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STRATEGIES FOR SUSTAINABLE USE OF THE GROUNDWATER RESOURCE AND ITS MANAGEMENT: AN ANALYSIS OF THE QATARI PENINSULA

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ABSTRACT:

The demand for clean water is rising globally due to the loss of naturally renewable water supplies. As more people become aware of the resource's limitations, the need for groundwater protection and restoration is becoming increasingly important. However, excessive groundwater use has significantly reduced the amount of groundwater available. This illustrates the necessity of managing and utilizing groundwater resources responsibly. The State of Qatar actively uses groundwater for domestic, recreational, and agricultural purposes, even though it is not used for the public's drinking water supply. Due to pressure from urbanization, agriculture, and climate change, groundwater salinity levels have risen significantly. The hydro geochemical characterizations of the Qatar aquifer are examined in this study. One of the opportunities highlighted by the current groundwater management methodologies, analyzing and monitoring groundwater quantity and quality, is one way to ensure sustainable groundwater use in Qatar. The water resource system in Qatar was examined using the groundbreaking Driver-Pressure-State-Impact-Response paradigm, which outlines the causal relationship between the driving forces and impacts before articulating the solutions.Groundwater abstraction is under a lot of strain due to the excessive use of groundwater for agricultural irrigation, which degrades the quantity and quality of the groundwater environment and affects the need for food and water. Therefore, the conclusion emphasizes the necessity of enhancing rainfall infiltration into the aquifers, recharging the groundwater aquifers with treated sewage effluent or desalinated water, creating groundwater treatment procedures, and utilizing effective water irrigation practices. The use of treated wastewater for irrigation, the creation of appropriate water-use tariff systems, and farmer awareness campaigns are other considerations.

Keyword: *Groundwater, Sustainable development, Water resource, National strategies, management*

INTRODUCTION:

Qatar is an arid country east of Saudi Arabia that stretches as a peninsula into the Arabian Gulf. Qatar has a total land area of 11,586 km2 and runs north to south. Qatar's maximum length is 180 kilometers, and its maximum width is 85 kilometers. The Arabian Gulf surrounds it except for the south, which is shared with Saudi Arabia. Qatar's population has grown significantly over the last few decades, and urbanization has resulted from rapid economic development based on the fossil-fuel industry. Qatar's population has grown immensely from around 50,000 in 1960 to approximately 2.8 million in 2020.This rise in population was accompanied by an increase in demand for the nation's meager water supplies. As a result, the nation's meager, renewable natural water resources have been grossly overused. The current global average for water use per person is 500 l/day. The only supply of fresh water in the nation is from aquifers. Groundwater levels and quality have significantly decreased due to widespread groundwater pumping for agriculture irrigation during the past few decades. Farm farms are predominantly gathered in Qatar's northern region, where fresh groundwater is found.The ever-increasing domestic demand caused by Qatar's population growth and urbanization are met by saltwater desalination. Domestic demand is satisfied through desalination to 99%, with groundwater providing the final 1% of the supply. The produced desalinated water is stored in small tanks that can last two days without needing replenishment. Diversifying water supplies, including artificial groundwater recharge, is thus one of Qatar's significant challenges in improving water security. Building a giant reservoir (on-land tanks) can extend water security from two to seven days, according to Qatar Electricity and Water Corporation.

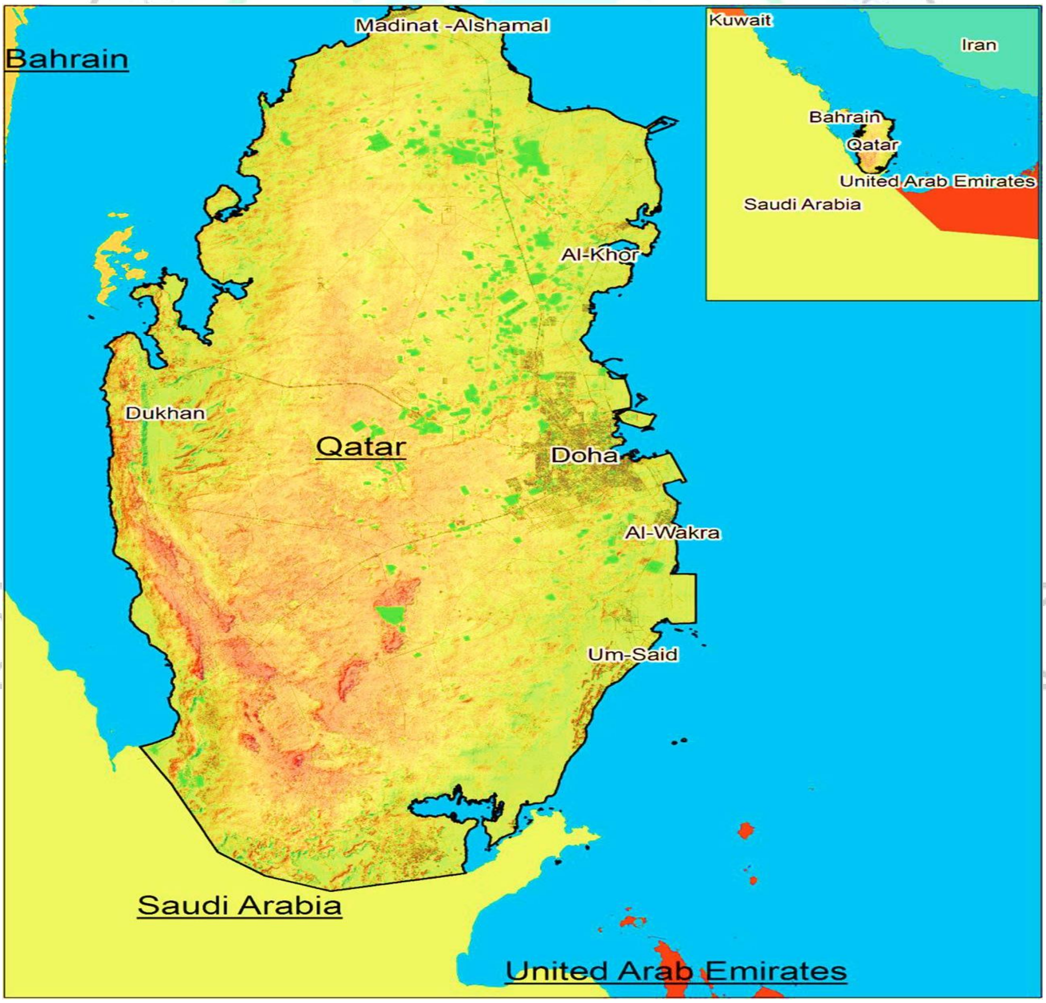

Fig: Location map of Qatar

In contrast, aquifer storage and recovery capacity are significantly higher. Using and managing treated wastewater can help meet a sizable amount of the non-domestic water demand. Since most of Qatar's treated wastewater is now being dumped into open fields, its potential is not being fully realized. For landscaping and fodder crops, only a tiny percentage of the treated wastewater (14% is utilized). The main difficulties for Qatar's sustainable development are the lack of renewable water resources and the rising demand for water from diverse economic sectors. In order to comprehend the intricacy of these problems and to develop a plan to solve them, it is crucial to look into and study the water supply and demand situation.The study provides further initiatives and suggestions for improving the long-term viability of the development of water resources. The existence of potable water has been examined in both rocks from the Cretaceous and Paleocene eras. In Qatar, brackish groundwater has been discovered in rocks from the upper Cretaceous, while potable water has been found in rocks from the Eocene.

Dammam formation and Rus formation are used to describe the Middle Eocene age in Qatar, whereas Umm er-Rhaduma is used to describe the Early Eocene/Paleocene era. The 50 m-deep Dammam Formation covers the vast majority of the Qatar peninsula. Limestone, known as the Abaruq Member, is on top of chalky limestone, the Umm Bab Member, in the upper portion. The Dukhan Member, a sizable clayey fossiliferous limestone, is in the lower part. A low carbonate attapulgite shale that ranges in color from yellow-brown to greenish-gray is also found beneath the Midra Shale Member. Significant fractures and voids in the upper portion.The Dammam formation is uniformly located beneath the Rus formation. In the north and center of the peninsula, the Rus formation ranges in thickness from 28 to 44 meters, while it is 110 meters thick in Qatar's southwest. It is rich in marl, dolomite, anhydride, and limestone. The Rus conformably lies beneath the Umm er-Rhaduma formation. It is made up of a dense series of roughly 300-500 meters of brownish or greyish limestone that is well-porous and dolomitic in the upper part and is distinguished by the presence of well-fractured karstic dolomite and argillaceous in the lower half. According to assessments, most wells in Qatar's center and south reach the Rus formation aquifer, which is situated above the gypsum layer that confines the Umm er-Rhaduma formation aquifer. According to reports, most wells in north Qatar access the Rus and upper Umm er-Rhaduma formation aquifers. In contrast, the older Aruma aquifers of the Aruma formation are apparently tapped by certain groundwater wells in the Abo Samra (southwest), which are from Saudi Arabia. Due to the erosion of the confining layers and the development of karst structures, aquifers of the Dammam formation are unconfined in several places except for the limited, slightly fresh water around Abu Samara, which receives inflow groundwater from west Saudi Arabia, all of the fresh groundwater in Qatar is derived from local rainfall. The more significant portion of the annual recharge is derivedfrom runoff infiltration, which typically gathers in surface depressions. According to estimates, rainfall recharges groundwater by 25 million m3 per year, comparable to other studies that looked at 7 to 10% of annual precipitation in the north of Qatar and 3.5 to 5% in the south.

WATER RESOURCE STATUS IN QATAR:

Groundwater and precipitation are Qatar's only natural sources of freshwater. The nation's only naturally occurring freshwater resourcesare found in the Trans Boundary Fossil Aquifers because the country lacks surface water. Qatar's municipal and industrial sectors are primarily dependent on desalination, while the agricultural sector uses groundwater resources for crop irrigation and cooling. Additionally, landscape and fodder irrigation are used for treated sewage effluent. Desalinated water has become the nation's preferred and primarywater source due to low energy costs (and an absence of natural freshwater supplies). While doing so, carbon emissions and marine pollutants impact the ecosystem.However, transitioning away from groundwater extraction and toward higher-value applications of treated sewage effluentand treated produced water from the oil and gas industry, as well as the implementation of the newest, most energy-efficient desalination technologies. Linking desalination with renewable energies should bevital to the freshwater sector strategy.Groundwater in Qatar mainly supplies the agricultural sector. The several formations that makeup Qatar's various aquifers overlay one another. Shallow aquifers are found in the top strata, which are made up of the Dam and Dammam Formations. Below, the Paleocene Umm er Rhaduma Formation represents the deeper aquifer with the highest salinity content, while the Lower Eocene Rus Formation was formed. The three primary basins are the northern, central, and southern basins, and as one moves from the north to the south, salinity levels range from low to high. The salinity of the Northern Basin ranges from 500 to 3000 ppm and can reach 10,000 ppm close to the coast (drinking water and agriculture irrigation water should be between 200 and 400 ppm). At a depth of 10 to 40 meters, it covers around 19% of Qatar.

About half of the nation is covered by the Southern Basin, which is only marginally salinized.The quantity of groundwater that can be safely removed from a basin over time without going above the long-term recharge is roughly 56 million m3 per year. But because of the current groundwater abstraction, which has reached just over 250 million m3 annually, aquifers are being depleted, groundwater levels are dropping, and salinity is rising. The overall stock increased from 108 million m3 in 2008 to 258 million m3 in 2020.The water balance decline, however, stayed essentially constant during the same period between 267 and 269 million m3. There has, as a result, been an annual water deficit between 2008 and 2019 that has ranged between 166 million m3 and 11 million m3. The primary source of additional water reserves is artificial recharge and irrigation returns. The reduction in water reserves is a result of water withdrawal for agriculture. Qatar has recently taken on the challenge of becoming the Middle Eastern region's most self-sufficient and sustainable nation. The nation's food output has since increased thanks to the agriculture and farming industries' growth.In Qatar, groundwatercontains about 47.5 million m3/year of water and is the leading renewable water source. For agricultural purposes, Qatar has traditionally relied on groundwater (92% of the total abstraction) and treated wastewater (almost 35% of the total production in 2015). Groundwater abstraction has caused a sharp decline in the groundwater table and a rise in salinity since it is 30 times more intensive than ordinary recharge rates.

QATAR'S WATER DEMAND:

In Qatar, groundwater, which contains about 47.5 million m3/year of water, is the leading renewable source. For agricultural purposes, Qatar has traditionally relied on groundwater (92% of the total abstraction) and treated wastewater (almost 35% of the total production in 2015). Groundwater abstraction has caused a sharp decline in the groundwater table and a rise in salinity since it is 30 times more intensive than ordinary recharge rates.Due to a shortage of freshwater resources and a heavy reliance on energy-intensive alternatives like desalination, Qatar's ability to preserve its water resources has been a concern, as it is for the other members of the Gulf Cooperation Council. A 30-year master plan was created in 2009, and between 2010 and 2015, the nation will invest more than USD 5 billionin desalination plants, wastewater treatment facilities, and other water infrastructure projects. However, from a demand perspective, is thought that the government and agricultural industries utilize the most water.

In 2015, groundwater accounted for 230 million m3 of the water utilized in agriculture, whereas treated wastewater accounted for 66.29 million m3. The industrial sector uses three primary sources of freshwater: mining and quarrying, manufacturing, generating electricity, and providing water and construction services: desalinated groundwater well water, desalinated seawater from Kahramaa, and seawater that has been desalinated on-site at the industrial facility. Without including desalinated industrial water, this industry used 34.18 million m3 in 2019. 85 million m3 of water were used in the commercial/municipal sector in the same year, which Kahramaa supplies exclusively.In 2019, the government sector consumed 156.65 million m3 of water, including water used for drinking from Kahramaa fountains and irrigation of green spaces from TSE. The final statistic is that 291.10 million m3 of water was used for household purposes in 2019. (Planning & Statistics Authority, 2021).

SUSTAINABLE GROUNDWATER MANAGEMENT:

Groundwater management and use must be sustainable for society's, the economy's, and the environment's progress to be accomplished. The quantity and quality of groundwater are also changing due to the widespread use of groundwater extraction and distribution technologies, despite their low cost. Therefore, new irrigation techniques like root-zone irrigation, greenhouse technologies, or reducing water use by reusing wastewater in homes should be adopted.However, the invisibility of groundwater resources, limited data, lack of knowledge, inadequate detection and monitoring systems, and the absence of integrated institutional (social, economic, technological, and ecological) frameworks contributed to the long periods during which the groundwater deterioration went unnoticed. In order to support sustainable water management, including preserving people, flora, and fauna, there is growing concerned about maintaining groundwater-dependent ecosystems. However, a comprehensive dataset is necessary for each location to preserve GDEs.

The goals of Qatar's national development strategy for 2018 to 2022, which include "ensuring availability and sustainable management of water and sanitation for all," are supported by conserving the quality and quantity of the country's groundwater resources. A significant amount of money has been invested in creating a sustainable water economy where desalination, sewage treatment, and reuse regulations can support a sustainable Qatar.An essential natural resource, groundwater accounts for 99% of the world's liquid freshwater and around 30% of all freshwater worldwide. Significant groundwater extraction and climatic changes like global warming were linked to the global fall in the water table and groundwater storage during the final six months of the 20th century. Roughly 2 billion people receive a sizeable portion of their fresh water from groundwater, which accounts for nearly 40% of the world's agricultural water and about 50% of the world's municipal water. Groundwater must be a source for irrigated food production to meet food needs. Climate change will increase global water demand for food production by 70–90%.

Table-Qatar sustainable water resources

Sustainable water resource	Quantity(millionm^3/year)
Groundwater	62
Surface water	0.0
Treated wastewater	330
Desalinated water	540
Domestic	500
Agricultural	250
Totalconventionalsources	62
Totalnon-conventionalsources	870

Source-QSA

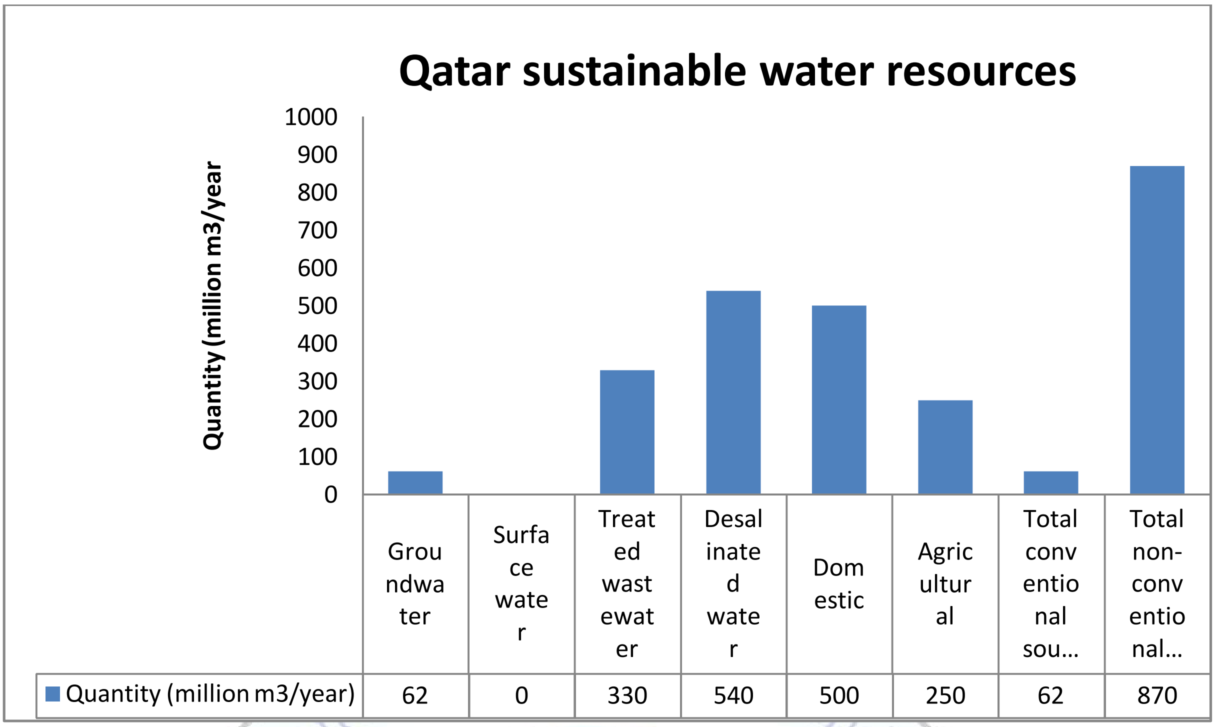

Fig: Qatar sustainable water resource

The safe groundwater yield in Qatar is roughly 55.8 million m3 per year. Although groundwater is being extracted at approximately 250.8 million m3 annually, this will deplete aquifers, lower groundwater levels, and increase salinity. It is interesting, considering that Qatar's population grew from 600,000 in 2000 to 2,685,000 in 2018, given the country's rapid economic growth. Irrigated agriculture used around 36.2% of Qatar's total water supply in 2011. Around 43% of the water utilized in agriculture is used to irrigate fodder crops, while flood irrigation uses around 70% of the water. According to FAO, surface irrigation was Qatar's most popular irrigation technique in 2000.The FAO estimates that 9707.2 hectares were irrigated using surface techniques like basins and depressions in 2008. While 546 ha are irrigated with bubbles, 868.6 ha are irrigated with drip irrigation, and 1813 ha are irrigated with spray irrigation. The management of irrigation systems and their effectiveness directly impact groundwater management. As a result, the government of Qatar has supported research and studies on irrigation with saline water and its economics, improving TSE for forage production, particularly Rhodes grass to feed animals, and using cutting-edge greenhouses and irrigation systems to increase the efficiency of groundwater use.By 2020, it's expected that Qatar's domestic cattle herd will have tripled in size due to more than doubling the share of TSE allotted to agricultural and fodder production.

The annual additions to the groundwater reserve are accounted for by treating treated sewage effluent, recharge wells, and recharge from irrigation. Contrarily, the recharge is accounted for by rainfall and inflow from Saudi Arabia, representing 43.4% and 2% of the recharge. Groundwater quality and quantity are controlled by using infiltration ponds, ditches, or injection wells to enhance infiltration, purify water that passes through soil layers, and store groundwater in aquifers by artificial recharge. It should be kept in mind that treated water may be used for direct or indirect recharge per the drinking water standards.A further natural treatment method could be improved by using deteriorated water for infiltration recharge. However, pre- or post-treatment of water should be simple and inexpensive for artificial recharge management. The management of artificial recharging depends critically on the economic cost. For instance, infiltration ponds could lower the water treatment price for recharge. By reducing or limiting the use of wells, the planning and production development and water resources section of Kahramaa (Qatar's available power and water corporation) put limitations on future groundwater extraction.On the Kahramaa website, future groundwater management initiatives are listed, including one that involves monitoring groundwater extraction from farms using sophisticated well water monitoring devices online from a distance. Kahramaa is also testing artificial desalinated water injections into the aquifer to address the demand for water.

Because groundwater recharge is being reduced, groundwater concentrations are negatively impacted by climate change, such as the rise in evapotranspiration and an increase in evapotranspiration. Over 40 years, from 1980 to 2020, Qatar experienced a considerable increase in climatic warming. For instance, excessive evapotranspiration from shallow groundwater may result in mostly gypsum and halite dissolving. Sand storms and soil erosion are climate-related factors that can significantly alter the topsoil's geochemistry.The salinity of groundwater is a significant environmental problem; salinization primarily results from intense groundwater use, introducing saline water from deep underlying basement rock, deep buried valleys, or nearby surface water bodies, which may be exacerbated by drought and sea level rise. Salinization may increase the total dissolved solids and improve the interaction between the water and the rocks. The hydrogeochemical conditions strongly influence the distribution of these naturally existing elements in groundwater, and there is a strong correlation between elevated levels of naturally occurring elements and salinity.

QATAR WATAR STRATAGIES:

Water security and the sustainability of the water sector are given top priority in Qatar's National Development Strategies 1 and 2, as well as in the plans for its National Vision 2030. Through these overarching frameworks, Qatar has made significant investments over the past ten years in developing sustainable water strategies, improving the water network and infrastructure, promoting sustainable water usage, and introducing campaigns to increase water awareness and conservation. The human, social, economic, and environmental development pillars are the four interconnected pillars along which the Qatar National Vision 2030, announced in 2008, defines the long-term development outcomes for Qatar. The text also provides a framework that may be used to create and carry out various plans and strategies.The primary objective is to strike a balance between the environmental pillar and the other three dimensions or between developing and preserving natural resources for future generations. The vision acknowledges the necessity for sound water management to maintain the nation's growth despite water resource shortage, and the Permanent Water Resources Committee of the country ordered the creation of the Qatar Water Security Policy. Qatar Water Strategy and Implementation Plan to offer the necessary strategic vision and action plan for a water-secure future.

The water sector strategy can guarantee continuity of water supply and pressure, the highest water standards, water storage, and water security for future generations by focusing on water as a human right and, consequently, the rights to water and sanitation. It also corresponds with Qatar's national vision for 2030. For the water sector, NDS-1 covers the years 2011 through 2016. It first identifies the reforms required for the sector, including the leaks and losses in the desalination network, over-abstraction of aquifers, and significant amounts of wastewater that are not collected, treated, or utilized. It highlights a variety of measures to address these difficulties, ranging from technological improvements to lower network water losses to the introduction of water-saving devices and user charges that more correctly reflect the actual economic cost, or at least the operation and management of the water resources. The concept also includes implementing crop blending and irrigation technology and altering water use patterns in the agricultural sector. In order to press for the necessary reforms in the water sector, new regulatory strategies must be put into place.A comprehensive National Water Act is developed in this vein to unify the disjointed structure of rules and regulations. To support the implementation of the QNV 2030, NDS-2, which is planned to run from 2018 to 2022, builds on the successes and results of NDS-1. The development of treated wastewater networks and encouraging their use are significant. There are three specific targets for TSE, which include:

1. By 2022, provide the infrastructure needed to utilize 70% of TSE generated across various initiatives.
2. By 2022, implement an integrated management system for water and associated pollution in industrial zones.
3. Reduce the rate of contaminated drinking water to 8% by 2022.

Both Qatar Vision 2030 and the National Development Strategy acknowledge the necessity of effective water management to support Qatar's rapid economic development despite the country's limited access to natural freshwater resources. The country's Permanent Water Resources Committee mandated the establishment of the Qatar Water Security Policy and Qatar Water Strategy and Implementation Plan to offer the necessary strategic vision and action plan toward a water-secure future. Stantec was chosen by the Qatar General Electricity and Water Corporation to provide a comprehensive framework for water resources policy and strategy. To develop a framework that directs the sustainable management of existing resources and long-term water security, we drew on our extensive field experience.As a result, Qatar's water balance model, which is currently the most accurate and detailed, was created. To follow the water's path throughout the system, we geospatially mapped the complete flow of water down to the plot level. Our team also conducted a thorough evaluation of the sector's institutional framework. The Qatar Water Strategy 2030 provides a clear and audacious plan to manage all waterways available to Qatar to support socio-economic development, a water-secure future, and national competitiveness. It is based on technical and governance evaluations of the Qatar water sector.

CONCLUSIONS AND POLICY IMPLICATIONS:

To ensure sustainable groundwater usage and management, techniques for supply and demand management should be adopted in Qatar. Agriculture uses a substantial amount of groundwater. A management plan should therefore concentrate on these actions. For demand management, educating the agricultural industry about the adverse effects of groundwater mining, promoting the use of alternate water sources, and employing effective irrigation methods to reduce groundwater are all important.Groundwater management decisions are made by weighing the costs and benefits of various options based on ecological factors like water quality assessments, engineering factors like water treatment technologies, societal factors like food availability, and individual perceptions of water quality. For Qatar's groundwater to be used and managed sustainably, supply and demand management techniques should be used.Moreover, reliable and affordable methods of groundwater remediation for poor quality.Developed monitoring systems, controlled storage, recovery projects, and artificial recharge through recharge wells and lagoons using treated wastewater and desalinated seawater should all be part of the supply management strategy. Due to Qatar's tiny groundwater users and low population density, some institutional strategies must be very effective to maintain a consistent supply of groundwater in terms of quantity and quality. Decision-makers now have access to essential data and expertise thanks to recent advances in data analysis technologies, remote sensing, modeling, groundwater characterization, and measurement.

In Qatar, sustainable development is focused on managing and securing the country's water resources. Their success has been emphasized in the country's initiatives since 2008, including the QNV 2030, the NDS-1 and NDS-2, the upcoming NDS-3 (2023–2027), and the countless local, regional, and international programs. Water in arid settings is still a major political issue in Qatar, and more action is required to advance the country's development and economy. Increasing public awareness of water issues and participation in water conservation initiatives by civil society and local communities complement the significant achievements in the water sector, which range from scientific and technological advancement to policy strategies, regulations, and legislation. More demands on water resources are anticipated as Qatar continues to prosper, strives for greater self-sufficiency in food production and industry, and grows its workforce. As a result, both old and new issues lie ahead, necessitating the planning and implementation of sustainable solutions that aim for a comprehensive strategy involving all the players and segments of the water sector. The management of sustainable water resources can be viewed from the angles of societal access and quantity as well as allocation efficiency.

Monitoring and enforcing rules are also essential because they guarantee water conservation and that aims and goals are accomplished, taken into account, and altered along the road if parameters, thresholds, or dynamics change. From the standpoint of water demand, actions to lower the municipal sector's per capita water demand should be further supported and complement Trashed initiatives to advance the reduction efforts. In light of the FIFA 2022 World Cup events, this would become vital, especially for the service sector, and should be accomplished through a coordinated and collaborative campaign among the various stakeholders.The current water tariff structure should also be revised and updated to correctly reflect the dearth of natural water resources and at least cover the costs of running and managing the water sector. On the supply side, the initiatives to stop leaks and losses within the water network must be advanced along with technology developments in produced water management, wastewater management, and the infrastructure required to step up, increase, and diversify the water inventory.Similar opportunities exist in the desalination industry, which uses fossil fuels to generate electricity and releases large amounts of highly concentrated brine into the atmosphere, making it unsustainable from an environmental standpoint. Last, water sector digitization, which focuses on integrating digital solutions and technology into Qatar's water management system, can significantly establishintelligent cities and water sustainability. To sum up, updating the KPIs and indicators used to assess water utility operations can open the door to creating managerial and regulatory incentives to enhance performance in the water sector.

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