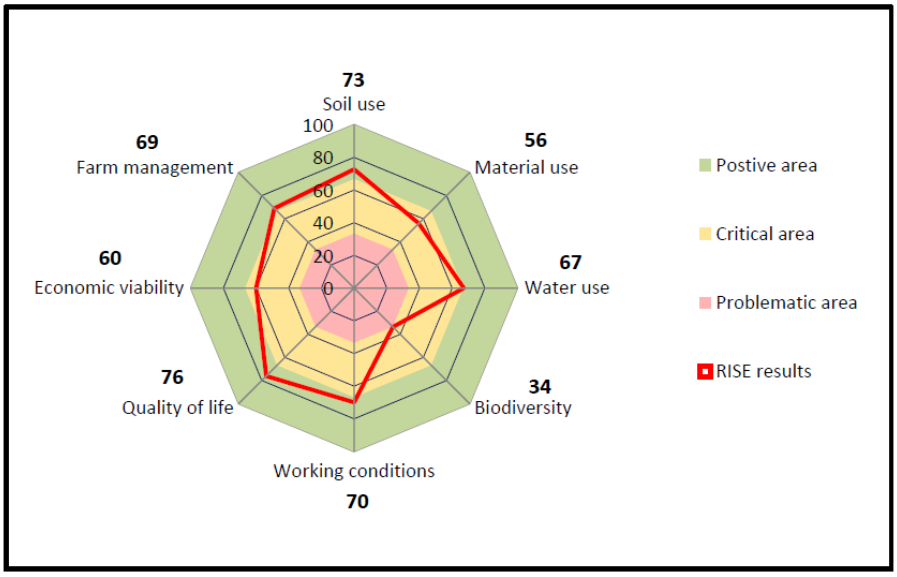


Figure 1. The average sustainable performance of 29 farms in Bahrain according to RISE

The above scores showed that farms achieved a good overall outcome with an average score of 63 points. Farms performed positively in five out of eight themes with values ≥ 67 (soil use, water use, working condition, quality of life and farm management). The values of the remaining three themes (material use, biodiversity and economic viability) were ≥ 34 which are considered critical. Farm management scored the highest (69 points) while biodiversity theme scored the least (34 points) among all themes. No theme of the analyzed 8 theme have fallen within the problematic area.

*3.2 Soil Use*

Soil is the main factor for plant growth process, as soil provides minerals and nutrients needed for plant growth. Sandy and clay soil were the predominant soil types as answered by farmers. The score for “soil use” theme and its six indicators were presented in Table 2. The overall results for this theme were positive (73 points), and the bulk of the indicators received good score. Only two indicators (soil management and soil reaction) received lower score and required more attention. The *soil erosion* received the highest score due to the absence of visible erosion on the farms. *Soil organic matter* received a score of 90 points, which indicates that the topsoil content was at least stable taking into consideration the crops grown and crops management. The *crop productivity* indicator compares the yields of all crops grown per hectare with the regional benchmarks for high and low yields. This indicator scored 79 points which indicates very high yield. *Soil compaction* refers to the potential for excessive compaction of the soil brought on by wheel load of tractors in conjunction with other implements during tillage, sowing and harvesting operations under adverse soil moisture conditions. Majority of farmers were not using heavy wheeled tractors and machines that were greater than 2.5 tons. The fact that this indicator received 77 points referred to slight soil compacting, but not to the extent that it should cause any concerns with seedlings establishment and roots development.

Table 2. The sustainability score for soil use theme in Bahrain

| Themes and indicators | Score |
|---|---|
| Soil use | 73 |
| • Soil management | 40 |
| • Crop productivity | 79 |
| • Soil organic matter | 90 |
| • Soil reaction | 51 |
| • Soil erosion | 100 |
| • Soil compaction | 77 |

The soil pH and the potential for salinization are also factors that are considered by the soil reaction indicator. The vast majority of farmers neither perform any kind of soil analysis during the time of their farming careers, nor did they take into account the exact quantity of fertilizers required. Consequently, there is increased concerns of soil salinity or soil infertility. This indicator received 51 points, with points deducted because the pH level was greater than 7 and the application of Urea or other physiologically acidic fertilizers was more than 100 kg/ha per year. For soil management, knowledge and technology are necessary. This indicator focused on farmer's assessment of the soil status through regular soil analysis, nutrient and soil organic matter balances, calculation of soil carbon content, and whether any agricultural land has been lost in the past 10 years. Unfortunately, farmers did not engage in such analytical processes. Bahrain's soil is typically shallow, with a coarse texture that varies from sand to loamy sand in the surface layer and loamy sand to sandy in the subsoil (Abahussain et al., 2014). Sandy soil needs to be fertilized more because the elements are lost faster due to the strength of drainage.

The pH level ranged between 7-8 (Ebrahim et al., 2016). A recent project conducted by Geographical Information Systems Directorate (GIS) under Information and eGovernment Authority (IGA) aimed to produce soil maps, conduct research and studies on the agricultural properties of the soil, and identify suitable agricultural areas. According to IGA's findings, sand is the most prevalent component in the Bahrain's soil, followed by gravel. Sandy soil dominates the coasts and lowlands, whereas gravel is found in mountains such as Sakhir and neighboring areas. Silt and mud pockets can be found across the Kingdom's central areas (IGA, 2022). Results of the present study showed that majority of farmers (n=23, 79.3%) brought agricultural soil to their farm sometime during the farms' life cycle. Seventeen of the interviewed farmers (58.6%) did tillage both by hands and machines, while ten of them (34.5%) used machines only and two farmers (6.9%) were still manually doing the tillage. In many countries, farmers are looking for inexpensive ways to enhance soil quality. Conservation tillage is becoming popular to many of them (Adkins, 2016). Moving towards no tillage saves energy, minimizes soil compaction, and therefore enhances soil fertility (Wezel et al., 2014). Conversely, a study by Behnke et al., (2018) found that corn and soybean yields both increased as a result of tillage. Moreover, tillage had no impact on total CO2 emissions. All of the interviewed farmers ploughed their fields once to twice a year. Tilling can be both beneficial and harmful, depending on how it is utilized and the conditions of a farm. The advantages of tilling include soil aeration, weed control, and pest management. Soil erosion, soil compaction, and soil disturbance are all disadvantages of tilling. It is essential to evaluate the advantages and disadvantages and consider alternative farming techniques, such as reduced tillage or no-tillage farming. The optimal frequency of tillage per year depends on the cultivated crops, soil type, and the weather conditions. To conserve soil moisture, limited tillage or no-tillage cultivation may be preferred in arid regions. Numerous methods can replace tillage such as conservation tillage, crop rotation, cover crops, and mulching.

Majority of the interviewed farmers (n=21, 72.4%) did not grow any legumes such as peas and beans to improve their soil fertility. Legumes roots have symbiotic relationships with nitrogen-fixing soil bacteria known as rhizobia. This symbiosis results in the formation of nodules on the plant root, within which the bacteria may convert nitrogen to ammonia that the plant can utilize (Wang et al., 2018). The cultivation of legumes has been shown in a large number of different studies to be an effective method for enhancing the physical characteristics of soil and preserving its fertility (Rubiales & Mikic, 2015; Stagnari et al., 2017; Zhao et al., 2022). The majority of farmers (n=21, 72.4%) grew trees and crops mixed together. When there are shortage of fertilizers and the soil fertility is low, mixed cropping can be useful (Beets, 2019). A study was conducted in Budaiya, Kingdom of Bahrain, to identify the presence of heavy metals and to examine the physicochemical characteristics of vegetable farm soil, and the outcomes were compared to the environmental standard composition of farm soil. Results revealed that heavy metal lead was present in vegetable farm soil, whereas cadmium was absent. Therefore, it is suggested that parallel studies be conducted using soil samples from various locations, monitoring the same parameters as those in the original study (Andeng, 2015). Farming methods that result in

excessive quantities of nitrogen in the soil can contribute to environmental issues.

*3.3 Material Use & Environmental Protection*

In this section, farmers were asked several questions to understand their practices in terms of fertilizers application, usage of harvest residues and the utilizing of on-farm variety resources to reduce reliance on external inputs in the agricultural systems. This theme scored (56 points) which is considered critical as shown in Table 3. The lowest score was for fertilization indicator (24 points) and the highest for air pollution (78 points).

*Material flows* indicator refers to whether farmers give priority to producing fertilizers on the farm or at least from local sources; whether equipment and materials used were sustainable; and whether farmers made an effort to reduce materials used through recycling. Most farmers either used agricultural wastes to produce fertilizers or purchased them from regional suppliers. Small farmers found to practice recycling, and an even smaller number made environmentally conscious choices, such as switching to solar-power lights or irrigate from air condition water. *Fertilization* scored the lowest (24 points) due to the following reasons: farmers never analyzed the amount of (N) or (P) in the soil, fertilization management was done based on gut feeling or old practice inherited from father. No planning or need based fertilization assessment was practiced to decide the appropriate time and quantity prior to applying fertilizers. The majority of farmers were observed combining fertiliser with water for the purpose of fertilisation through irrigation (fertigation). Additionally, it has been observed that majority of farmers applied urea as a fertiliser.

The implementation and dissemination of appropriate agricultural practises are vital, and this responsibility falls within the role of extension services under the Ministry of Municipalities Affairs & Agriculture. *Plant protection (PP)* indicator assessed the management of PP and ensured that it was in line with the principles of integrated plant protection. This indicator scored (63 points) which indicated that most farmers (n=21, 72.4%) were selecting crop varieties that are resistance to pests and tolerance to diseases, (51%) of farmers identified species before applying the protection treatments, and (65.5%) did use or preferred to use biological and mechanical rather than chemical treatments. *Air pollution* addressed the storage, use, and disposal of items without releasing gaseous emissions to the limit that affect the environment or humans. This indicator scored positive (78 points) which indicated no major pollution incidents and no risks occurring. No actual soil and water pollution were reported by farmers such as effluent, spillages from fertilizers stores or feed. *Soil and water pollution* addressed the storage, use, and disposal of items without causing liquid or solid emissions to the limit that threatened the environment or humans. This indicator scored positive (73 points) as there were no slurry storage on farms, no spreading sludge practices were found.

Table 3. The sustainability score for material use & Environmental Protection theme

| Themes and indicators | Score |
|---|---|
| **Material use & Environmental Protection** | **56** |
| **• Material flows** | 42 |
| **• Fertilization** | 24 |
| **• Plant protection** | 63 |
| **• Air pollution** | 78 |
| **• Soil and water pollution** | 73 |

Considering the sustainability, nitrogen (N) and phosphorus (P) are of particular importance. Both of these chemical elements are commonly associated with increased yields (agricultural productivity). Local research and extension services in each country typically provide actionable recommendations and guidance on nutrient management for different crops, and to better understand the desirable amount of nutrient application per hectare. The FAO nutrient management guidelines were referred to as a reference, since there are no such guidelines issued locally. Before farmers persuade to purchase mineral or organic fertilizer, they must first understand the impact of such inputs on crop yield in both ecological and economical aspects. Once they have decided to utilize fertilizers, they must make the difficult decision of which fertilizer to be used and how much to apply. Abu Dhabi Agriculture and Food Safety Authority (ADAFSA) issued Practice Guide No. (11)/2011 regarding the use of fertilizers, which aims to explain the ways and means that contributed to improving agricultural production methods and raising its efficiency in fertilization and plant nutrition while ensuring the application of best sound practices (ADAFSA, 2011). In Bahrain, there is no such clear guidelines that would make it easier for farmers, engineers, and agricultural extension workers to use as guidance during implementation. Given that soil is the basis of nearly all types of agricultural production, effective soil management is essential to the practice of sustainable agriculture. This required knowledge and access to data regarding soil fertility. Establishing

governmental monitoring system in Bahrain is highly recommended to employ knowledge-based approach to soil management. The amount of urea applied per hectare (kg/ha) in this study is presented in Figure 2. The association between farm size and amount of urea applied in farms found to be insignificant with P<0.430. This indicates that small sized farms were using urea more than the bigger sized farms.

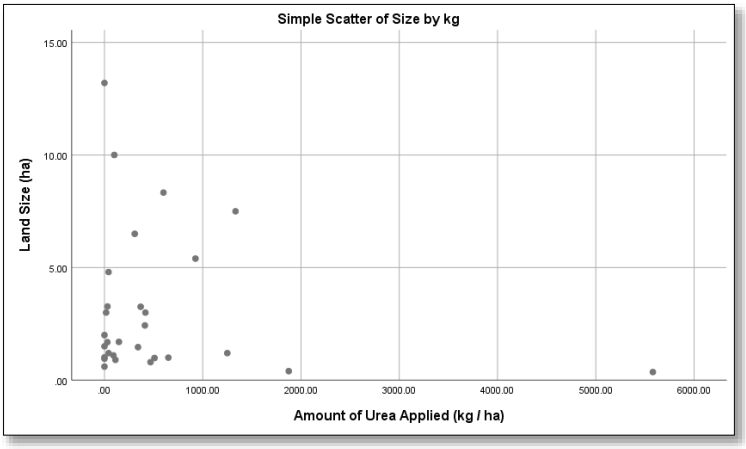


Figure 2. Amount of Urea application per hectare (kg/ha)

The majority of farmers (n=20, 69%) burned their agricultural wastes, 19 farmers (32.2%) chose to feed animals from the farm crop's residues. The remaining chose to either throw it away, give it to other animal farms, leave it in the field, make compost or sell it (22%, 15.3%, 13.6%, 11.9% and 5.1% respectively). Agricultural crop residues could be more efficiently used by directly added to fields or used as compost. Those good practices are recommended to enhance soil physical and chemical properties. Farmers can use agricultural waste to produce biofuels, mineralization and efficiency of nutrient uptake. Burning crop residue also indirectly adds to the rise in ozone pollution which pose negative effects on the soils and atmospheric quality. Most farmers (n= 21, 72.4%) considered the type of cultivars that were resistant and tolerance against pests and diseases. Farmers are constantly looking for plants capable of best performance in the future and have the highest rates of resistance. The choice of resistant varieties is essential for achieving high levels of pest and disease resistance, high levels of environmental adaption, high levels of yield, and high levels of profitability (Guesmi, 2013). Moreover, most farmers (n=15, 51.7%) confirmed identifying pests, diseases and weeds prior to applying plant protection products. It has been commonly observed that farmers were typically applying pesticides as a preventive measure prior to even identifying any disease in order to guard against potential infections. Majority of farmers (n=19, 65.5%) tried the biological pest control and only seven of them (24.1%) preferred this type of pests control and found it useful. Biological pest control is the use of natural enemies to replace chemical pesticides in agroecosystems (Wezel et al., 2014). Another biological control method is to use pheromones to disrupt the reproduction of specific insect. In Bahrain, farmers are using biopesticides derived from Neem Trees (*Azadirachta indica*). This practice was supported by Nchanji et al., (2017) who proposed new methods to reduce the environmental impact of pesticides by using neem leaves to control pests in vegetable and crop cultivation.

### *3.4 Water Use*

Agriculture is water-dependent and is becoming susceptible to water shortage risks. Farmers use water for irrigation, fertilizer applications, fruit and vegetables cleaning, and livestock. In this section, farmers were asked many questions related to water sources, water management and usage. The overall score for this theme is 67 points which is positive as shown in Table 4. This indicator considered water quality and quantity, water use and irrigation practices. *Water management* scored 59 points which is critical. This indicated that most farmers did not monitor water consumption nor did they apply water saving measures. *Water supply* is another indicator under water use which scored the lowest among all indicators theme (49 points). Bahrain fell under the category of high-water stressed countries and this caused a reduction in the score. Moreover, farmers often faced problems with water supply and some of them had to increase the depth of wells which negatively affected the score. *Water use intensity* scored (89 points). Most farms depend on external water supply, and due to Bahrain's climate, the water consumption is more than the annual rain fall volume. *Irrigation* scored positive (69 points). Most farms used efficient irrigation methods such as drippers. The majority did not face salinization problems or other

undesirable environmental impacts on irrigated areas due to inadequate drainage. However, it has been observed that some farming practices did not value water conservation, and groundwater was used for reasons other than irrigation.

Table 4. The sustainability score for water use theme

| Themes and indicators | Score |
|---|---|
| **Water use** | **67** |
| **• Water management** | 59 |
| **• Water supply** | 49 |
| **• Water use intensity** | 89 |
| **• Irrigation** | 69 |

Farmers use three types of irrigation: drip irrigation, which is commonly used to irrigate palm trees, trees, shrubs, and vegetable crops planted in the open field or inside green houses, flood irrigation, which is used to irrigate vegetable crops grown in basins or open ground, and sprinkler irrigation. Timer devices are used in some farms. Very few farms have embraced cutting-edge technologies such as hydroponics. Tertiary treated sewage effluent (TSE) is the main source of water used by the majority of farmers (n=28, 96.6%), while 20 farmers (69%) used groundwater, and only 7 farmers (24.1%) used desalinated groundwater. In addition, 25 farmers (86.2%) were using drip irrigation, while 22 farmers (75.9%) were still using flood irrigation on their farms, and only 3 farmers (10.3%) were using sprinkler in addition to the above irrigation methods. Desalination and (TSE) were increasingly utilized to meet agricultural water demand in Bahrain (Saleh & Ansari, 2013). The Kingdom of Bahrain produced about 70 million cubic meters of (TSE) and 80 million cubic meters of dual treated water (totaling 150 million cubic meters annually). It consumes about 40 million cubic meters of the total (TSE), and the rest (110 million cubic meters) is discharged into the sea (EWA, 2018). A study was conducted in Bahrain to evaluate the effect of long term irrigation using (TSE) on the soil, results concluded that (TSE) irrigation for 10 years and 20 years did not cause heavy metal concentration in the soil (Ebrahim et al., 2016). Groundwater used by the agricultural sector includes water used for irrigation, livestock, sheep grazing, and fish farming. Due to lack of rainfall, agriculture is irrigated and heavily dependent on groundwater; as a result, agriculture is the largest user of groundwater, consuming about 104 million cubic meters in 2019 (EWA, 2018).

A research by Bani (2020) examined efficient water consumption for certain crops production (tomato, cucumber and lettuce) using three different methods of cultivation (traditional, greenhouse and hydroponic methods) in Bahrain. The impact of imposing water tariffs on farm's profitability was investigated. According to the findings, the overall water consumption should be decreased by 50% and a water tariff of 15 fils per cubic meter (CM) could be applied in order to prevent overextraction of groundwater. The imposition of such water tariff has a negligible effect on farm's profit while it will significantly increase water conservation, which indicates financial and economic sustainability of such a policy option. Water storage plan was also found neglected at many farms, the majority (n= 17, 58.6%) did not have tanks to store water in case of any emergencies or water cutoff by the government. Water tanks can be used to store (TSE) water. Zhou et al., (2015) found that more treatments may be required before reusing the treated wastewater that has been stored for some time. Pathogens such as Shigella and Salmonella were found in a lake where first cleaned treated water was kept for later use. The storage of (TSE) water is known to result in the degradation of its quality as well as the growth of bacteria, fungi, and algae. It is essential for the government to acknowledge this phenomenon as a form of secondary pollution. Therefore, it is crucial to implement strict standards and laws and regulations pertaining to (TSE) that is intended for agricultural production.

*3.5 Biodiversity*

Agricultural biodiversity includes all native and domestic types of organisms found on farms, including plant species, animal breeds, soil organisms, pests, and pollinators (EC, 2022). Enhancing biodiversity is an outcome of a sustainable environmental management practices (OECD, 2001). Biodiversity had the lowest score among all themes (34 points) as shown in Table 5, which is just one point away from reaching the problematic area. The absence of advice, awareness, and sharing knowledge in this matter from the concerned bodies such as the Supreme Council for Environment had a significant impact on the current practices. Overall, farmers did not receive comprehensive advice on biodiversity, no measures to promote biodiversity was implemented. Farmers did not keep area for nature to preserve biodiversity. Plant protection product was used also on ornamental trees.

Table 5. The sustainability score for biodiversity theme

| Themes and indicators | Score |
|---|---|
| **Biodiversity** | **34** |
| **• Biodiversity management** | 28 |
| **• Ecological infrastructures** | 10 |
| **• Intensity of agricultural production** | 59 |
| **• Distribution of ecological infrastructures** | 27 |
| **• Diversity of agricultural production** | 44 |

Biodiversity advice to promote rare species and habitats was not provided to the majority of farmers (n=25, 86.2%). Only four farmers confirmed receiving advice (13.8%) but it was rather superficial or incomplete. Additionally, the majority (n= 22, 75.9%) did not carry out any check to see whether rare species worthy of protection were found on the farm. Moreover, if rare species worthy of protection were found on the farm, the majority of farmers (n= 19, 65.5%) did not implement any measures to promote these species.

The government shall aim to optimize the utilization of every meter of agricultural land to enhance food security and promote environmental sustainability. It is important to emphasize the significance of awareness as well as intensify visits conducted by the Supreme Council for Environment. Moreover, the Kingdom has established protected areas, such as Al Areen Reserve and Hawar Islands, to ensure the preservation of biological diversity. This necessitates achieving a balance between agricultural lands and protected areas. Such integration and balance in land management and investments are crucial for ensuring sustainability while achieving the desired economic returns and contributions. Farmers managed their land with only an eye toward profit running the risk of seeing groundwater depletion, water and soil quality deterioration, and biodiversity loss (Gutzler et al., 2015). It is required to have an integrated national strategy for sustainable development that includes the biodiversity protection of different species on agricultural lands and routine inspections by authorities to enhance the ecosystem. According to Bahrain's National Biodiversity Strategy and Action Plan (2016 - 2021), the status of habitats showed that agriculture ecosystems, along with other habitats, are suffering significant levels of threats (Sattout, 2016). Strengthening oversight inspection and law enforcement mechanisms and programs, and the implementation of laws and regulations is direly required, especially those related to reducing negative impacts on the environment. Promoting education and awareness in the various fields of sustainable development especially in the field of environmental protection.

*3.6 Working Conditions*

The foundation of any successful farm is its hardworking and dedicated workforce. The results shows that majority of farmers (n=17, 58.6%) employed 1 to 5 workers per land, seven farmers (24.1%) employed 6 to 10 workers, and just two farmers (6.9%) employed 21 to 25 workers. The net wages varied between 120BD to 150BD for the majority of farms (n=17, 58.6%). Furthermore, the vast majority (n=23, 79.3%) held work permits and were registered with the Labor Market Regulatory Authority (LMRA). Almost all farms (n=26, 89.7%) had no professional safety strategy in place. Moreover, all farms (n=29, 100%) did not routinely report safety potential risks in farms.

This theme scored (70 points) which is relatively good as shown in Table 6. Personnel management and wage and income level scored equally (89 points). Majority of workers (n=22, 75.9%) received paycheck slips and a written employment contract (n=23, 79.3%). No discrimination was recorded. *Working hours* on the other hand scored low (38 points). This is because farmers often work for long hours and barely take days off; consequently, some farmers did not get their yearly entitled leave. *Safety at work* scored 64 points. Majority of the farmers stated having one accident or illness per year. Most of the farmers reported that they had properly maintained PPPs and that they always used protective goggles and clothing when applying PPPs.

Table 6. The sustainability score for working condition theme

| Themes and indicators | Score |
|---|---|
| **Working conditions** | **70** |
| **• Personnel management** | 89 |
| **• Working hours** | 38 |
| **• Safety at work** | 64 |
| **• Wage and income level** | 89 |

According to the Northern Municipal Council, Bahrain's total agricultural workforce was 9,120 people, with just 650 of them being Bahrainis. The council expressed that the vast bulk of the workers were foreigners (GDN, 2020). The most recent data presented on AgroBH platform managed by NIAD, showed that approximately 1,583 individuals were employed in the agricultural industry, with 108 Bahrainis (7%) and the remaining 1,475 expats (93%) (AgroBH, 2021). The government of Bahrain demonstrated an increasing interest in raising the level of occupational safety and health in various production sites, in order to protect the workforce from occupational risks and accidents (Naumann et al., 2018). This is shown through the formation of the Occupational Safety and Health Council by the Prime Minister under resolution No. (2) of 2015, which is responsible for drawing and following up the implementation of the general policy in the field of occupational safety & health and securing the work environment. The majority of farmers (n=22, 75.9%) provided training to their workers on the usage and storage of plant protection products (PPPs). However, seven farmers (24.1%) stated their workers did not acquire the necessary training. Aside from that, ten farmers (34.5%) failed to secure the safety of PPP users by protecting them from skin/eye contact or vapor inhalation. The majority of farms (n=27, 93.1%) stored PPPs in accordance with manufacturer recommendations and legal requirements. All farmers (n=29, 100%) affirmed the acknowledgment of the PPPs safety period that is known as Restricted Entry Interval (REI) or Pre-harvest interval (PHI) and are complying to the established rules.

### *3.7 Quality of Life*

When personal objectives were presently being met, quality of life is achieved. Farmers were asked on their level of satisfaction with their work and life in general, the majority (n=14, 48.3%) were satisfied with their aspects of work and life. This has a great impact on the successfulness of their chosen strategy on social aspects, as none of the farmers answered unsuccessful. The majority also (n=25, 86.2%) did not have any significant conflict with people/groups/firms outside the farm.

This theme scored 76 points which was the highest among all themes, and all of its indicators scored positive as shown in Table 7. This showed that majority of farmers were happy with almost all aspects under quality of life (financial situation, social relations, personal freedom & values and health). Financial situation scored (88 points), which indicates that most farmers were satisfied with their situation. Moreover, most farmers were satisfied with their relationships with family & friends. The majority were also satisfied with their economic situation. Except for occupation and training, farmers are having some concerns regarding the workload, work timing and level of training.

Table 7. The sustainability score for quality-of-life theme

| Themes and indicators | Score |
|---|---|
| **Quality of life** | **76** |
| **• Occupation and training** | 79 |
| **• Financial situation** | 88 |
| **• Social relations** | 75 |
| **• Personal freedom and values** | 69 |
| **• Health** | 69 |

### *3.8 Economic Viability*

This section primarily examines the financial status of the year 2020/2021, as determined by RISE. Only two farmers (6.9%) promoted their produce to only one distributor, whereas the vast majority (n=27, 93.1%), were partnering with many distributors to market their agricultural crops. Most farms (n= 17, 58.6%) were facing difficulties to further invest in maintenance and expansion, this is due to land insecurity and lack of financial support. According to farmers, the state of the infrastructure on their farm ranged from most to entire areas were in good condition (n=24, 82.8%; n=5, 17.2%). Farmers did not report poor infrastructure situation during the interview. According to a study conducted by Atakli & Agbenyo (2020), there is a significant positive correlation between financial situation and productivity. The process of recording revenues and payments is still primitive in most farms, which depends on placing documents such as receipts and invoices in files or writing them down in the ledger. Almost all farmers (n=28, 96.6%) did not use any kind of accounting system to record this data via the computer except for one farmer (3.4%) who used such system to accurately record and track transactions as well as generate invoices and reports autonomously. In addition, this farmer was also being audited by an auditing company.

This theme scored (62 points) with the majority of indicators scored less than (67) as shown in Table 8. Farmers

were not willing to share their financial details, and therefore, this theme was assessed directly through inputting their opinion on each indicator by rating it from 1 (not fulfilled) to 5 (very good). Liquidity indicator scored (57 points) due to majority of farmers (n=20, 69%) did not have cash reserve enough for 40 weeks. Many farmers (n=15, 51.7%) required more than 5 years to pay their debts, some farms (n=14, 48.3%) were profitable, some of farm's infrastructure were in good condition (n=12, 41.4%), and the majority of farm's income is sufficient (n=16, 55.2%) to secure the economic livelihood of their members.

Table 8. The sustainability score for economic viability theme

| Themes and indicators | Score |
|---|---|
| **Economic viability** | **62** |
| • **Liquidity** | 57 |
| • **Stability** | 63 |
| • **Profitability** | 62 |
| • **Indebtedness** | 59 |
| • **Livelihood security** | 67 |

*3.9 Farm Management*

Farm management is very important in achieving profitability and sustainability. With respect to the modern agricultural techniques, majority of farmers (n=19, 59.4%) did not use modern techniques in farms (Figure 3). Only five farmers (15.6%) tried the hydroponic system and some of them stopped, while four farmers used cooled greenhouses and installed one solar lighting (12.5% equally).

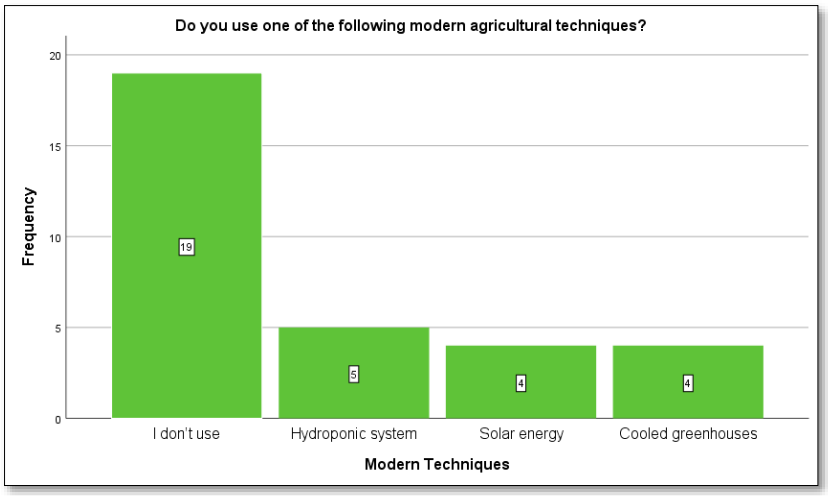


Figure 3. Type of modern agricultural technique applied by farmers

The majority of farmers whom did not use modern techniques specified the reason due to the high installation cost (22.5%), lack of materials in the country (15%), lack of sufficient familiarity with the technique (12.5%), high material cost (7.5%) and insufficient technical training (2.5%) as shown in Figure 4. Bani (2020) analyzed three types of production methods in Bahrain: conventional, greenhouse, and hydroponic. Results showed that greenhouse and hydroponic approaches surpassed traditional methods in terms of cost and revenue. Her results were in line with the responses received in this study. Further analysis showed that only four farmers (13.8%) were satisfied with their farm management.

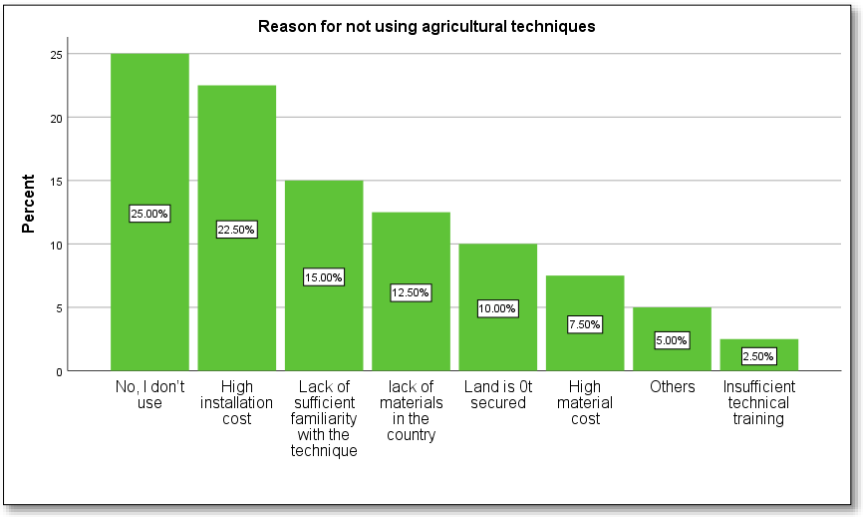


Figure 4. Farmers reply to the reasons behind not using agricultural techniques

The majority (n=17, 58.6%) were somehow satisfied, six (20.7%) were dissatisfied, and two (6.9%) were very dissatisfied. Furthermore, the overall findings revealed that farmers were dissatisfied with the current state of farmer's cooperation, as eight farmers (27.6%) were extremely dissatisfied, and seven (24.1%) were dissatisfied. Ten (34.5%) were partially satisfied and the remaining four farmers (13.8%) chose to say "don't know" rather than share their opinion. Furthermore, the majority of farmers (n=25, 86.2%) reported no significant conflict with persons, groups, or businesses outside the farm, while only four (13.8%) reported some conflict.

The sustainability of the farm and the outcomes of the other themes are highly dependent on the management approach and standard of the farm. This theme scored 69 points as presented in Table 9. According to their statements, farmers seemed to have thought-out goals, had fair access to necessary information such as data on prices and markets, knew the threats and risks posed to the farm, had stable relationships with other farms and individuals.

Table 9. The sustainability score for farm management theme

| Themes and indicators | Score |
|---|---|
| **Farm management** | **69** |
| **• Business goals, strategy and implementation** | 74 |
| **• Availability of information** | 57 |
| **• Risk management** | 64 |
| **• Sustainable relationships** | 80 |

There is an agreement that agricultural sustainability could be centered on a set of best management practices (Triviño-Tarradas et al., 2020). According to Salvia et al., (2018), farmers' willingness to adopt best agricultural management is proportional to their training level.

## 4. Conclusions

The study has made a significant contribution to the recognition of local farming practices in the context of Bahrain. The average score for the 29 farms was successfully calculated using RISE. Farms achieved a good overall outcome with an average score of (63 points) of Bahrain's sustainability. Farms fared well in five of the eight areas (quality of life, water use, working conditions, soil utilization, and farm management) with values (≥ 67). The values of the remaining three themes (economic viability, biodiversity and material use) were all (≥ 34 points), which was deemed essential. The topic of biodiversity received the lowest score of (34 points) out of all the themes, while quality of life earned the most at (76 points). Majority of farmers were not using heavy wheeled tractors and machines that were greater than 2.5 tons. Farmers neither perform any kind of soil analysis during the time of their farming careers, nor did they take into account the exact quantity of fertilizers required. Consequently, there is increased concerns of soil salinity or soil infertility. Most farmers (72.4%) were selecting crop varieties that are resistance to pests and tolerance to diseases, (51%) of farmers identified species before applying the protection treatments, and (65.5%) did use or preferred to use biological and mechanical rather than

chemical treatments. Most farms used efficient irrigation methods such as drippers, however, farmers did not monitor water consumption. Biodiversity advice to promote rare species and habitats was not provided to the majority of farmers (86.2%). Majority of farmers were happy with almost all aspects under quality of life (financial situation, social relations, personal freedom & values and health). 17 farms (58.6%) were facing difficulties to further invest in maintenance and expansion.

The outcome of the RISE analysis affirms the success of adapting it to accommodate the characteristics of agricultural production in small-scale settings or countries with constrained natural resources. However, land security which is considered the biggest dilemma facing the agricultural sector in the Kingdom was not measured. While acknowledging the limitations of the small sample size, it is important to note that these findings regarding the sustainability performance of crop production farms in Bahrain can serve as a foundational reference point for future studies and research endeavors.

It is recommended to include land tenure or incorporate an active engagement of stakeholders to develop a Bahrain-specific set of indicators. It is also recommended to enhance the King Hamad Prize for agricultural development by introducing new category that focuses on the recognition of the Best Sustainable Farm. This addition aims to acknowledge and incentivize farmers, fostering their commitment to adopting good agricultural practices and contemporary agricultural systems.

**Acknowledgment**

We would like to acknowledge the generous support received from the National Initiative for Agricultural Development and the Ministry of Municipalities Affairs & Agriculture. We also thankful to Dr. Mohammed Etman for his valued comments. Sincere appreciation is extended to all the farmers who graciously granted us access to their farms, participated in the questionnaire without causing any discomfort even during the COVID pandemic, and did not withhold any information that would have been advantageous to this research.

**Authors contributions**

Dr. Asma M. Ali was responsible for data collection, analysis and drafted the manuscript. Dr. Qaisar Mahmood and Prof. A.W. Abdelhadi were responsible for the study's design and revision. All authors read and approved the final manuscript.

**Funding**

Not applicable

**Competing interests**

Sample: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Informed consent**

Obtained.

**Ethics approval**

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

**Provenance and peer review**

Not commissioned; externally double-blind peer reviewed.

**Data availability statement**

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

**Data sharing statement**

No additional data are available.

**Reference**

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