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Harnessing biosaline agriculture for food security in the arid GCC

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EXTENDED ABSTRACT

Water scarcity is a prominent challenge threatening efforts to achieve food security in the GCC. A predominantly arid region characterized by scant and erratic rainfall combined with high potential evaporation rates exacerbates the profound and widespread impacts of accelerating water scarcity on local agricultural sustainability. The increasing demand for freshwater to meet the growing need for food to sustain the growing population remains a pressing concern amidst the constrained freshwater supply. Agriculture, consuming over 70% of the available water resources in the GCC, faces a forecasted 50% increase in water demand by 2050, intensifying competition with other essential water sectors.

Climate change's present and anticipated impacts on agriculture and water resources suggest a worsening situation for arid regions such as the GCC. Rising temperatures, variable rainfall, and increased occurrences of extreme droughts and floods are set to exacerbate water scarcity, jeopardizing vulnerable farming communities and food security. Global warming is expected to lead to higher temperatures across many regions, including the Middle East. Higher temperatures can intensify evaporation rates, potentially leading to increased water loss from soils, wadis, oasis, and reservoirs. North Africa is predicted to get drier, with an annual rainfall deficit reaching more than 50% by the end of this century under a high-emission scenario. The annual rainfall predictions for the GCC are more optimistic, with a potential increase in the annual rainfall reaching more than 50% by the end of this century under a high-emission scenario. However, this rainfall increase is insufficient to meet the growing demand for freshwater.

Soil and water salinization also present a growing concern in the MENA, the GCC region, and globally, posing a threat to some of the most productive lands currently utilized for irrigated agriculture. Rapid soil degradation due to salinization and soil sodicity has emerged as a significant challenge in recent decades, leading to substantial risks to global food security and environmental sustainability.

These mounting pressures severely undermine the region's capacity to ensure equitable access to water and food for all. The agr-innovative programs the International Center for Biosaline Agriculture implemented provided locally suited solutions for increasing food production in arid conditions with limited freshwater availability. This research for development programs focused on four main thematic areas of research. The first program is climate-smart crops that are heat, drought, and salt tolerant. These crops can grow under harsh, arid environments, where a range of crops that can tolerate different levels of salinity were provided to many farmers in these arid regions. For example, for low soil and water salinity levels ranging from 5 to 8 ds/m, Amaranth, Sorghum, Pearl millet, Mustard, and Sunflower produced a significant yield increase of 30% compared to conventional varieties or crops. Similarly, for higher salinity levels up to 30 ds/m, important forages, fruits, and crops such as Salicornia, Sporobolus virginicus, distichlis Spicata, date palm trees, and quinoa were

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grown. In addition to selecting and introducing these crops, ICBA provided a holistic solution through farms' best practices of inputs and fertigation, irrigation, and enhancing the value chain from the farm to the fork.

The second program is land and water, providing smart solutions for improving water use efficiency and agricultural water productivity. On-farm management practices utilizing water-saving and fertigation technologies have proven effective in conserving water and maximizing farmers' benefits per unit of water used. Scaling up these best practices through field extension projects and training initiatives can enhance the quantity and quality of food production, meeting market demands while minimizing environmental impact.

Watershed management using GIS and remote sensing techniques helped to manage the available water resources at the basin and sub-basin levels. Land use and land cover mapping were used to delineate the change in the agricultural areas needed to track and monitor agricultural production and productivity, and it also allowed the calculation of the actual water use of selected crops. In addition to brackish water, other non-conventional water resources such as treated wastewater, desalinated water, and its valuable by-product, the brine, were used in ICBA's research and development projects. These water resources are crucial in averting food crises and sustaining food production. ICBA promoted using non-conventional water resources in agricultural production because they are crucial for addressing water scarcity. Fortunately, many countries in the GCC region have incorporated non-conventional water resources into their national water balance and strategies, encompassing policies, institutional frameworks, regulations, and more.

Improving soil health through mixing with suitable soil amendments such as biochar helped to achieve a better crop yield, saved water up to 30%, and allowed for carbon sequestration. Adding the soil amendment improved the soil water retention near the crop roots. The rehabilitation of degraded soil due to salinity and sodicity showed significant improvement in agricultural production, bringing degraded lands to be productive again. Many farms are abandoned due to increasing soil salinity or degrading the water quality. Best practices to improve the soil health provided to the farmers through demonstration farms, farmers' field schools, and extension works improved the farms' yield and protected the environment from further degradation.

With the emergence of big data, the data-driven program succeeded in modeling the effect of climate change on agricultural production using several global and regional climate and emission scenarios, which helped the countries monitor and plan their water resources to adapt to or mitigate its effect. The Center built the staff capacity in four countries in the MENA region, Morocco, Tunisia, Jordan, and Lebanon, by developing decision support tools to allow them to monitor the drought events and make the right decision at the right time.

Remote sensing and satellite images integrated with in situ field sensors controlled by the Internet of Things (IoT) provided more precise estimates of crop water requirements and appropriate irrigation scheduling by irrigating the right volume of water at the right time. High-resolution satellite images were downscaled from global databases and used with less than 30 meters resolution. Several applications and tools were developed using machine learning and AI, and they benefited from these open-source images.

Significant innovative solutions were provided under the novel production program, which focused on improving Controlled Environment Agriculture (CEA) by developing desert-type CEA in collaboration with a Korean program. The research addressed significant issues of greenhouse cooling, new structural designs, growing media, and relevant materials. The water saved from irrigation and cooling was about 30% compared to the conventional CEA. Alternative water sources for cooling were tested at ICBA's farm, such as brackish water and treated wastewater. The results showed the potential to use these alternative water resources in cooling, but further research is still needed on their technical and financial feasibility.

The Integrated Agri-Aquaculture Approach showed realistic results and was considered a relevant agricultural solution for the arid environment. The approach incorporated circular economy concepts by using brine as a water source instead of considering it a waste. This provided additional benefits to the farmers by growing fish in the fish tanks using brine water, and sequentially, the aquawater is used to irrigate halophytic crops. The experiment's results showed a potential to scale out this approach for many farmers using small-scale RO units on their farms.

In conclusion, in the face of increasing water scarcity and the challenges posed by aridity, harnessing biosaline agriculture emerges as a promising strategy for securing food production in the arid GCC region. The extensive efforts of the International Center for Biosaline Agriculture underscore the potential of innovative agricultural practices tailored to thrive in harsh environments characterized by limited freshwater availability and high salinity levels.

ICBA's multifaceted approach, spanning climate-smart crops, efficient land and water management, and integrating non-conventional water resources, exemplifies a holistic strategy toward sustainable food production. Significant yield increases have been achieved by introducing heat, drought, and salt-tolerant crops suited to the region's conditions, offering a viable alternative to conventional varieties. Moreover, optimizing water

use efficiency through on-farm management practices and adopting water-saving technologies contributes to conserving precious freshwater resources while maximizing agricultural productivity.

The utilization of non-conventional water sources such as treated wastewater and desalinated water, coupled with innovative irrigation techniques, not only mitigates water scarcity but also enhances the resilience of agricultural systems against climate variability. ICBA's emphasis on improving soil health through soil amendments and rehabilitation techniques boosts crop yields and rejuvenates degraded lands.

Moreover, ICBA's pioneering initiatives in harnessing big data, remote sensing, and IoT technologies enable precise monitoring of agricultural systems, facilitating informed decision-making amidst changing climatic conditions. By leveraging cutting-edge advancements in Controlled Environment Agriculture (CEA) and integrated agri-aquaculture approaches, ICBA pioneers sustainable farming practices that promote resource efficiency and circular economy principles.

As the GCC region navigates the complex interplay of climate change, water scarcity, and food security, the transformative potential of biosaline agriculture becomes increasingly evident. The GCC can unlock new pathways towards resilient, sustainable, and food-secure futures in the arid landscape by scaling up these innovative solutions and fostering collaboration between research institutions, governments, and farmers. Through concerted efforts and strategic investments in biosaline agriculture, the GCC can transcend the challenges of aridity, ensuring food security for generations to come.

Keywords: Water scarcity; Food security; Agricultural sustainability; Global warming; ICBA; Water resources; Climate change; Agri-aquaculture approach; Remote sensing; IoT technologies