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Impact of Implementing Constructed Wetlands on Supporting the Sustainable Development Goals

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Abstract: The United Nations Sustainable Development Goals' (UN SDGs) action call promotes worldwide social, environmental, and economic prosperity. Each country developed a local plan to achieve the SDGs' objectives and targets. The UN presents an annual global SDG progress report, based on an international indicator framework and regional available data. Wetland ecosystems contribute to the SDGs; however, more research is required to evaluate wetlands' impact on sustainable development. This study investigates how implementing constructed wetlands (CW) at a local scale can contribute to achieving and promoting the SDGs with application in Kuwait. A preliminary design of a constructed wetlands wastewater treatment system is proposed alongside a local scoring framework based on regional information to assess the future projection of the SDGs in Kuwait. Overall, CW implementation plans contributed positively to improving the level of achievement of SDG 2: Zero Hunger, SDG 3: Good Health, SDG 6: Clean Water, SDG 7: Affordable and Clean Energy, and SDG 15: Life on Land. The analysis also highlights synergies that need to be considered for integrated environmental governance and enhanced policy coherence for Kuwait's sustainable development management.

Keywords: sustainable development goals; circular economy; nature-based solutions; constructed wetlands; produced water treatment

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1. Introduction

The sustainable use of water and wetlands, by protecting the services they provide, is critical to enable society to achieve sustainable social and economic development, adapt to climate change, and improve social cohesion and economic stability [1,2]. Wetlands have great potential to be used as nature-based solutions (NBS) due to their vital physical and social components of a country's natural capital, as well as providers of ecosystem services to local and national communities [3–6]. The development of constructed wetlands (CWs) has a variety of advantages, including water treatment, reducing air pollution, carbon sequestration, recreation, and biodiversity support [7,8]. However, despite all their promising benefits, there are limited CW applications, especially in the Middle East and Gulf countries.

Kuwait Petroleum Corporation (KPC) is the national company bringing together all of the state-owned elements of the Kuwait oil sector under one corporate umbrella. KPC activities are focused on petroleum exploration, production, petrochemicals, refining, marketing, and transportation. Kuwaiti oilfields produce about 7% of the world's total crude oil [9]. Produced water is a mixture of injected water, formation water, dissolved hydrocarbons, and treating chemicals, and the amount of produced water production increases as the oilfield ages [10–12]. Kuwait oilfields consist approximately of 40% water with a steady increase in water production due to maturing oilfields, which generates the problem of dealing with the increased rate of produced water. Oilfields are responsible for more than 60% of daily produced water generated worldwide, whereas Kuwait oilfields

approximately produce 2 million barrels of water along with production of 3 million barrels of oil [13]. The facilities incorporated are water collection centers, water injection plants, water injection wells, and oil reservoirs [14]. The Kuwaiti government is supporting and encouraging initiatives to enhance produced water management across all reservoirs [15]. Kuwait's current water management activities are related to water production, injection, and disposal [16]. The main produced water management practices are related to items shown in Figure 1. Hence, this was a great motivation for this research to promote the wetlands treatment sustainable system to maximize the produced water recovery and circulate it in greenery applications.

Figure 1. Produced water management [16].

The relations between sustainability and wetlands are diverse; there are many aspects to assess and value them, including measuring the communities and livelihoods supported and/or protected from natural hazards during the peak, and/or reducing water contamination and food security [4,17]. Moreover, interrelations and interactions between the environmental, social, and economic footprints of wetlands can support SDGs directly and subsidiarily [18]. This gives priority to investigating the connection between sustainable development, wetlands, and Kuwait's SDGs forecasting. Nature-based wastewater solutions are considered a crucial point for achieving sustainability. Accordingly, constructing and sustaining wetlands for wastewater treatment is relevant to the proposed SDGs in some way or another [19].

The proposed SDGs offer a universal agenda that, for the first time, recognizes the need for restoration and management of water-related ecosystems, including wetlands, as a basis for addressing water scarcity and water risks [20]. Wetlands offer various solutions for several key challenges around the world related to water, food, and climate, and contribute to meeting the SDGs. Most of the proposed SDGs are relevant in some way or another to wetlands, but the following are of particular importance: SDG 6: Clean Water and SDG 15: Life on Land [21,22]. Consequently, there is a need for a systems approach to relating wetlands development and implementing the SDGs. Few literature and international reports on wetland services, such as Ramsar and the Global Wetland Ecohydrological Network (GWEN), addressed this challenge and highlighted that identifying wetlands' effect must start with prioritizing and linking the interactions of SDGs in wetlands [3,18,23].

The UN final list of proposed Sustainable Development Goal indicators directly associated wetlands, including natural and constructed, with SDG 6 and 15 [22,24].

This research presents a preliminary proposal for constructed wetland implementation in Kuwait and attempts to measure its effect on SDGs. The project is contributing to applying a circular economy (CE) in the water management sector, leading to saving the scarce water resources in Kuwait since the local climate is typically dry and arid with unbalanced insufficient rainfall events and disposing of stormwater directly to the sea. Approximately 25% of untreated wastewater in Kuwait is dumped directly into the gulf waters without recycling [25]. Adopting the CE practices in wastewater means achieving the majority of SDGs where both concepts can be combined to create potential local waste management plans [26]. GWEN (2019) attained the top prioritized wetland goals related to SDG 2: Zero Hunger, SDG 4: Quality Education, SDG 6: Clean Water and Sanitation, SDG 8: Decent Work and Economic Growth, SDG 11: Sustainable Cities and Communities, SDG 12: Responsible Consumption and Production, SDG 13: Climate Action, and SDG 15: Life on Land. These results were selected by 15 among 49 researchers (30%) in 45 wetlands locations studied worldwide, identifying the most important goals that should be primarily accomplished to achieve sustainable development in their wetlands. Wetlands, including natural and constructed, were directly linked to indicators goals 6 and 15.

In Sweden, a study was done to understand the different characteristics of wetlands and ecosystem services in Sweden [18], with the aid of international reports on wetland status from organizations such as Ramsar and the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) on freshwater resources; these reports were used for indications and predictions on current and coming changes for wetlands on a global scale. The criteria for sustainable wetlands and positive linkages with the Sustainable Development Goals (SDGs) are presented in Table 1 [3,27].

Table 1. Positive interactions between the United Nations Sustainable Development Goals (SDGs) and their targets and Swedish wetland ecosystems [18].

Interaction	Name	SDGs (Targets)
+3	Indivisible	1(7.1), 6(11.8), 13(14.1 and 14.8) and 155(14.1 and 14.8)
+2	Reinforcing	2(2.4), 3(3.9) and 12(12.2)
+1	Enabling	7(7.1), 11(11.8) and 14(14.1 and 14.8)

2. Objectives of the Study

2.1. General Objectives

This study aims to investigate the impact of constructed wetlands implementation on the achievement of UN SDGs with application in the State of Kuwait.

2.2. Specific Objectives

In order to address the above aim, the following specific objectives of this research work are:

1. Map the relation between Kuwait National Vision 2035 and UN SDGs.
2. Propose the possible location for implementing CW in Kuwait.
3. Generate a preliminary plan for the CW treatment plant.
4. Mapping and scoring the synergies between the Kuwait (Vision 2035) targets and their relevant SDGs.
5. Compare Kuwait SDG achievements to GCC countries and asses the state position improvements after implementing SDGs.

3. Materials and Methods

The research methodology achieved to attain the objectives of this chapter is shown in Figure 2.

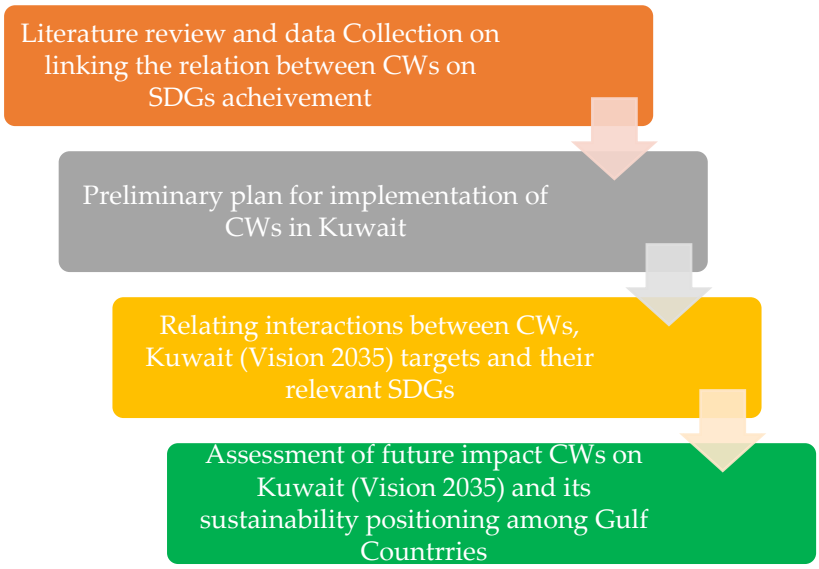

Figure 2. Research methodology.

3.1. Mapping the Relation between Kuwait National Vision 2035 and UN SDGs

The Kuwait Voluntary National Review (VNR 2019) reported that Kuwait had a National Development Vision 2035, New Kuwait 2035, adopted from the SDGs, which consists of seven pillars supporting the whole strategy. The country prioritized six goals, highlighted in red (4, 8, 10, 13, 16, and 17) and showed the highest achievements (84–100%) in no poverty, good health and wellbeing, and clean energy, while limited progress (28–38%) in responsible consumption and production, and life below water, and moderate progress in the remaining goals (40–75%). Hence, environmental studies must contribute to the New Vision 2035 and SDG achievement. A mapping between Vision 2035 with SDG interconnection is done to assess the contribution of the CW project to the sustainable positioning of Kuwait.

3.2. Proposing the Possible Location for Implementing CW in Kuwait

The proposed CW system is planned to treat the produced petroleum water in a sustainable and cost-effective method. The petroleum fields map was downloaded to select the appropriate location for the CW plant. The fields are operated by the National Kuwait Oil Company (KOC) and oilfields are distributed in four main sections: north (N), west (W), south (S), and east (E) fields [9,28].

3.3. Generating a Preliminary Plan for the CW Treatment Plant

Produced water has a complex composition with varying pollutants having different natures and properties compared to domestic or municipal wastewater [29]. This challenge was solved by the development of the lab-scale CW systems and testing the treatment of produced water contaminants, and hence concluding the effectiveness of implementing full-scale CW and concluding its configuration. The result of this study is not yet published. The hydrocarbon content was reduced by almost 90% from the produced water treated by the lab CWs without the use of any chemicals nor consumption of energy since the gravity flow of water supported natural processes in removing the hydrocarbons with the aid of the used filter media and oil separator. The same lab CW configurations were used to plan for the site-planned CW to treat the same rate of petroleum-produced water. The estimated cost of the wetlands was calculated based on information from local contractors and was compared to the assumed wetland construction costs equation by knowing the area, where CW $Cost = 812 * A^{0.704}$ [30].

3.4. Mapping and Scoring the Synergies between the Kuwait (Vision 2035) Targets and Their Relevant SDGs

The scoring framework is established to stimulate the importance of SDGs based on their interactions and to help assessments by identifying wetlands' effects and positive interactions. The International Council for Science (ICSU) and others developed a framework tool to understand the nature and dynamics of these interactions and to assess whether the impact of the relationship is positive or negative, as shown in Table 2 [20,31,32]. The tool is intuitive and relatively easy to use as the first level of assessment of the interlinkages among the SDGs is to determine potential synergies and trade-offs, which will help ensure that policymaking is more effective.

Table 2. Scoring scale for measuring the interaction between the SDGs and their targets (UN-Water, 2016).

Interaction	Name	Explanation
+3	Indivisible	Inextricably linked to the achievement of another goal.
+2	Reinforcing	Aids the achievement of another goal.
+1	Enabling	Creates conditions that further another goal.
0	Consistent	No significant positive or negative interactions.
−1	Constraining	Limits options on another goal.
−2	Counteracting	Clashes with another goal.
−3	Cancelling	Makes it impossible to reach another goal.

The UN SDGs are a vision for achieving a sustainable future; hence, reliable, timely, comprehensive, and consistent data are critical for measuring SDGs' progress and achievements [33]. Data from environmental science represents one new source of data that could be used for SDG reporting and monitoring. However, information is still lacking regarding the current and potential contributions of future sustainable development and projection models to the SDG indicator framework. Satisfaction of SDG indicators is the cornerstone and measuring stick for the viable fulfilment of Agenda 2030 [34]. The 17 SDGs are associated with 169 targets, and 232 indicators were mapped with Kuwait 2035 Vision and a score is assigned to show the strength of their interaction. It was very important to score the SDG and Kuwait 2035 Vision interaction considering the impact of CW on the entire SDGs and Kuwait 2035 Vision schemes. The comparative advantages of the scoring system aid in measuring effectively the impact of CWs in supporting Kuwait's SDGs achievements.

3.5. Comparing Kuwait SDGs Achievements to GCC Countries and Assessing the State Position Improvements after Implementing SDGs

The values of the benefits provided by wetlands, per unit area, have been consistently shown to be orders of magnitude higher than for other ecosystems with the major benefit delivered through improving water security. Hence, an integral role to contribute to the Kuwait Agenda 2035 and the SDGs is forecasting the impact of wetlands based on a planned wetland area. There is a large body of literature related to empirical time-series forecasting; the data were downloaded from the Sustainable Development Report (SDR) [35]. The Excel Workbook is called SDR 2021 and the database, which was extracted into the Excel Worksheet, presents the data for Trends Kuwait SDGs. The data from the Trends is a collection of all of the indicators from which the files for Kuwait and the other five Gulf Cooperation Council (GCC) countries from 2000 to 2020 were downloaded. The sustainable positioning of Kuwait is easier to be monitored when compared with the GCC countries due to the similarity of the nature, social, and economic conditions. The SDGs datasets available are used, while the goals which were missing are ignored. For the figures and tables provided, the available main indicators for Kuwait were selected accordingly for other GCC countries' datasets.

The method used for measuring the trend of SDGs from the years 2020 to 2035 is the simple arithmetic mean CARG, which is recommended by UNSD, and was applied to assess the trend from 2010 to 2020 in the UN SDGs progress report [36]. Equation (1) is used to calculate the annual growth for the corresponding years:

$$CAGR_{i,j} = \left(\frac{S_{j,T}}{S_{i,j,t}} \right)^{\frac{1}{[(T-t)+1)}} - 1 \quad (1)$$

where, $\overline{S}_{j,T}$: *SDG i′ s score for country j during time T*,
$\overline{S}_{i,j,t}$: *SDG i′ s score for country j during time T*,
i 1 . . . 17 *j*=1 . . . 6 *t*≡2010 & *T*≡2035
The projected SDGs for the future years are computed from Equation (2) as

$$ProjectedSDGs = SDGbaseline + CAGR_{i,j} * (T - t) \quad (2)$$

The overall SDGs scores simple arithmetic means: $Si,j,t=1Ni\Sigma I$, i refers to a given SDG. Using a growth rate method, CAGR, the projection for SDGs in Kuwait and the GCC was forecasted using Excel.

4. Results and Analysis

The keystone for the fulfilment of Kuwait Vision 2035 is the UN 17 SDGs. Linking the UN SDGs to New Kuwait is shown in Figure 3, adopted from the report [37] to relate the Kuwait Development Plan to SDGs and their percentage of achievement (the government prioritised six goals highlighted in red).

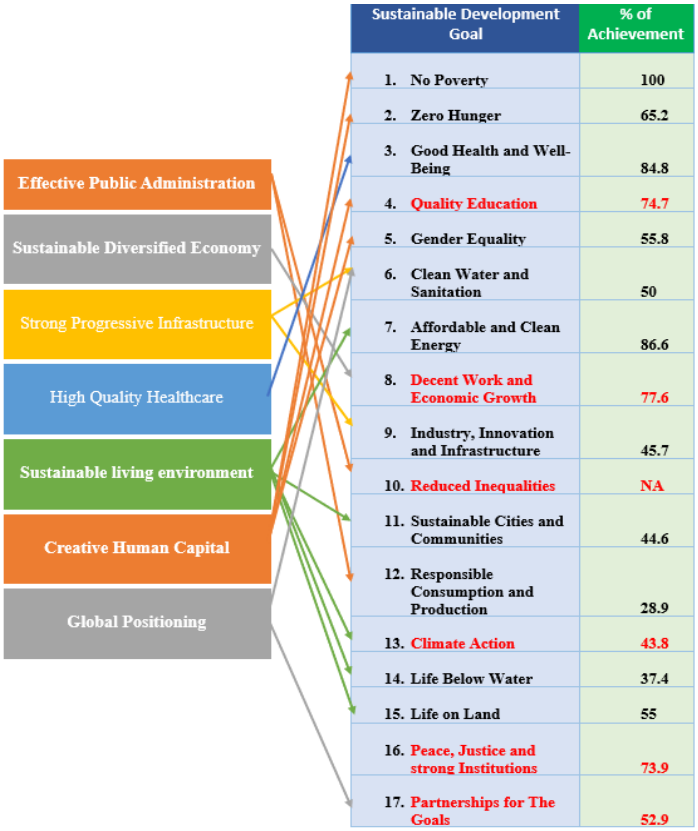

Figure 3. Mapping the Kuwait National Institutional Development Plan to SDGs adopted from the Kuwait Voluntary National Review [37].

The proposed project location is in the northern sector of Kuwait, as shown in Figure 4, where there are more than a thousand production wells and five assembly centers, and there are still many oil reserves to be produced.

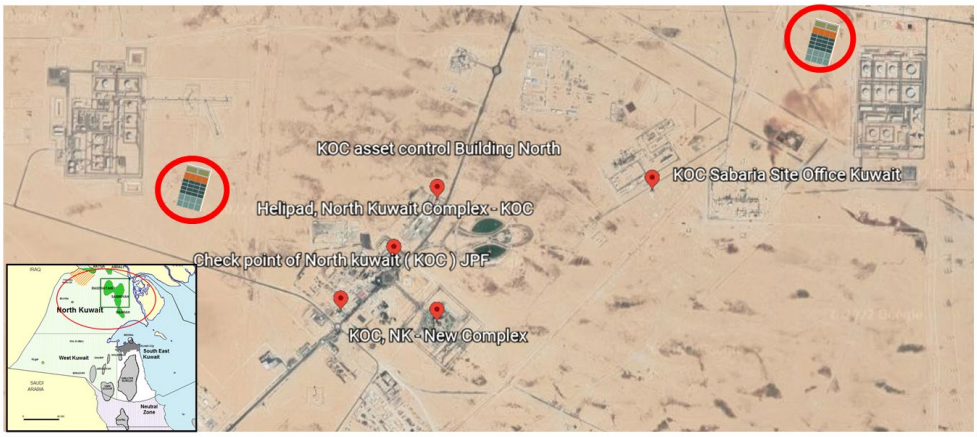

Figure 4. Proposed locations for constructed wetlands.

The two chosen locations are selected for several factors: their proximity to oilfields and facilities. Additionally, the national plan for the environmental preservation of the northern part of Kuwait is the core of several sustainable projects including the Sabah Al Ahmed natural reserve area and the planned Silk City, which is the future development of Kuwait [38] and its Vision 2035.

The proposed wetlands project supports the implementation of a circular economy in produced water management. An integrated water management approach is planned to reduce the amount of disposed water, and to maximize recoverable water and treatment of produced water with natural and energy saving technology. This will help in cost reduction, better management, and utilization of produced water in North Kuwait. The capacity of the planned CW treatment plant project in North Kuwait is 4.8 km^3 to treat a total of 90,000 m^3 of produced water per day. The elements of the potential produced water treatment project are stated in Table 3 and the project plan is shown in Figure 5.

Table 3. The elements of the potential CW.

No.	Item	Quantity (Units)	Configuration (L × W × D) in Kilometers
1	Produced water collection tanks	2	2.0 × 0.5 × 0.01
2	Oil separators	4	0.5 × 0.5 × 0.01
3	Surface low horizontal wetlands	16	1.0 × 0.5 × 0.01
4	Vegetation area	1	1.2 × 4

The estimated construction cost for one CW treatment plant is calculated based on the total area, as mentioned in the Methodology, and the prices given by local contractors, as shown in Table 4. This nature-based solution can be an energy efficient technology for the sustainable treatment of produced water, with the opportunity for multiple CW treatment plants implemented for greater economic and environmental benefits.

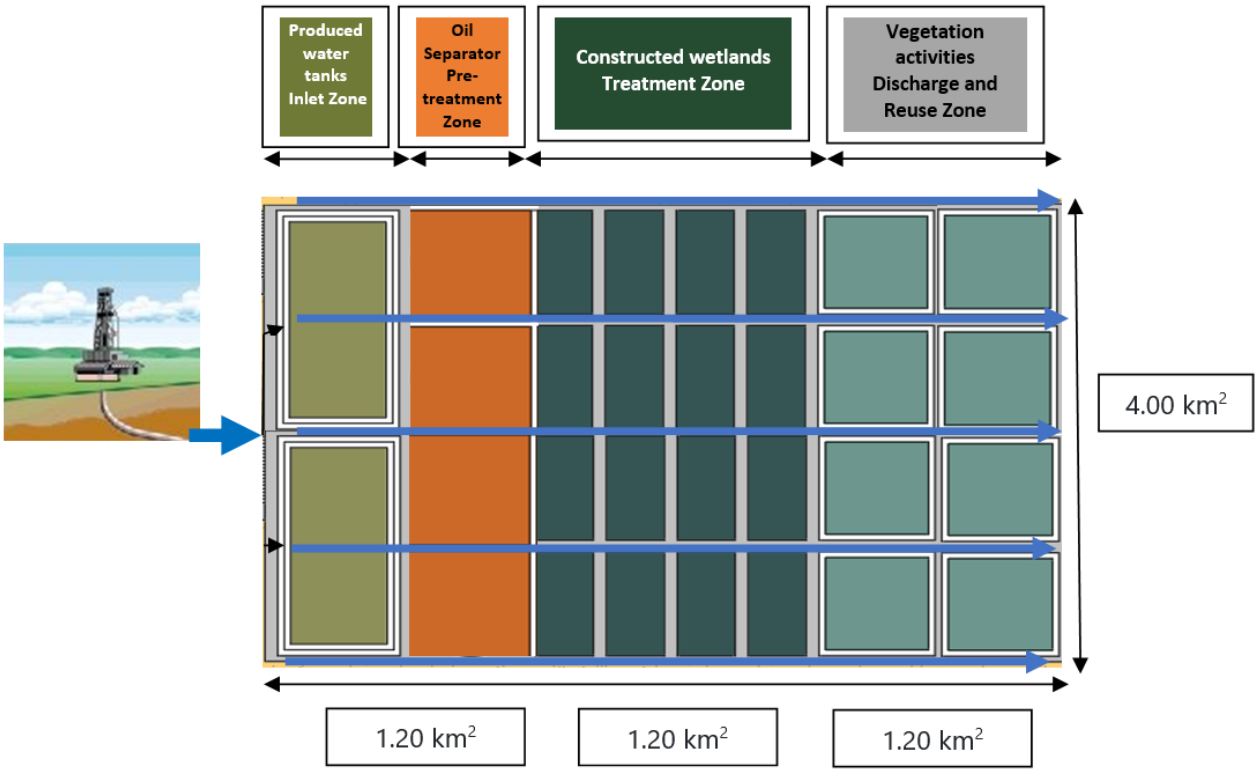

Figure 5. Constructed wetlands plan.

Table 4. The estimated cost of the potential CW.

No.	Item	Cost (KWD)
1	Pre-treatment oil separator	12,000
2	Drainage pipes and network	9500
3	Sand and gravel for filtration	7000
4	Total cost including +10% (the investment costs)	45,000

The 17 SDGs are associated with 169 targets and 232 indicators balancing the various dimensions of sustainable development. Within the scoring framework applied to Kuwait, positive SDG interactions are assigned a score of +1 (enabling), +2 (reinforcing), and +3 (indivisible); the magnitude of the score provides an indication of how influential a given SDG or target is on Kuwait Vision 2035 based on the available regional data.

The synergies between the Kuwait Vision 2035 targets and their relevant SDGs are demonstrated in Table 5; hence, according to the Kuwait 2035 Vision, regarding SDG 6, water and sanitation were viewed as the means for the development and preservation of natural processes for the inner circle of SDGs (2, 3, 7, 8, 9, 11, 12, 13, 14, and 15), while the availability of water and sanitation was considered an enabler of sustainable development and human well-being for the outer circle of SDGs (1, 5, 4, 10, 16, and 17). SDGs 3, 6, 7, 9, and 13 are directly associated with SDG15, and SDGs 2, 8, 11, 12, and 17 are not as closely associated with their immediate work, whereas SDGs 1, 4, 5, 10, and 14 are distantly related with almost no impact on their work.

Table 5. The synergies between the Kuwait (Vision 2035) targets and their relevant SDGs.

Wetlands Relevant SDGs	Kuwait Vision 2035						
	Effective Public Administration	Sustainable Diversified Economy	Strong Progressive Infrastructure	High Quality Healthcare	Sustainable Living Environment	Creative Human	Global Positioning
2 ZERO HUNGER						+2	
3 GOOD HEALTH AND WELL-BEING				+2			
4 QUALITY EDUCATION						+1	
6 CLEAN WATER AND SANITATION			+3				+3
7 AFFORDABLE AND CLEAN ENERGY					+1		
8 DECENT WORK AND ECONOMIC GROWTH		+3					
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE			+2				
11 SUSTAINABLE CITIES AND COMMUNITIES					+1		
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	N/A						
14 LIFE BELOW WATER					+1		
15 LIFE ON LAND					+3		

The criteria of the Kuwait 2035 Vision are linked to multiple SDGs, demonstrating the holistic approach of the SDGs in addressing vital issues of sustainability. The majority of the Kuwait 2035 criteria are strongly linked to SDG 6, which ensures availability and

sustainable management of water and sanitation for wetlands to ensure fresh water, help replenish ground aquifers, and purify and filter harmful waste from water, including heavy metals and toxins from industry; SDG 8, by enabling decent work and economic growth by having diversified sustainable economy; and SDG 15, to protect, restore, and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss. However, there was no available local data for Kuwait SDG 2 progress; therefore, it was not taken into consideration.

The values of benefits provided by wetlands, per unit area, have been consistently shown to be orders of magnitude higher than for other ecosystems with the major benefit delivered through improving water security.

For the figures and tables provided, the available main indicators for Kuwait were selected accordingly for other GCC countries' datasets [35]. A side-by-side comparison is shown in Figure 6 for the overall SDG performance from 2010 to 2021 in all GCC countries and Kuwait.

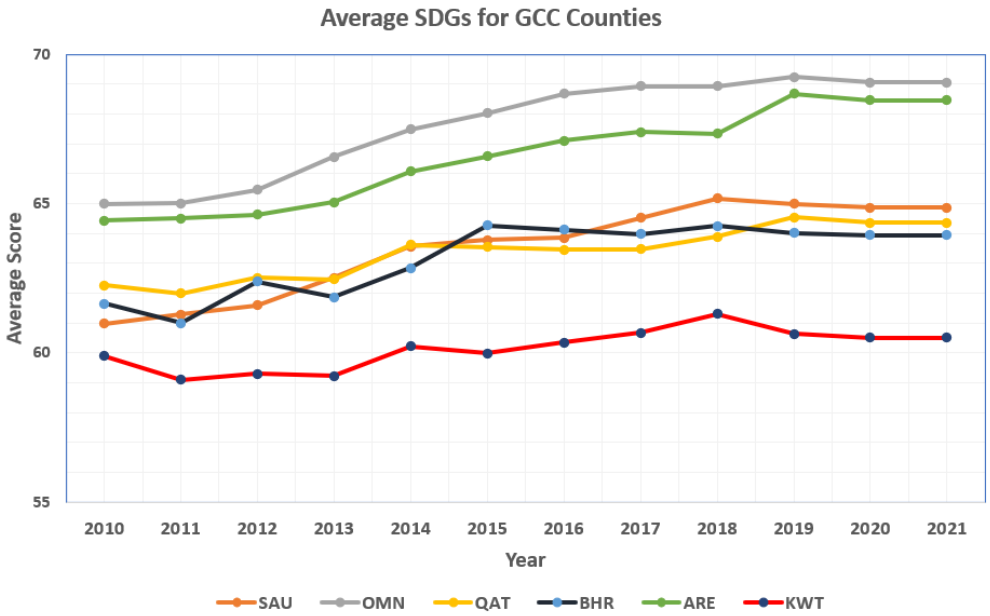

Figure 6. GCC SDG performance until 2021 generated from UN SDR 2021 [35].

In the six countries belonging to the GCC, the conditions of sustainability differ according to each country's sustainable development implementation and improvement; however, Kuwait is the country that presents the most favorable financial conditions among the GCC members [39,40], but it remains at the lowest sustainable level, as shown in Figure 6, which makes it very challenging but encouraging to achieve future improvement.

According to the future projection of the SDGs until the year 2030, the results presented in Figure 7 demonstrated that there are several SDG forecasts worth mentioning that showed great improvement in the position of Kuwait, such as SDGs 2, 3, 6, 7, and 15. Furthermore, for SDGs 4, 8, 11, and 14, there was not any visible improvement. SDG 2, the exceptional trend growth rate, was entirely explained by Kuwait leading the GCC countries in that goal due to its economic strength and no hunger situation.

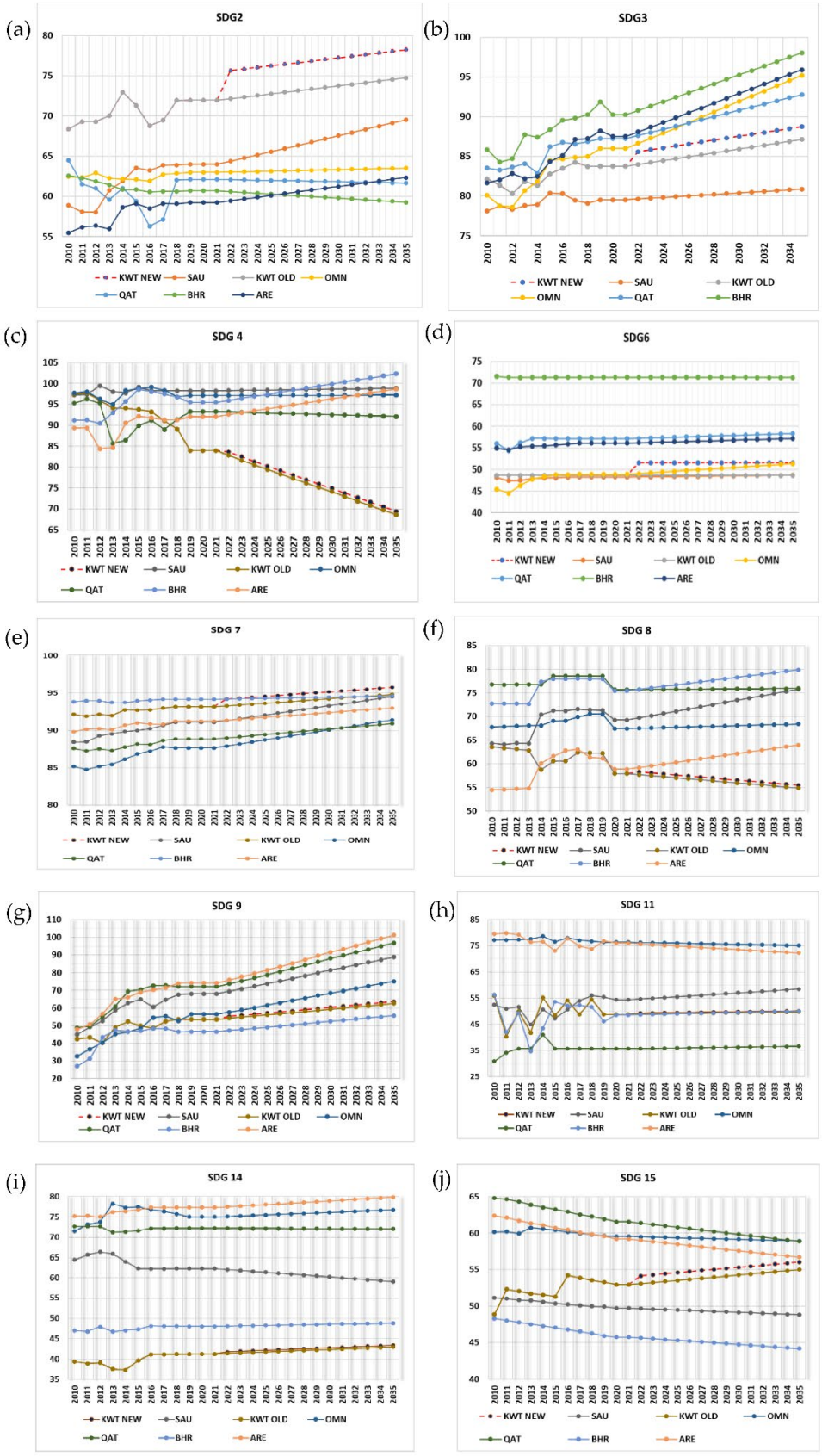

Figure 7. GCC SDGs (**a**–**j**) forecast until the year 2035.

5. Discussion and Conclusions

Our analysis showed that there are noticeable promising inputs from CW implementation in the treatment of produced water to the SDGs framework and Kuwait Vision 2035, presented by the positive linkages with SDGs achievement related to SDG 2: Zero Hunger, SDG 3: Good Health, SDG 6: Clean Water, SDG 7: Affordable and Clean Energy, and SDG 15: Life on Land. Additionally, there was a moderate improvement in SDG 4: Quality Education, SDG 8: Decent Work and Economic Growth, SDG 9: Industry, Innovation, and Infrastructure, and SDG 14: Life Below Water. On the other hand, the was no change in the performance of SDG 11: Sustainable Cities and Communities. The assessment of future CW contribution to SDGs was influenced by the past and current sustainable position and performance of Kuwait. Although the country is rich in economic and fossil fuel resources, it holds a lower overall SDGs ranking than similarly wealthy neighboring GCC countries, which indicates that sustainable competitiveness is not linked to wealth, but rather to high levels of sustainability applications in developments and management. This was highlighted in the massive leadership of the SDG 2 projection due to the strong monetary status, while there was no visible improvement on SDG 11 since the country is ranked among the top 10 polluted countries worldwide [41].

Realizing the full potential of wastewater NBS and CWs on communities' wellbeing, energy savings, and their value in the ecosystem, they are suspected to contribute to global long-term carbon emissions reductions. This research supports leveraging Kuwait government investments and facilitation in implementations of CW to enhance its use, and especially that low-cost treated water can be used to supplement the limited water resources. Adopting the CE practices in produced water treatment and reuse aids in achieving the majority of SDGs, where both concepts can be combined to create potential local industrial and petroleum wastewater management plans. However, information is still lacking regarding the potential contributions of NBS to the industrial and petroleum wastewater treatment sector in Kuwait. Hence, the government should consider future applications of NBS in the recycling of industrial and petroleum wastewater to prevent further pollution and loss of the limited water sources and maximize the social and economic benefit through the circulation of the treated water for different industrial and agricultural purposes.

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