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Circular Agriculture Approach: Towards a Sustainable Agricultural Waste Management in the Kingdom of Bahrain

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Abstract

The agricultural sector plays a crucial role in human development and serves as the backbone of economic growth. However, agriculture has both positive and negative impacts on the environment and ecosystems. More than 70% of total agricultural production is wasted, posing a significant threat to human health through environmental pollution and potential economic losses. Nevertheless, agricultural waste can be repurposed for various beneficial uses. The increasing population, urbanization, and environmental degradation underscore the need to transition to a circular agriculture approach for sustainable agricultural waste management. Circular agriculture is a fundamental aspect of the circular economy and is a key approach to achieving the Sustainable Development Goals (SDGs). This research aims to investigate current agricultural waste practices and farmers' perspectives through a questionnaire with a response rate of 40%. Additionally, it proposes a framework for adopting sustainable agricultural waste management. The study concludes that farmers should be enlightened, trained, and empowered to participate in broader discussions and decisions regarding the future of sustainable agriculture management. To implement the proposed framework successfully, cooperation and coordination among all the concerned stakeholders are crucial for achieving national agricultural objectives and facilitating sustainable agricultural transformations.

Keywords

Circular economy, agricultural waste, sustainable approaches, sustainable agricultural practices, sustainable development goals (SDGs)

1. Introduction

The global agriculture sector between 1950 and 1980 witnessed the conversion of more lands to agriculture to provide food for the growing population, which is expected to reach 9 billion people [1]. By 2050, in order to meet the demand for food, global agricultural production must increase by 70%. This increase should be balanced to ensure sustainable natural resource management while meeting the needs of food production. In return, this increase will lead to the generation of a significant amount of agricultural waste, exacerbating major environmental issues. Therefore, the agriculture sector should develop a sustainable waste management infrastructure and reuse the by-products. For instance, this can be achieved by producing compost from organic waste. Thus, adopting circular agricultural (CA) models will enhance resource use efficiency and minimize or avoid agricultural waste generation [2-7].

By 2050 the demand for water and energy will increase by 55% and 80% respectively, where the agriculture sector consumes a hefty portion of natural resources of water and energy [8]. Agriculture has both positive and negative impacts on humanity and

the environment ecosystems. For instance, a substantial portion of agricultural emissions is made up of carbon dioxide, methane, and nitrous oxide [9], and toxic agricultural chemicals (such as pesticides and fertilizers) used to control pests and diseases could contaminate freshwater, air, soil, and marine ecosystems [10]. Adopting sustainable agricultural practices is the most effective approach to remedy those negative impacts. In this vein, the transition from conventional agriculture to CA has various benefits, such as improving resource efficiency, reducing negative environmental impacts, and enhancing economic performance [11]. This transition process required additional efforts to develop innovative technologies and implement sustainable practices. Since 2014, the focus on circular economy (CE) in the agricultural field has increased [12], thus, there is a need to enhance CA in the context of the concepts and approaches of the CE [13, 14]. The circular economy focuses on recycling and reusing waste to prevent economic losses. Therefore, agricultural waste can be utilized in the circular economy context to minimize the reliance on virgin raw materials, generate electricity, reduce agricultural waste, reduce water consumption, slow down the depletion of natural resources, cut costs, and minimize environmental impacts [12, 15, 16]. For instance, farmers should consider using agricultural waste recycling technology as an environmental protection solution. Since agricultural waste management and environmental pollution control are ethical issues [17]. It is crucial to minimize, repurpose, and recycle agricultural waste to conserve soil quality and biodiversity and ensure global food security. This approach will help alleviate environmental pressures on economic growth [18].

Agricultural wastes are the residues generated from producing and processing raw agricultural products, such as food and field crops. The composition of these residues may contain materials that can be useful either directly or indirectly [19, 20]. A solution to agricultural waste is to practice sustainable agriculture, maximizing resource usage, reducing waste generation, and promoting eco-friendly practices. Therefore, agricultural waste can be converted into valuable resources, offering sustainable waste management solutions and creating new business opportunities. Building upon the above, the first essential step is for the national policy level to incorporate the sustainability dimension into agricultural policies to improve sustainable agricultural management practices. The implementation of these policies will encourage farmers to transition to sustainable agriculture. In addition, farmers should become more environmentally aware and improve their practices of agricultural waste management to avoid environmental impacts.

This study is the first of its kind in Bahrain as it aims to investigate the status of agricultural waste practices and management systems. It also aims to discuss circular agriculture and establish a proposed framework for achieving sustainable agricultural waste management in Bahrain.

2. Sustainable Agricultural Waste Management

The key to solving agricultural waste impacts is adopting sustainable approaches supported by effective policies and strategies and considering socio-economic aspects. Also, it can greatly benefit from national solid waste management legislations and strategies, ensuring a secure and institutionalized disposal system. According to [20], the recycling and reuse of agricultural waste are widely practiced in peri-urban and rural regions with the assistance of extension agents. Recycling agricultural solid waste reduces greenhouse gas (GHG) emissions, decreases dependence on fossil fuels, creates jobs, and produces bio-energy and animal feed [21, 22]. It is worth mentioning that the agricultural sector contributes about 21% of GHG emissions [23]. Further, agriculture waste emits methane (CH_4), sulfur dioxide (SO_2), nitrous oxide (N_2O), and smoke which have significant environmental impacts [24]. In this context, He et al. recommend that scholars should focus on GHG reduction from agricultural waste management based on effective social policies towards significantly reducing GHG emissions [25].

Agricultural solid wastes are often mismanaged due to a lack of knowledge among farmers regarding effective waste management and its associated health impacts [23]. Moreover, conventional disposal methods of agricultural pesticide waste can harm natural resources (soil and water) and threaten human health at a regional scale [26], and open-air burning of agricultural waste is a major contributor to serious air pollution [25]. Thus, through sustainable practical measures, effective policies, and educational and awareness campaigns, agricultural waste can be properly managed and utilized for other purposes. The sustainable agriculture approaches are adopted to mitigate environmental impacts and health hazards and enhance socio-economic development.

2.1 Circular agriculture approach

Since the publication of the Brundtland Report in 1987, the concept of sustainable agriculture has gained prominence alongside the overarching idea of sustainable development [27]. Thus, sustainability has become increasingly important in the agricultural sector, encompassing integrated management, policies, production, and waste practices. Sustainability should be future-oriented to ensure long-term viability in agriculture. The importance of adopting sustainable agricultural waste strategies is to ensure sustainable agricultural growth. Numerous attempts have been made to propose appropriate agricultural practices and integral solutions aimed at achieving sustainability in agriculture to make the concept more tangible. Most importantly, farmers, extension professionals, policymakers, and other stakeholders should understand all aspects of sustainable agriculture to practice it

effectively [28]. Thus, government role and business initiatives should assist farmers in transitioning towards sustainable agriculture.

One of the recent global scientific initiatives was a meeting of 19 scientists in Morocco in 2019 to discuss and exchange ideas and experiences on "designing sustainable and circular agricultural systems for the year 2100", which was focused on some significant options "to increase yields per hectare, use novel food sources, improve food waste and nutrient management cycles, and produce nutrients off-farm" [29]. The CA approach is emphasizing the mutual relations between the adaptive and alternative approaches and in practice has not been extensively studied to date [30, 31]. CA is a novel approach based on the cradle-to-cradle environmental concept, aiming to minimize waste and repurpose it as a valuable resource. For instance, Fareed et al. concluded that incorporating each type of nano agriculture waste ash into asphalt binder and mixture is an eco-friendly disposal and sustainable method [32]. Further, the CA approach enables farmers to reduce their reliance on external fertilizer inputs. For example, date palm residues provide an alternative source of organic materials and supplement other fertilizers. Additionally, dry palm residues can be collected, recycled, and utilized in agricultural soils to meet various cropping system requirements [33].

CA is an essential element of eco-effective agricultural management and a pivotal approach to achieving the 17 SDGs [34]. Sustainable nitrogen management is essential for achieving most of the Sustainable Development Goals (SDGs) as it is the primary nutrient for continuous food production to meet human needs. For example, the emissions of N_2O and GHG from agricultural waste contribute negatively to climate change (SDG 13), while recycling agricultural waste contributes positively to sustainable production (SDG 12) [35, 36]. The CA approach's vision is ambitious and a long-term strategy, focusing on logistics, closed-loop business strategies, and waste management from an adaptive perspective [31]. Thus, CA is an effective model for managing agricultural waste by integrating it within production processes, enhancing sustainable agricultural production, and increasing efficiency in the agricultural industry [37]. Furthermore, CA is regarded as a sustainable solution for environmental issues stemming from the agriculture sector. It encompasses climate resilience, enhancement and sequestration of carbon sinks, improvement of soil health, enhancement of crop-animal production, nutrient cycling, and environmental protection [38]. Most importantly, international cooperation is highly required to enhance CA by establishing "common norms and standards for waste management and reduction, sustainable procurement practices, agricultural value chains, and reporting on food loss and waste" [39]. In line with this notion, the global political-economic context is crucial to ensure the success of sustainability regulations in developing countries [40].

CA focuses on enhancing efficiency by minimizing emissions, enhancing feed and soil management, managing waste flows, embracing sustainable agriculture, and reassessing the focus on economic growth [41]. CA involves sustainable farming practices incorporating scientific progress advances, eco-innovations, and novel technologies [39]. According to Atinkut et al. CA is defined as a “facet of the circular economy that targets the challenges of the farm-based rural economy and environmental issues” [17]. El Janati et al. define CA as a beneficial method from a soil perspective, aimed at managing soil organic inputs to improve soil fertility and support the sustainability of cropping systems [33].

3. Bahrain’s Agricultural Sector

Agriculture has been a crucial sector of the Bahraini economy despite the region's low rainfall and poor soil. Before the oil industry emerged, palm cultivation dominated the agricultural landscape, yielding sufficient dates for both local consumption and export. Further, at least twenty-three varieties of dates are grown, and all parts of the palm, including the leaves, branches, buds, and flowers, are widely used. During the 1950s to the 1970s, shifts in food consumption patterns and rising salinity in groundwater used for irrigation contributed to a gradual decrease in agriculture. Since the 1980s, many palm groves have been replaced by other agricultural activities such as vegetable gardens, tree cultivation, flower nurseries, poultry production, and dairy farming. In 1993, the cultivated area in Bahrain had decreased from 6,000 hectares before independence to 1,500 hectares. The cultivated land comprises approximately 10,000 plots, varying in size from a few square meters to four hectares. There are approximately 2,400 farmers (farms workers), and 70% of them rent the farmland or work for the landowner [42].

Since 1980, the government policy has aimed to enhance domestic crop production through various programs. These include free seed distribution, technical assistance in adopting new and more efficient irrigation techniques, and low-interest loans. Although these programs have contributed to significant increases in the production of eggs, milk, and vegetables, the potential for further increasing production capacity is limited by the small arable area in Bahrain [42].

The date palm census in Bahrain was conducted in 2018 using a satellite image, which revealed approximately 257,000 palm trees. The highest numbers were found in western regions such as Janabiyah, Zallaq, and Al-Jasra. The palm trees are distributed across the governorates as follows: 50% in the Northern governorate, 29% in the Southern governorate, 15% in the Capital, and 6% in the Muharraq governorate [43].

Bahrain's agricultural sector is evolving, emphasizing sustainable practices such as horticulture. The cultivated land covers 2.5% (20 km^2) of the total area, with cultivated land accounting for 50% of the arable land [44]. The agriculture sector contributes 0.3% to Bahrain's real GDP [45]. According to a report by Mordor Intelligence, Bahrain's agriculture is predicted to grow at a

compound annual growth rate of 1.5% from 2019 to 2024, encompassing food crops, fruits, and vegetables [46]. The total agricultural crop production in the Gulf Cooperation Council (GCC) reached approximately 12.1 million tons in 2021, showing a growth rate of 32.9% compared to the 9.1 million tons produced in 2017 [44]. In Bahrain, vegetable production is the highest among plant products since seeds are not cultivated locally. Figure (1) illustrates the distribution of plant production (%) in the GCC countries for the year 2021.

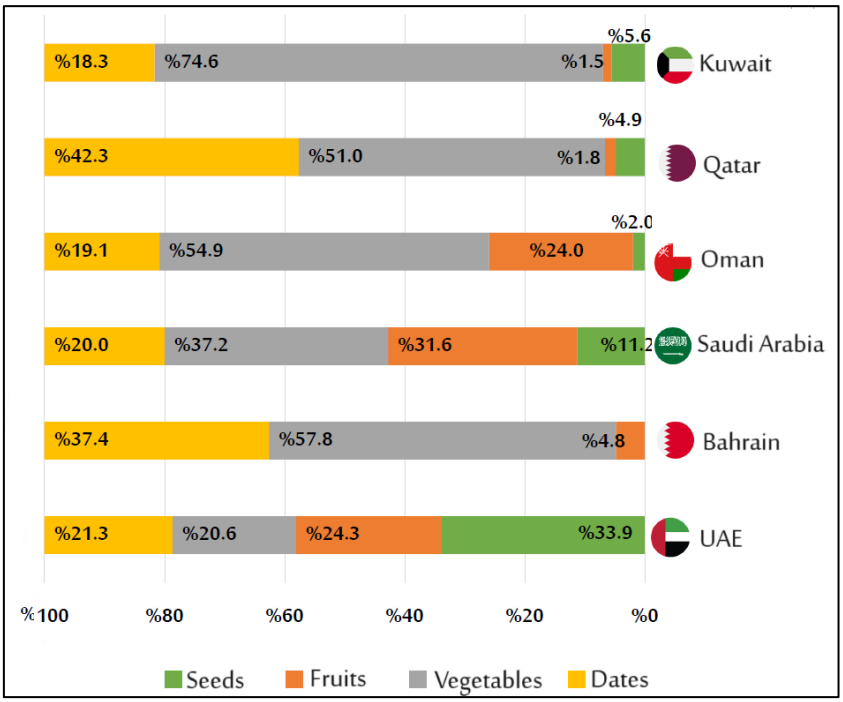

Figure 1. The distribution (%) of plant production in the GCC countries, 2021 [44].

Bahrain is making great efforts to manage waste generated from various sources. While there is no detailed data available on agricultural waste in terms of its sources, types, and quantities. The only available data is under the category of "green waste," demonstrating a fluctuation in the quantity collected by private waste collectors over a span of ten years, as depicted in Figure 2.

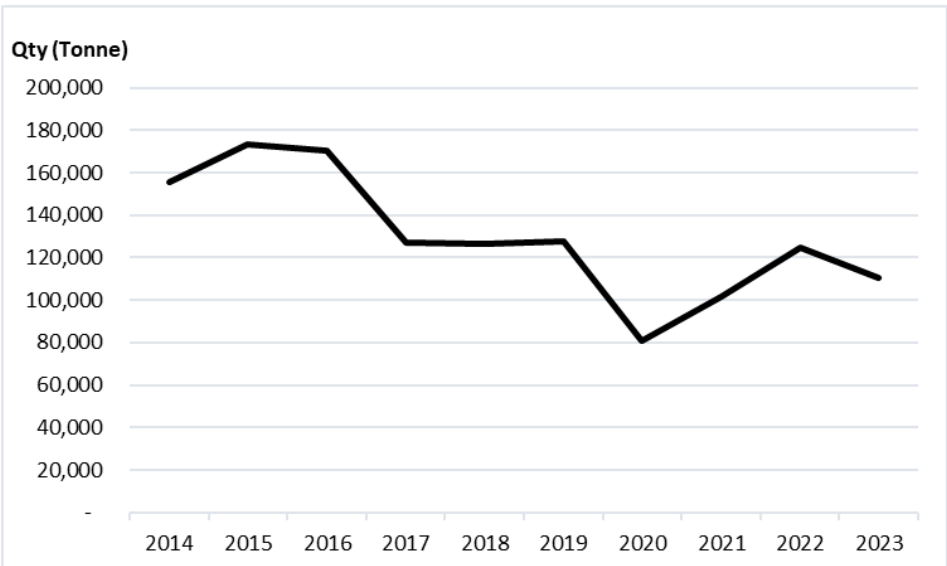

Figure 2. Green waste generation in Bahrain, 2014-2023 [47].

The National Initiative for Agricultural Development (NIAD) was established in 2010 to drive continuous revitalization of the agricultural sector. This initiative aims to engage all relevant authorities, consolidate existing efforts to revive the agricultural sector's prosperity, and address challenges such as water scarcity, land scarcity, and reliance on traditional farming practices. Furthermore, it provides solutions by coordinating the efforts of relevant authorities and utilizing modern agricultural technologies, while offering essential funding, training, and qualifications for local farmers. Additionally, NIAD is working on projects to support agricultural workers, increase green areas, strengthen agricultural manufacturing industries, and raise awareness of agricultural culture through education and training to develop specialized national capacities in this field [48].

AgroBH is the first agricultural database and a significant initiative led by the NIAD, aiming to unite efforts towards enhancing the development and strengthening of Bahrain's agriculture sector. Through this database, NIAD seeks to support the achievement of Bahrain's economic, social, and environmental development goals and to establish a compliant agriculture sector in alignment with the Economic Vision 2030. The database functions as a central hub for data management, investment incentives and aid, historical documentation, and research and development [48].

3.1 The existing situation of agricultural waste practices management in Bahrain

3.1.1 Method

A short questionnaire consist of ten questions was developed to gather data and information, and it was reviewed and validated by three experts for reliability before being distributed to farmers. The questionnaire aimed to studying and understanding the existing situation of agricultural waste practices in Bahrain. The questions are formulated in Arabic in easy and direct terms, and the question types are multiple-choice, yes/no and one question asks to mention the most common agricultural waste and its quantity, considering the farmers' education levels. The questionnaire was prepared in Google Forms to be filled out and sent back, and was sent to farmers via WhatsApp. The author sought assistance from the Farmers' Association to encourage farmers to fill out the questionnaire. The response period and follow-up took approximately two months. The study population is 47 farmers registered in the official agricultural database (www.agro.bh) belonging to NAID and only 19 respondents (40%). The responses will clarify the willingness of the farmers to be involved in the sustainable agriculture transformation process.

3.1.2 Results and discussion

Q.1 Which type of agricultural waste is generated at your farm? (Select all that apply)

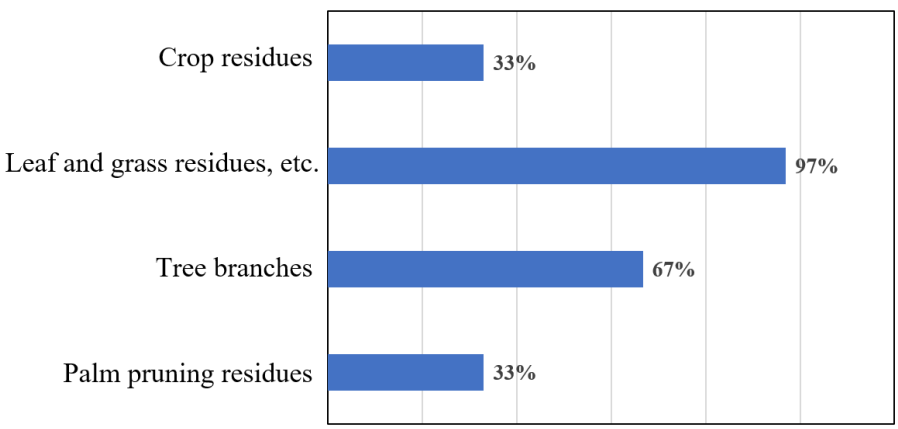

Figure 3. The responses to question 1.

As shown in Figure 3, the major generation type of agricultural waste is leaf and grass residues (97%), and the second type is trees' branches (67%). Whereas, crop residues and palm pruning residues are similar generation percentages (33%).

The power of data is key to solving environmental issues; therefore, there is a need to emphasize studying agricultural waste types more deeply in detail.

Q.2 What is the most common agricultural waste your farm produces annually? Can you estimate the amount?

Not all farmers were answering this question, the common agricultural waste is cropping residues, and the quantity mentioned is 1 to 1000 tons, and 10 to 15 containers.

The farmers do not seem interested in recording the waste generated on their farms. Therefore, there is a need to conduct an intensive study on the quantity, types, and sources of agricultural waste. Subsequently, waste specialists and experts can offer appropriate solutions for agricultural waste.

Q.3 What methods do you currently use to dispose of agricultural waste?

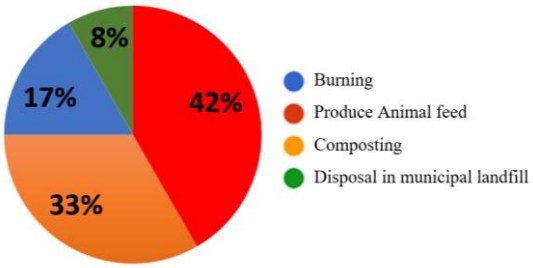

Figure 4. The responses to question 3.

As depicted in Figure 4, most farmers (42%) currently reuse agricultural waste to produce animal feed. The second method is to convert agricultural waste into compost (33%). The burning of agricultural waste is high (17%) compared to waste landfilling (8%).

According to Ugwuoke et al., it is proven that dioxins, even in small amounts, cause health and environmental problems because they persist in the environment for a long time, accumulate in fatty tissues, and can be transported over long distances in the atmosphere. This is due to the burning of chlorinated pesticides. For instance, during intense agricultural burning in Taiwan, dioxin concentration in the atmosphere is up to 17 times higher than normal. Therefore, it is vitally important to study the impact of burning agricultural wastes on the environment and health. Further, need for strictly enforced legislation to stop or control this practice [49].

Q.4 What are the best ways to effectively utilize agricultural waste? (Select all that apply)

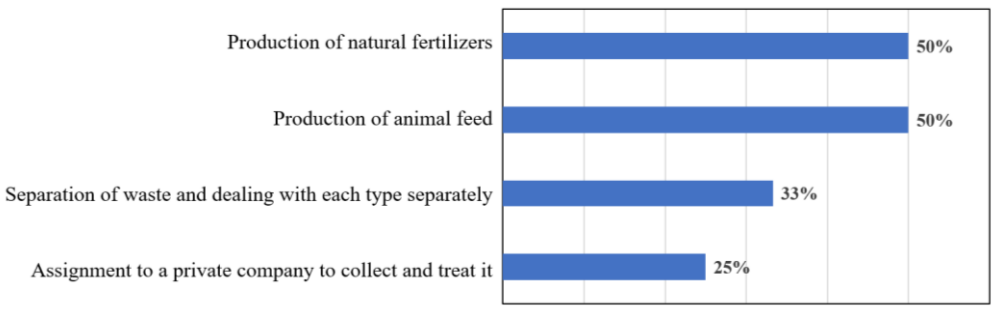

Figure 5. The responses to question 4.

As indicated in Figure 5, the farmers expressed that utilizing agricultural waste effectively can be achieved through natural fertilizers (50%) and animal feed production (50%), while the least effective method is to assign waste collection to the private sector (25%). Whereas, waste separation is more effective than waste privatization.

Based on the results, there is an opportunity to enhance the skills and capacity of farmers through training courses on composting and animal feed production to prevent waste disposal. Compost is a stabilized organic matter, which can be effectively utilized for the restoration of degraded soils and the enhancement of their fertility. It also aids in carbon sequestration in the soil, reducing the need for chemical inputs, which leads to cuts in production costs and minimizes negative environmental effects [50].

Q.5 How can farmers be motivated to participate in proper agricultural waste management?

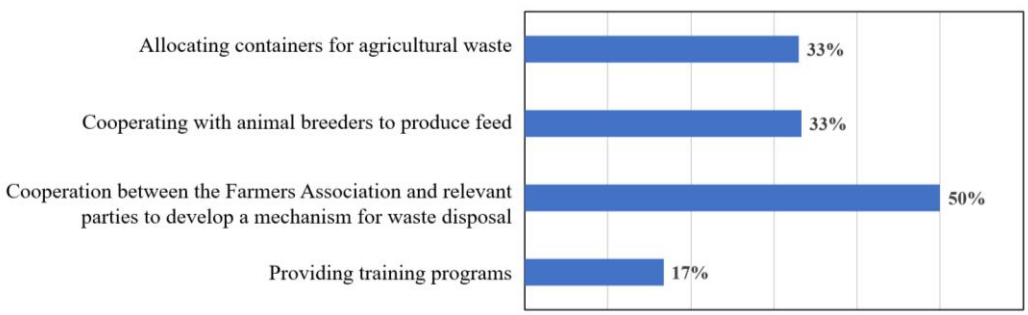

Figure 6. The responses to question 5.

As shown in Figure 6, the farmers expressed that cooperating with the Farmers Association and relevant stakeholders to develop a waste disposal mechanism is a more favourable motivation for proper agricultural waste management (50%). Both allocating special containers for agricultural waste and cooperating with animal breeders to produce feed are similar percentages (33%). It was not expected that the farmers would not be favourable to training programs, with the response rate reaching only 17%.

Another opportunity is to move beyond traditional management practices and promote collective action by establishing a cooperation mechanism between the Farmers' Association and other stakeholders. This will empower all involved parties to explore various agricultural waste management options. Adopting a variety of farming practices and goals could be challenging due to the conventional agriculture paradigm [51]. Therefore, sustainable agricultural transformation should be collectively developed with all stakeholders.

Q.6 Do you think there should be more awareness campaigns on the proper management of agricultural waste?

Q.7. Do you think it is important to involve the private sector in agricultural waste management?

Q.8. Do you think it is necessary to issue legislation on the proper management of agricultural waste?

Q.9. Are you willing to participate in training programs on the proper management of agricultural waste?

Q.10. Are you aware that improper management of agricultural waste can cause health and environmental damage to farms and the surrounding environment?

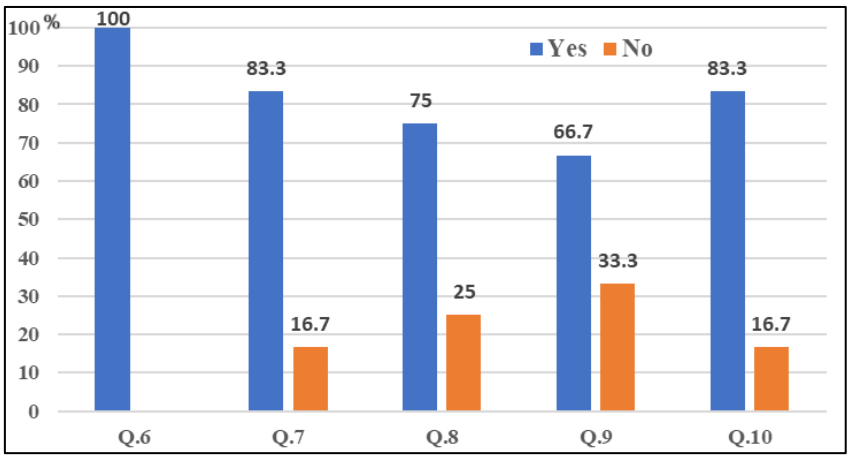

Figure 7. The responses to questions 6 to 10.

As shown in Figure 7, interestingly all farmers agreed on the need for more awareness campaigns regarding the proper management of agricultural waste (Q.6). In addition, 83% of the farmers believe that involving the private sector in agricultural waste management is important (Q.7), while 75% of the farmers consider legislation on the proper management of agricultural waste to be necessary (Q.8). It is surprising that only 67% of the farmers are willing to participate in training programs on the proper management of agricultural waste (Q.9). In terms of the environmental and health impacts of burning agricultural waste, the majority (83%) of the farmers are aware of these impacts (Q.10).

In sum, the farmers' responses clearly indicate their support for agricultural change. Therefore, farmers should be part of the process of sustainable agricultural transformation. However, there is a need to gain a deeper understanding of sustainable agricultural transformation, its outcomes, and the factors that influence them. Sustainability is an amenable concept but needs efforts to localize it at the national level. Agricultural waste is a critical environmental issue that can benefit from a sustainability approach to provide long-term solutions.

3.2 Proposed sustainable agricultural framework for Bahrain

The proposed framework (Figure 8) contributes to the current study of agricultural waste in Bahrain in terms of sources and practices. The framework aims to activate and integrate various sustainable pathways and alternative agricultural approaches. It offers an advantage by creating an opportunity to deeply engage all stakeholders in shaping a sustainable agricultural transformation process with potential positive outcomes. Sustainable agricultural transformation is a novel process aimed at improving the entire agricultural sector. The framework is centered on the sustainability pathway supported by national sustainability actions and multi-stakeholder partnerships. All relevant stakeholders involved in agricultural transformation processes must participate. Importantly, farmers should be acknowledged as crucial contributors and primary beneficiaries of the agricultural systems.

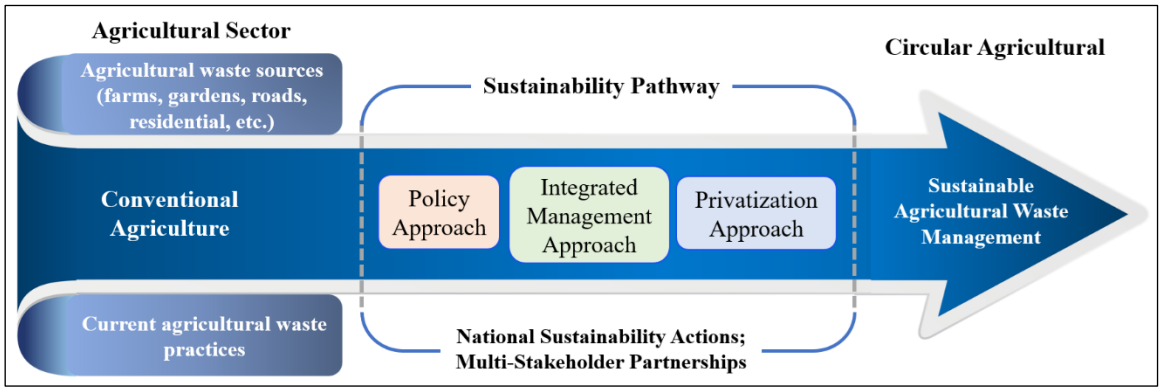

Figure 8. The proposed sustainable agricultural framework in Bahrain.

The proposed sustainability pathway considers various approaches (policy, management, and privatization) to address all agricultural sector issues to achieve sustainable agricultural transformations. The agricultural transformations should be framed as actions and strategies to move systematically and proactively to succeed in attaining sustainable agricultural management. Thus, the sustainability pathways take advantage of the effective policy context to formulate sustainable actions by updating the existing policies to ensure the agricultural transformation process within a certain planned time and increase farmers' contributions. This policy approach is the basis of the sustainability pathway. The policy approach in agriculture should be translated into concrete measures to tackle practices that cause environmental degradation and focus on sustainable practices and innovative technical solutions. According to the UN DESA, "a comprehensive set of policies, technologies, and institutions are needed to promote adopting circular agricultural practices in rural areas" [39].

Within the integrated management approach, institutional development is grounded in a procedural system that facilitates sustainable transformation based on national policies or strategies. This approach encompasses regulations, norms, practices, and legislations, as well as the knowledge and skills of farmers. Effective agricultural management plays a crucial role in driving sustainable transformative change to overcome key obstacles to achieving sustainability. Consequently, all stakeholders can pinpoint actionable, effective, and legitimate agricultural adaptation measures and sustainable transformation pathways. The sustainability path is nested with social, environmental, and economic systems, culminating in the integration of agricultural management elements, thereby ensuring sustainable management practices.

Globally, privatization has been viewed as a policy tool aimed at assisting the public sector in better managing its projects to improve public service efficiency. In this context, the private sector is a partner of the public sector. The private sector plays a significant role in providing waste collection services, but it should be supported by a robust waste database. However, privatization of waste management services is not the only solution to address waste management challenges; it should be complemented by a strong regulatory framework to ensure the efficiency and effectiveness of waste management services. Therefore, this approach should involve both policy and integrated management approaches.

Most importantly, agricultural transformations can be achieved and utilized as a positive force towards more sustainable agricultural systems. To achieve this, it is essential to establish a national framework for agricultural enhancement to tackle its challenges. A significant endeavour, the suggested framework aims to promote circular agriculture in Bahrain, which can be realized by effectively integrating three approaches tailored to the national context to achieve sustainable agricultural waste management.

4. Conclusion

This study aims to investigate the status of agricultural waste practices and management systems. It also aims to discuss circular agriculture and establish a proposed framework for achieving sustainable agricultural waste management in Bahrain. The proposed framework is designed to guide future sustainable agriculture transformations and reform existing unsustainable agricultural waste practices. The framework focuses on sustainability pathway approaches and acknowledges farmers as pivotal stakeholders in transforming agricultural systems. The framework is an opportunity for localizing the sustainable development goals (SDGs) related to agriculture at the national level as well. Cooperation and coordination among all stakeholders are crucial for successful sustainable agricultural transformations and achieving national agricultural objectives. It is also vital to consider the environmental, social, and economic implications. Environmental integrity is a key aspect of sustainability. Therefore, it should empower farmers to engage in broader discussions and decisions regarding the future of sustainable agriculture pathways.

Most importantly, farmers' enlightenment, training, and education are crucial for raising awareness about the hazards of

agricultural waste to the environment and its health impacts. Additionally, the capacity and willingness of farmers to act and support the implementation of best practices and legislation that manage agricultural waste are essential. Their actions will significantly enhance the current situation and pave the way towards sustainable agricultural management. Furthermore, in the policy context, agricultural policies must be reviewed and updated. New agricultural legislation or strategies are necessary for the transformation process to facilitate best waste management practices and ensure the achievement of sustainable transformation in the future.

Generally, due to the novelty of CA, only a few fields of practical research studies have been conducted, limited to analyzing frameworks to prove and measure the efficiency of this approach. However, enhancing CA within the context of the CE model is crucial for conserving agricultural resources and achieving the SDGs. This study can be useful for agricultural authorities in Bahrain to facilitate the adoption of CA models. Furthermore, it contributes to overcoming the limitations of adopting this model in the agricultural sector and guiding practical strategies. Further studies are required to accelerate the adoption of CA.

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