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Original Article

Analysis of Challenges and Barriers to Promoting Climate-Smart Agriculture in Rural Areas of the Sistan Plain: A Qualitative Approach

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Abstract

Purpose – This study examines the barriers to promoting climate-smart agriculture (CSA) in rural areas of the Sistan Plain. Using a qualitative approach and focus group discussions, data were collected from farmers and local experts (54 participants). The discussions were analyzed through inductive content analysis, coding, and classification systems.

Findings – The results reveal that barriers to CSA promotion fall into seven main categories: financial, institutional, technical and infrastructural, knowledge gaps, demographic, environmental, and market challenges. Key challenges include high initial costs, weak policies and institutional support, lack of practical knowledge and training, and adverse climatic conditions. Practical recommendations involve conducting specialized training, establishing pilot projects, and strengthening communication infrastructure. From a policy perspective, developing national strategies, providing financial incentives and credit facilities, and fostering collaboration across various sectors are crucial. This study offers comprehensive and integrated solutions to assist policymakers and agricultural practitioners in achieving sustainable development and strengthening CSA resilience.

Practical Implications – This study proposes several practical solutions to address the identified challenges, including organizing specialized and operational training programs for farmers and experts, implementing pilot projects to demonstrate CSA effectiveness and benefits, developing communication and technical infrastructure such as high-speed internet access and advanced equipment, formulating national policies to provide financial and institutional support for CSA, and fostering collaboration among governmental, private, and local community sectors.

Originality/Value – This research is one of the first comprehensive studies analyzing barriers to CSA promotion in Iran. Given the unique conditions of the Sistan Plain, the findings can serve as a model for other underprivileged regions in Iran and similar countries. The practical solutions and effective policy recommendations presented here mark a significant step toward sustainable development and greater agricultural resilience to climate change.

Keywords- Agricultural productivity, Climate-smart agriculture, Farmer resilience, Rural development, Sistan Plain.

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1. Introduction

Climate change refers to any change over time, whether resulting from natural variability or human activities (Kom et al., 2020). Researchers largely attribute climate change to the accumulation of greenhouse gases emitted from human activities (Jamshidi et al., 2015; Abegunde et al., 2019). However, it affects natural and social systems (Makamane et al., 2023). Climate change is evident in continuous global warming, including the increased frequency of heat waves, the decline in rainfall events, the loss of rainfall in arid and semi-arid regions, the rise in sea level, and the increased probability of these aspects developing in a nonlinear and unpredictable manner (Komba & Muchapondwa, 2018; Atal, 2024). In pursuit of variations in climatic conditions, farmers who rely on minimally adaptive rainfed farming systems will be seriously affected, making them extremely vulnerable to climate change (Mujeyi et al., 2020; Mabhaudhi et al., 2025). Furthermore, smallholders have inherently low resilience to cope with the consequences of extreme climatic conditions (e.g., drought and flood), deep climatic disharmony, and change.

Agricultural production is the main source of livelihood in most rural communities of developing countries (Serote et al., 2021). It is essential for ensuring food security and alleviating poverty (Mutekwa, 2009; Adhikari et al., 2024), a point also mentioned in the Quran (Munir & Glorino Rumambo Pandin, 2023). The Food and Agriculture Organization (FAO, 2020) argues that the agricultural activities of rural households form the foundation of the food system and contribute to achieving two major sustainable development goals: no poverty and no hunger. Smallholder farmers are at the forefront of the rural economy in Iran. It is estimated that there are 500 million smallholder farmers worldwide, supporting the livelihoods of over 2 billion people, particularly in developing countries (Serote et al., 2021; Kamara et al., 2019). These farmers provide agricultural products for consumption, supply essential nutrients, and generate income to supplement social financial aid and government bills (Podineh et al., 2017; Abegunde et al., 2019; Larasati et al., 2024). In Iran, climate change has led to declining yields, complete crop losses, reduced quality, and the increasing spread of pests and diseases, severely affecting vegetable production (Pakrooh & Kamal, 2023; Najafi et al., 2023; Jahansoozi et al., 2024; Amani-Male et al., 2024).

Cooperation is essential in the fight against the effects of climate change (Musafiri et al., 2022). One key intervention is the adoption of climate-smart agricultural methods by smallholders. Climate-smart agriculture (CSA) is a sustainable approach developed by the FAO to support farming under changing climatic conditions. CSA benefits farmers facing the agricultural impacts of climate change, such as prolonged droughts, declining rainfall, and shifts in rainfall patterns, which negatively affect crop and livestock productivity (Ouédraogo et al., 2019). CSA serves as an alternative agricultural method, promoting environmental conservation while helping to meet the world's growing food demand (Musafiri et al., 2022; Oteng & Egbendewe, 2024).

CSA refers to a set of farming practices and technologies designed to simultaneously enhance productivity, improve adaptation, and reduce greenhouse gas emissions (Sahoo et al., 2025; Kagabo et al., 2025). While CSA builds upon existing agricultural knowledge, technologies, and sustainability principles, it stands out in several key aspects. First, it explicitly focuses on addressing climatic variations within agricultural systems. Second, it systematically considers the synergies and trade-offs between productivity, adaptation, and mitigation of effects. Third, it encompasses a broad range of practices and technologies tailored to specific agro-ecological conditions and socio-economic contexts. These include the adoption of climate-resistant species, conservation agriculture techniques, agroforestry, precision agriculture, water management strategies, and improved animal management. Despite its potential, CSA faces significant challenges in developing countries like Iran. A lack of attention to these challenges could hinder efforts to achieve sustainable agricultural development.

This research aims to uncover the challenges hindering the promotion and application of CSA practices in the Sistan plain, as seen from the perspectives of local experts and farmers. Many farmers in this region suffer agricultural losses due to Afghanistan's violation of water rights and severe climatic effects, such as consecutive droughts and the 120-day winds. The Sistan plain, one of Iran's oldest agricultural regions, relies on the inflow of water from the Hirmand River for its survival. Given the arid and semi-arid climate of the region, agriculture is only viable if Afghanistan ensures a sustainable supply of water rights. However, in recent years, the decreasing water inflow, caused by factors such as dam construction in Afghanistan (e.g., the Kamalkhan dam), climate change, and declining rainfall, has created a severe crisis for farming and rural livelihoods. This hydrological drought has not only affected farmlands but has also dried local wetlands, intensified dust storms, and worsened rural migration. Several factors contribute to these vulnerabilities, including the region's unique geographical exposure to climatic disasters, fragile livelihoods, poor infrastructure, and demographic challenges, particularly the high dependence on agriculture for employment. By identifying the barriers to adopting CSA practices, policymakers in the agricultural sector can develop strategic plans for its advancement, focusing on facilitating farmers' adoption of these interventions.

In general, it can be acknowledged that the Sistan plain faces serious agricultural challenges, with one of the primary issues being the water supply crisis due to reliance on Hirmand water rights and Afghanistan's failure to uphold its international commitments. As a result, local agriculture is plagued by severe uncertainty and unsustainability, leading to declining productivity, increased migration, and worsening water security. These challenges are further exacerbated by climatic factors such as the 120-day winds, rising mean annual temperatures, and decreasing soil moisture, all of which negatively impact agricultural production. In such conditions, modern approaches like CSA can play a role in strengthening farmers' resilience. However, implementing CSA in a region already struggling with a water crisis requires a thorough examination of its constraints, opportunities, and practical requirements. Accordingly, this research aims to identify the barriers and challenges to promoting CSA in the rural areas of the Sistan plain.

2. Research Theoretical Literature

It is argued that the poor adoption of CSA technology is linked to several limiting factors, including high initial costs, technical knowledge requirements, expensiveness and limited availability, lack of insurance plans and financing mechanisms, and inadequate frameworks for monitoring smallholders (Ogunyiola et al., 2022). Makamane et al. (2023) highlighted that CSA practices play a crucial role in improving farmers' returns. However, challenges such as a lack of information, financial constraints, shortages of labor and inputs, and insufficient farm training hinder farmers from fully adopting CSA on their farms. As a result, key socioeconomic factors, farm characteristics, and institutional frameworks significantly influence the utilization of CSA by smallholders.

Another study identified key barriers to implementing CSA practices, including increased outbreaks of diseases and pests, limited access to agricultural technologies, and the high cost of various improved crops. The researchers concluded that smallholders' adaptation can be strengthened through the effective implementation of CSA practices (Baffour-Ata et al., 2023). File and Nhamo (2023) found that smallholders' decisions to adopt local practices for climate change adaptation were influenced by socio-demographic characteristics, access to farm capital, farm distance, the availability and reliability of the practices, input availability and cost, land ownership, access to extension services, and socio-cultural beliefs. Gabriel et al. (2023) concluded that farmers' needs on climate-smart adaptation, alleviation of implications, and profitability were solutions to reduce in-season crop loss, increase water use efficiency, and improve productivity.

Recent studies indicate that several factors influence farmers' decisions regarding the effective adoption of CSA technologies. Existing research primarily highlights economic benefits, along with other influential factors such as the farmer's education, farm location, household resources, farm size, farming experience, access to credit, availability of extension services, agricultural asset grants and information, market access, and support from local officials (George & Rwegasira, 2017; Kurgat et al., 2020; Nhantumbo et al., 2017). According to Sanogo et al. (2023), CSA adoption is significantly shaped by social factors, including age, educational level, experience in production systems, gender, marital status, and membership in cooperatives. Additional determinants of adoption include access to extension services, market availability, credit access, agro-climatic conditions, topography, water availability, policies and incentives, effective farmer training, family labor, crop insurance availability, economic viability, and technical capability for utilizing technology (Maddison, 2007; Alare et al., 2018; Zakaria et al., 2020; El-Chami et al., 2020).

Lupogo and Mkuna (2023) argue that farmers' decisions to adopt technology are influenced by socioeconomic, institutional, informational, and climatic factors. Socioeconomic factors include the age of the household head, gender, marital status, educational level, family size, off-farm family income, farming experience, and farm factors. Institutional factors encompass access to extension services, credit availability, membership in agricultural organizations, and farm distance from the market. The informational factor refers to access to climate-related information, while climatic factors include temperature and rainfall. The literature review suggests that a combination of challenges and barriers can slow down CSA extension and development. Identifying and categorizing these challenges from the perspectives of both farmers and experts can provide valuable insights for shaping CSA development policies.

Unlike previous studies that have primarily focused on the technical and climatic aspects of smart agriculture, this research emphasizes water governance and its role in CSA feasibility and viability in the Sistan plain. In addition to climatic challenges, we examine the influence of institutional, policy, and social factors in assessing the feasibility of this agricultural model. Building on the findings of previous studies, this research aims to offer a more comprehensive and pragmatic approach to sustainable agricultural development in the Sistan plain.

3. Research Methodology

3.1 Geographical Scope of the Research

The research was conducted in the Sistan plain, located in Sistan and Baluchistan province in southeastern Iran. Covering an area of approximately 15,000 km², this key agricultural region relies heavily on the water rights of the Hirman River, which flows from Afghanistan. The area experiences a hot and arid climate, characterized by 120-day winds and severe fluctuations in water resources. These conditions have led to ongoing crises, including water scarcity, rural emigration, and a decline in farming productivity in recent decades.

Based on the latest administrative divisions in Iran, the Sistan plain consists of five counties, nine urban districts, seven cities, 18 rural districts, and 823 inhabited villages. This plain accounts for approximately 9.3% of the total area of Sistan and Baluchistan province and about 15.8% of its population. Data from the synoptic station indicate that the region receives an annual average precipitation of about 59 mm, with a mean annual temperature of approximately 22°C. The absolute maximum temperature recorded is 45.9°C, while the absolute minimum is around -4.4°C. The annual evapotranspiration rate reaches 2579 mm, and the estimated evaporation rate from cultivated land is about 5.87 mm.

3.2. Methodology

The challenges and barriers to CSA promotion were identified using a qualitative methodology, for which the focus group technique was employed. This approach facilitates a structured group interview to gather opinions on a subject or phenomenon under study (Krueger & Casey, 2015). In other words, a focus group enables an organized discussion among selected individuals who are believed to represent various social classes (Mohammadpour, 2013). Like most qualitative research methods, this study utilized a purposive, qualitative, and criterion-based sampling technique. To implement the focus group, the practical design outlined by Stewart and Shamdasani (2015) was followed. This design consists of eight steps, addressing the rationale, procedures, and distinctive characteristics of the focus group method. The first step is to define the research problem and formulate guiding questions. Identifying the problem helps establish an operational definition of research objectives and facilitates their achievement. The key problem is that the agricultural sector in the Sistan plain is facing challenges and barriers to the promotion of CSA. Accordingly, the central research question was developed to examine these challenges and barriers from various perspectives: What are the challenges and barriers to CSA promotion in the Sistan plain?

The second step is to define the sample framework. In this phase, researchers determine the required number of participants and establish the characteristics that the sample should possess. Additionally, the sample is assessed for homogeneity and interpersonal relationships. It must accurately represent the perspectives of the research population. In this study, the sample consisted of farmers familiar with CSA practices and relevant experts in the Sistan plain. A total of 54 participants—27 experts and 27 farmers—were divided into six separate focus groups. The third step is to identify facilitators. Unlike interviews or surveys, the focus group method relies on facilitators rather than researchers. Facilitators should possess expertise in group work and have a strong reputation for leading effective discussions. Their role is to encourage participation and prevent a few individuals from dominating the conversation. In this study, agricultural extension agents at the county level served as facilitators and moderators. The fourth step is to recruit the sample. When inviting participants to the research, they must be informed about the time and location of the focus group meeting. Thus, an invitation letter outlining the topic, schedule, and meeting location is sent to participants. In this study, the heads of Agricultural Extension Offices in each county were first informed about the meeting, after which participants were invited.

The fifth step is to develop and pre-test the interview guideline. This guideline, which outlines the research objectives and questions, is prepared for the participants and then distributed to them and the facilitators before the meeting. This ensures that everyone is informed about the process and encourages greater participation. The sixth step is to conduct the focus groups. During this phase, the facilitator guides the discussion using the questions listed in the interview guideline. The facilitator should also focus on facilitating the discussion among the members. In this step, time must be managed carefully, and personal negotiations or side discussions should be avoided to keep the conversation focused. The interviews must be recorded in addition to taking notes throughout the meeting. In this study, each focus group session lasted an average of 2 hours and 20 minutes.

After the focus group sessions are conducted, the collected data must be analyzed and interpreted. In this step, discussions from each meeting should be summarized and examined, paying close attention to words, contexts, relationships, and other subtle aspects of the data. This study employed inductive content analysis, along with coding and the development of classification systems, to process the discussions. Each category was linked to subcategories, and the conception continued. Then, once classification was established, the codes were counted. The final step is reporting. The report must be prepared with care and patience. Additionally, it is recommended that the final report or its summary be shared with individual participants.

4. Research Findings

4.1. Characteristics of focus group participants

The results showed that the majority of participating experts (55.6%, or 15 individuals) were male, while the remaining 44.4% (12 experts) were female. All farmers in the focus groups (27 individuals) were male. Regarding age, the experts had an average age of 46.33 years (ranging from 38 to 60 years) and an average of 22 years of work experience (ranging from 12 to 30 years). The farmers' mean age was 55.11 years (ranging from 43 to 71 years), with an average of 32.07 years of farming experience (ranging from 11 to 60 years). All 54 participants—both farmers and experts—were married. In terms of education, 18.5% of the farmers held high school diplomas, 29.6% had associate degrees, 40.7% had bachelor’s degrees, and 11.1% had master’s degrees. Among the experts, 29.6% held bachelor’s degrees, 48.1% had master’s degrees, and 22.2% had PhDs. The primary occupation of 59.3% of the farmers was crop farming, while 14.8% were involved in animal farming and 25.9% in horticulture. Regarding land area, farmers had an average of 8.37 hectares of crop land or orchards (ranging from 3 to 16 hectares). The findings on CSA educational course participation revealed that, on average, farmers attended 3.96 courses in the past year, while experts attended 5.37 courses.

4.2. Barriers to CSA promotion in rural areas

Data was analyzed using a coding process consisting of open, axial, and selective coding. First, the recorded discussions were transcribed and carefully examined to extract key concepts (analysis units) during the open coding stage. This process resulted in a set of concepts, characteristics, and subcategories. Next, subcategories were defined based on these extracted concepts, marking the axial coding phase. In the final stage, the main categories were derived by integrating the subcategories, considering their shared concepts—this was the selective coding phase. At this stage, the relationships between categories and subcategories became evident.

Based on the results derived from data coding and classification, the challenges of CSA promotion in the Sistan plain fall into seven broad categories: financial challenges, institutional challenges, knowledge gaps, demographic challenges, market challenges, technical and infrastructural barriers, and environmental challenges. Each of these categories contains subcategories, referred to as concepts. The findings indicate that financial challenges ranked highest among the barriers to CSA promotion, appearing 199 times in the data and representing the most diverse category. This category consists of six key concepts: inadequacy of government subsidies and support, unequal access to resources, limited availability of financial resources, high initial costs, economic profitability uncertainties, and structural poverty in agriculture.

The barrier of inadequate government subsidies and support was the most repeated among financial challenges. The government does not provide sufficient subsidies for the purchase of climate-smart technologies, and most subsidies are not directed toward smallholders or regions experiencing severe crises. In other words, it can be said that subsidy reforms have largely failed. Government investment in CSA projects in Sistan and Baluchistan province remains very limited. The allocated budget is primarily spent on high-priority projects, such as water supply initiatives, rather than the advancement of modern technologies. Additionally, there are no specific regulations incentivizing farmers to adopt modern and smart technologies, such as tax exemptions for those utilizing these innovations. Furthermore, no agricultural cooperatives have been established in the province to financially support climate-smart projects, and there are no collective investment frameworks for innovative farming initiatives.

The second subcategory of financial barriers is unequal access to resources. Most investments are concentrated in central Iran, leaving farmers in deprived regions, such as Sistan and Baluchistan, with a disproportionately small share. Moreover, financial and credit resources are unequally distributed across provinces and regions, with economically disadvantaged areas receiving significantly less support. The situation in rural areas is further complicated by frequent power outages, which reduce the efficiency of power-driven smart systems. High energy costs also hinder the implementation of certain technologies, such as smart water pumps, in financially restricted regions. Additionally, monopolies in technology distribution by agricultural machinery-supplying companies limit farmers' equitable access to climate-smart technologies.

Limited access to financial and credit resources is a significant financial barrier to CSA promotion in Sistan and Baluchistan province. Most smallholders are unable to secure loans due to a lack of financial guarantees, and banks and financial institutions do not offer low-interest loans specifically for climate-smart farmers. Additionally, the absence of effective insurance to compensate for losses from climatic and agricultural risks discourages farmers from investing in new technologies. Another concern is that financial resources and credits intended for agricultural development are often redirected to other sectors or granted to individuals who are not physically present in the Sistan region. In many cases, recipients use their credit for purposes unrelated to agricultural advancement.

The high initial cost of implementing CSA technologies is also a major barrier to the development of this approach in most cases. Equipment such as smart sensors, drones, drip irrigation systems, and smart surveillance systems requires substantial upfront investment, which is unaffordable for many farmers. Beyond the initial cost of purchasing equipment, the maintenance expenses for these technologies pose an additional financial burden. Furthermore, most climate-smart tools are imported, making their prices vulnerable to fluctuations in foreign exchange rates.

The relationship between water scarcity and CSA development barriers in the Sistan plain is both mutual and complex. On one hand, the water crisis, resulting from the violation of Hirmand water rights, groundwater depletion, and inefficiencies in water projects, has significantly impacted agricultural infrastructure, making sustainable development planning increasingly difficult. On the other hand, CSA, as a complementary approach, can enhance farmers' resilience by optimizing water usage, predicting atmospheric patterns, reducing evaporation, efficiently utilizing soil moisture, and adopting drought-compatible cropping patterns. However, implementing these technologies without a minimally sustainable water supply will have limited effectiveness. Therefore, any investment in CSA development must be accompanied by efforts to manage water resources, improve water rights policies, and integrate modern irrigation systems to ensure meaningful returns.

Uncertainty in economic profitability, including the lack of adequate practical evidence demonstrating the economic benefits of CSA and the absence of clear short-term financial benefits, which naturally discourages farmers from investment in CSA, has significantly slowed the promotion of CSA in Sistan and Baluchistan province.

Finally, structural poverty in agriculture, rooted in farmers' low income and limited land ownership, is the last subcategory within the category of financial barriers. Most farmers in the studied province have low and unstable incomes, restricting their financial capacity to adopt new technologies. In addition, farmers with insufficient or no land may lack the motivation to invest in sustainable agricultural methods. Figure 1 presents additional relevant findings.

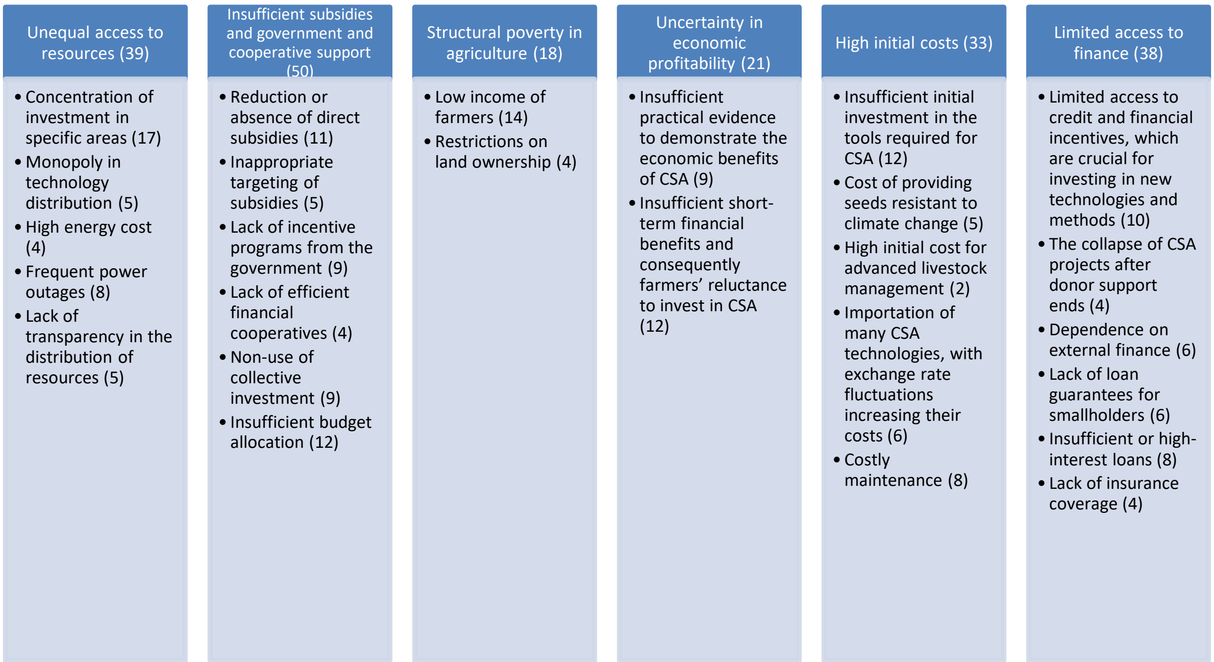

Figure 1. The financial challenges of CSA promotion in rural areas

The second category of challenges with the highest frequency (170 repetitions) was institutional barriers. These barriers were composed of four concepts: policy and governance, awareness and capacity-building, institutional support, and poor project monitoring and evaluation. Among institutional barriers, policy and governance emerged as the most frequently mentioned. Currently, there are no clear policies or strategic plans for CSA development at the national or regional levels. In other words, policymakers have yet to formulate a comprehensive and cohesive plan for regions like Sistan and Baluchistan, which are struggling with climatic crises. Existing agricultural policies primarily focus on rich and developed areas, leaving deprived provinces like Sistan and Baluchistan with lower priority. It means that macro-decisions are made in the capital city, limiting the authority of local institutions to create policies and implement localized programs. Policymaking instability and frequent administrative and managerial changes have further disrupted agricultural policies and programs, affecting long-term CSA projects. Additionally, there are no legal obligations to ensure the optimal use of water resources, the adoption of smart irrigation systems, or proper crop monitoring. Sanctions on technology imports have also hindered CSA promotion. Due to economic sanctions, CSA technologies and equipment are either unavailable or imported at prohibitively high prices. Furthermore, the lack of interaction with CSA-leading countries has stifled investment in this field. Another challenge is the absence of strong political commitment and effective transboundary policy frameworks, leading to inconsistent management of shared resources such as water. The region's heavy reliance on the Hirmand River (originating in Afghanistan) and the reduction in water received from Afghanistan are eminent examples of this issue. This challenge stems from Afghanistan's violation of historical agreements, including the 1972 Hirmand Agreement, which defines Iran's water rights.

Water resource governance and CSA development are two distinct categories that cannot achieve sustainable success without one another. On one hand, efficient management of water resources—particularly securing Hirmand water rights—is a fundamental prerequisite for agricultural planning. On the other hand, given that water scarcity has become a structural crisis, CSA technologies can play a crucial role in increasing the productivity of limited resources, reducing water wastage, and enhancing farmers' adaptability to local climatic conditions. Therefore, effective water governance, coupled with diplomatic efforts to secure water rights, can support the implementation of scientific and technological policies. This approach not only fosters local agricultural independence from water resources but also strengthens resilience against environmental challenges through modern farming methods.

The second most frequently cited subcategory of institutional barriers was awareness and capacity-building. This category encompasses several key issues, including the shortage of technical training centers, neglect of smallholders' rights, lack of experts, inattention to practical training, and disregard for farmer feedback. Smallholders, who constitute the majority of farmers in the province, lack adequate regulatory support. Additionally, they have limited access to training programs focused on smart agricultural technologies. Existing educational and promotional initiatives are predominantly theoretical, often failing to incorporate practical and applied CSA training. Furthermore, the shortage of trained and specialized CSA personnel within local agricultural departments hinders the delivery of effective extension and educational services. Compounding this issue is the absence of structured feedback collection from farmers and agricultural stakeholders, preventing research from evolving in alignment with farmers' needs.

Institutional support, identified as a major barrier, encompassed poor institutional frameworks, insufficient support by the public and private sectors, weak coordination among stakeholders, lack of institutional transparency, and lack of after-sales services. Participants noted that various agencies—including the Ministry of Agriculture, the Ministry of Power, and the Meteorological Organization—lack sufficient coordination in implementing CSA projects. In some cases, the lack of transparency in the administrative process and resource allocation impairs the efficiency of project execution. Additionally, when CSA equipment malfunctions, there are inadequate support centers available to repair or replace it.

Poor project monitoring and evaluation were identified as the final institutional barrier. It was found that Sistan and Baluchistan province lacks an effective system for assessing the performance of CSA projects, preventing the identification and resolution of their shortcomings. Additionally, many government resolutions and projects stall at the implementation phase or remain incomplete due to insufficient monitoring.

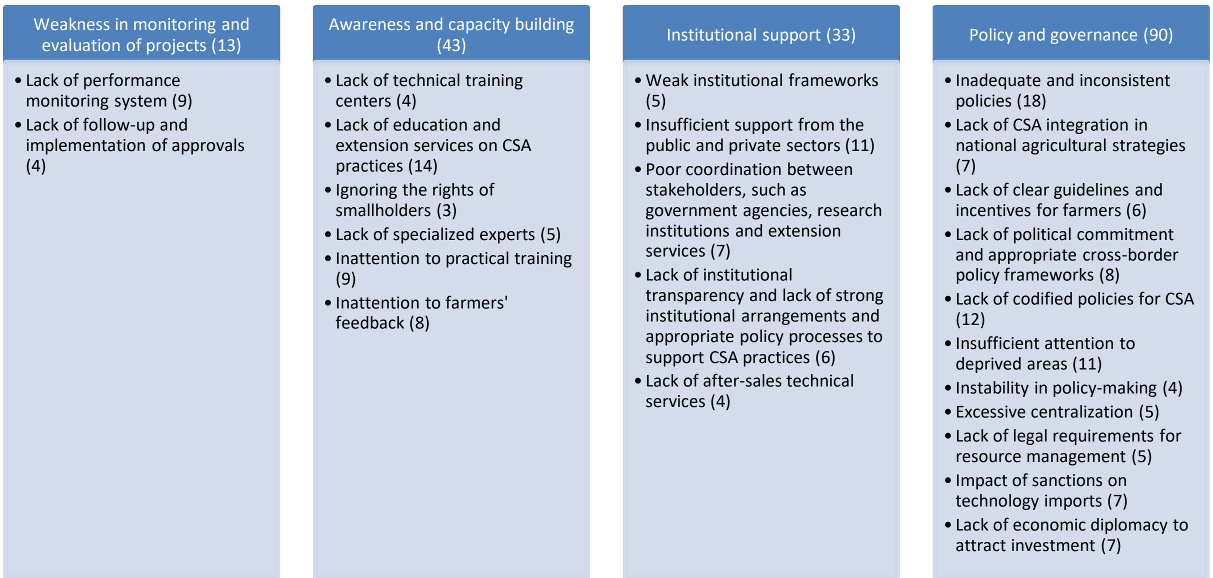

Figure 2. The institutional challenges of CSA promotion in rural areas

Technical and infrastructural challenges, cited 51 times, represent another set of factors that disrupt CSA development. These challenges are composed of five concepts, including poor research infrastructure, weak water resource management, lack of modern equipment and limited access to technologies, inadequate communication infrastructure, and ineffective collection and monitoring of climatic and agronomic data. Among these barriers, poor research infrastructure had the highest frequency of repetition. Investment in CSA research projects from both the public and private sectors has been extremely limited. Misallocation of budgets has marginalized research efforts, leaving existing research centers in the province underfunded and lacking modern tools and facilities necessary for conducting specialized tests and projects in the field of CSA properly. Moreover, private sector participation in financing research projects remains negligible, forcing most initiatives to rely exclusively on government funding. The lack of collaboration with international universities and research institutions has further hindered the advancement of innovative research in climate-smart and sustainable agriculture. As a result of financial constraints and inadequate facilities, researchers lack the motivation to pursue long-term and practical research. Due to limitations and shortages of facilities, many experts and researchers have left the province to work in better-equipped institutions in other provinces. Additionally, the absence of an effective evaluation system to monitor research activities and assess their success has led to wasted resources and unnecessary duplication of studies.

The second subcategory of technical and infrastructural challenges is the poor management of water resources. Despite the severe water scarcity crisis in the province, advanced irrigation systems, such as smart drip irrigation and automatic soil moisture control, are rarely available to farmers. This issue is further exacerbated by outdated and deteriorating water transfer systems, which increase water wastage and hinder efficient resource management. Additionally, precise data are not collected on water resource status and its application in smart irrigation planning.

The lack of modern equipment and restricted access to advanced technologies further exacerbate technical and infrastructural barriers to CSA. Essential technologies—such as agricultural drones, soil and moisture sensors, and irrigation management systems—are either unavailable or poorly distributed across the region. Since most smart technologies are imported, they are not only expensive but also difficult for local farmers to access. Even when available, the absence of skilled technicians to install and maintain these systems poses an additional challenge. Furthermore, much of the existing agricultural machinery is outdated and inefficient, making integration with modern technologies impractical.

Inadequate communication infrastructure, a subset of technical and infrastructure-related challenges, disrupts CSA promotion. Many rural and agricultural areas in the province lack access to high-speed internet, despite climate-smart technologies relying heavily on digital communication, such as remotely sensed data analysis and smart irrigation management. Additionally, poor telecommunication and mobile network coverage in certain regions hinders the use of smart tools, e.g., agricultural applications and quick messaging services. Similarly, the installation of smart systems like soil and moisture sensors requires an Internet of Things (IoT) platform, which is unavailable in the area. Moreover, farmers struggle to access essential knowledge and expertise because they lack communication networks that connect them with specialists.

Weaknesses in collecting and monitoring climatic and agronomic data pose a significant technical and infrastructural barrier. Addressing this challenge requires access to advanced meteorological stations, remotely sensed data, local climate prediction software, and natural resource monitoring and management systems. Accurate climatic data is essential for smart agricultural management, yet the province lacks sufficient advanced meteorological stations. In addition, CSA relies on satellite data for soil analysis, crop growth analysis, and resource management, but these data are currently inaccessible to local farmers. Furthermore, precise weather forecasting tools and localized climate change analysis systems have not been developed. The absence of smart monitoring tools for the analysis of water, soil, and air status prevents sound and optimal environmental resource management.

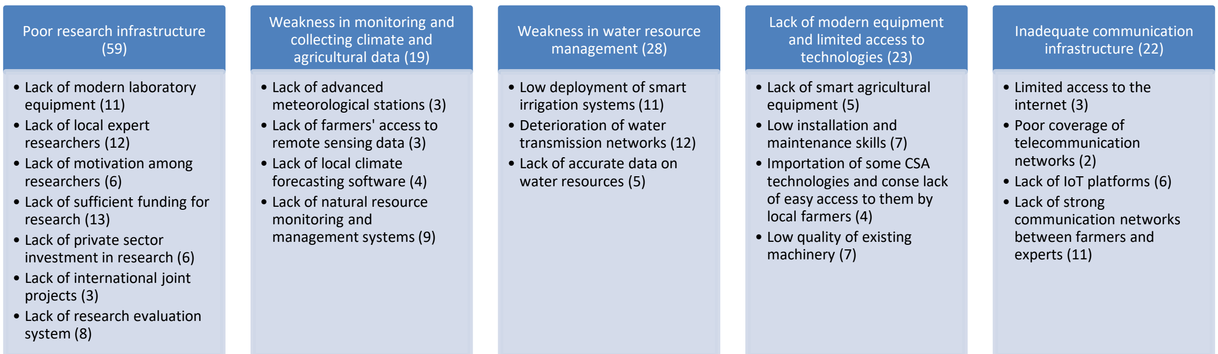

Figure 3. The technical-infrastructural challenges of CSA promotion in rural areas

Demographic barriers, cited 99 times, represent another major challenge to CSA promotion in Sistan and Baluchistan province. These barriers stem from the region's distinctive cultural, social, and economic characteristics. This category is divided into four subcategories: culture and community (38 repetitions), awareness and education (31 repetitions), immigration and the loss of farm labor

(16 repetitions), and women's limited role in CSA (14 repetitions). Within the culture and community subcategory, many farmers are reluctant to adopt new technologies, perceiving them as high-risk due to their reliance on traditional and well-established farming practices. Fear of failure and the potential for economic loss further discourage farmers from shifting to new methods. Some farmers, however, believe that climate-smart technologies are unnecessary and suited only for more developed areas. Negative past experiences with government programs or new technologies have also weakened trust in the efficiency of climate-smart tools. In some cases, farmers view the adoption of new tools as a threat to their cultural identities, influenced by traditional beliefs and local customs. Additionally, cultural differences among ethnic groups in the region may contribute to varying degrees of resistance to change. The lack of a strong culture of collaboration and teamwork among farmers further limits the sharing of resources, knowledge, and equipment.

Regarding awareness and education, participants acknowledged that a significant number of farmers lack the basic literacy required to understand and apply new technologies. Even literate farmers may struggle with the complexity of smart technology guidelines. Additionally, many farmers do not perceive education and learning as essential and often choose not to attend training courses or workshops. Furthermore, a large portion of the farming community remains unaware of the benefits of CSA in enhancing productivity and mitigating risks.

Immigration and the loss of farm labor are additional demographic barriers to CSA promotion. The region faces a shortage of skilled labor capable of managing and utilizing climate-smart technologies. However, due to limited job opportunities and low farming incomes, young workers often migrate to urban areas, leaving behind an older population that is generally less receptive to adopting new technologies.

The participants also highlighted the limited role of women in CSA. In some regions, sociocultural beliefs restrict women's involvement in agriculture and decision-making related to farming. Additionally, many women are employed in agricultural jobs that offer little to no wages, discouraging them from learning new technologies. Furthermore, female farmers and members of farming households often lack access to CSA-related education.

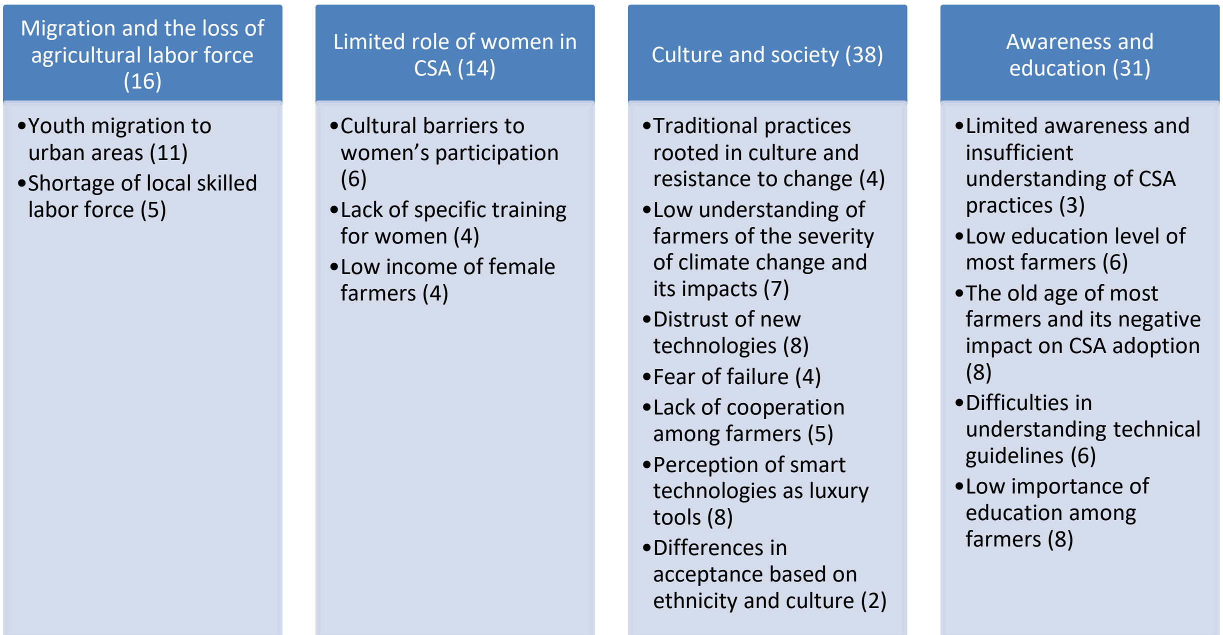

Figure 4. The demographic challenges of CSA promotion in rural areas

Environmental challenges, cited 88 times, pose another set of significant obstacles to CSA promotion in Sistan and Baluchistan province. The region's unique climatic and environmental conditions complicate CSA development, negatively impacting natural resources and farming practices. These barriers reduce productivity and discourage farmers from adopting new technologies. Environmental challenges are categorized into four main areas: environmental pollution, extreme climatic changes, water scarcity and crisis, and soil erosion and land degradation. Due to limited awareness and a lack of alternative technologies, farmers frequently overuse chemical fertilizers and pesticides, leading to soil and water pollution and diminishing agricultural productivity. Additionally, dust storms not only damage crops but also reduce sunlight exposure, disrupting the photosynthesis process and further harming plant growth.

The withdrawal of water rights by Afghanistan, coupled with extreme climate change in recent years, has severely impacted all farming activities and plans in the region. Consecutive droughts—particularly in the north of the province (the Sistan plain)—have led to the drying of critical water sources, including the Hirmand River and Hamoun wetlands, drastically reducing water availability for farm irrigation. As a result, not only has the adoption of CSA technologies become increasingly difficult, but farming itself has, in many cases, become unfeasible. In addition to the decline in rainfall in Afghanistan and the political decisions affecting agricultural planning in the Sistan plain, irrigation and cropping plans also suffer from irregular and short-term rainfalls. Climate-smart technologies require precise environmental predictions, yet the lack of consistent and sustainable rainfall complicates their effective implementation. Additionally, Sistan and Baluchistan province has experienced rising temperatures in recent years, accelerating surface water evaporation and depleting soil moisture. This has severely diminished crop productivity and further heightened the need for smart water transfer systems and improved water resource management.

Water scarcity and crisis, a subset of environmental challenges, have further slowed the promotion of CSA. Over-extraction of groundwater in recent years has significantly depleted water levels, threatening non-renewable water resources. In many areas, farmers rely on saline and brackish water for irrigation, which diminishes crop yields and degrades soil quality. Additionally, the drying of the Hamoun Wetland—one of the region's critical water sources—has created a serious crisis for the agricultural water supply. Environmental changes have also led to the decline of local drought-resistant plant species, despite their crucial role in CSA. Climate change and environmental degradation have further reduced biodiversity in the region, negatively impacting the agricultural ecosystem.

Sistan and Baluchistan province is a major center for dust storms and wind erosion in Iran, which severely depletes its land quality. Desertification—driven by droughts, soil erosion, and vegetation degradation—poses a fundamental barrier to climate-smart and sustainable agricultural development. Long-term severe winds, such as the 120-day winds, displace soil and strip it of fertility. Additionally, mineral accumulation from irrigating with saline water, coupled with the absence of smart irrigation management systems, has led to soil salinization and declining crop yields. Overgrazing and unauthorized exploitation of forests and pastures have further degraded vegetation cover, endangering the region's environmental sustainability. Furthermore, the lack of smart programs for pasture management and optimal land use has contributed to increased soil erosion and accelerated desertification.

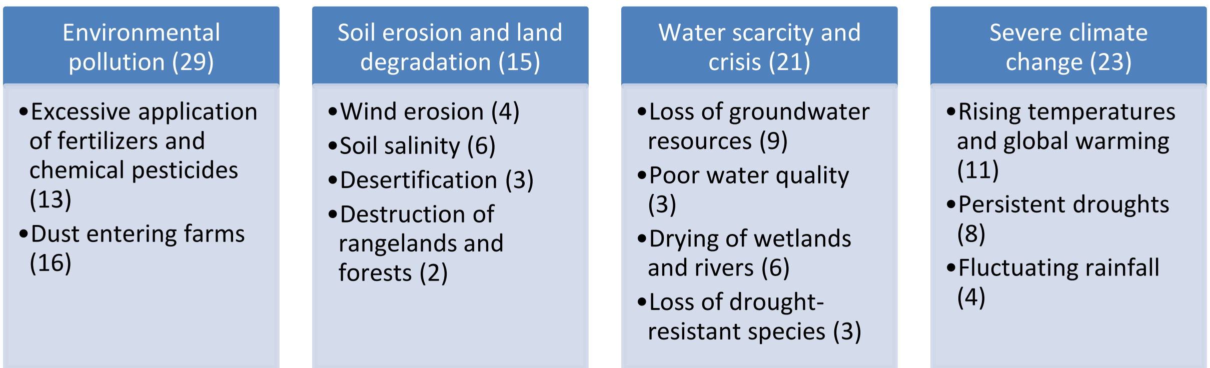

Figure 5. The environmental challenges of CSA promotion in rural areas

Another significant barrier to CSA promotion is knowledge gaps, cited 64 times. The lack of pilot projects to demonstrate the effectiveness of climate-smart technologies undermines farmers' trust in these methods. Additionally, there is insufficient funding for scientific research and technologies specifically adapted to Sistan and Baluchistan's climatic conditions. In other words, research and development receive inadequate attention. The absence of strong communication channels between researchers and farmers further complicates the advancement of CSA measures. Scientific findings are not effectively translated into practice due to weaknesses in the agricultural extension system and the lack of a reliable mechanism for transferring research outcomes to farmers. Moreover, some CSA methods require high levels of technical expertise and management.

Complexity and intensity of management (17)

- Some methods requiring high levels of management and technical expertise (5)
- Low compatibility of some methods with existing farming practices (7)
- Lack of user-friendliness of some CSA practices (5)

Interdisciplinary research and policy integration (34)

- Lack of more interdisciplinary research to build a stronger theoretical base (4)
- Lack of examination of changes in farming systems and land use (2)
- Low attention to research and development (R&D) (6)
- Weakness of reliable criteria for environmental and social protections (7)
- A need for significant R&D of some measures such as the establishment of stress-resistant breeds and varieties (6)
- Lack of support for pilot projects (9)

Farmer knowledge and training (13)

- Significant gap in farmers' knowledge and technical capacity on CSA technologies and practices (5)
- Lack of strong communication between researchers and farmers (8)

Figure 6. The knowledge gaps in CSA promotion in rural areas

The final category of CSA promotion challenges in Sistan and Baluchistan province consists of market barriers, cited 37 times. These barriers include crop price fluctuations and the absence of a well-developed value chain. Instability in crop prices discourages farmers from investing in new methods, as the investment return is not guaranteed. Rapid shifts in market demand—especially for climate-smart crops—can further reduce farmers' motivation to adopt new technologies. A weak value chain in the region presents another major obstacle. Deficiencies in crop processing, packaging, and marketing lower farmers' income, thereby limiting their ability to invest in smart technologies. Additionally, the lack of farmers' direct connection with local, national, or international markets, along with the absence of digital platforms for selling crops, poses long-term challenges to CSA promotion.

Lack of proper value chain (15)

- Weakness in crop processing, packaging and marketing (12)
- Weakness in connection with end markets (3)

Fluctuations in crop market (22)

- Unstable crop prices (9)
- Unstable market demand (6)
- Unpredictability of crop prices (7)

Figure 7. The market challenges of CSA promotion in rural areas

5. Discussion and Conclusion

The results of the present study, which were derived from a systematic and thorough analysis of CSA promotion challenges in rural areas of the Sistan plain, revealed the complexity and multiplicity of barriers to implementing CSA practices. These barriers were divided into seven categories: financial, institutional, technical, infrastructural, demographic, environmental, and market barriers, as well as knowledge gaps. Financial issues emerged as the most frequently cited obstacles, including high initial costs, limited access to credit sources, and insufficient governmental support. Smallholders, who constitute a significant portion of agricultural producers in the Sistan plain, struggle to invest in CSA technologies due to a lack of financial support and targeted subsidies. These findings align with those reported by Bhatnagar et al. (2024), Ogunyiola et al. (2022), Mungai et al. (2021), and Hussein (2024), all of whom identified financial constraints and high equipment costs as key barriers to CSA adoption. Additionally, uncertainty in economic profitability is another obstacle that has challenged the adoption of these technologies. Many farmers hesitate to invest in CSA technologies due to the lack of practical evidence demonstrating their financial benefits. This concern was also emphasized in research by Baffour-Ata et al. (2023).

Poor policymaking and the lack of institutional support are other essential impediments to CSA promotion. The absence of coherent and stable policies for deprived regions like the Sistan plain, along with governmental instability in decision-making, has slowed the development of these technologies. Similar findings have been reported by El-Chami et al. (2020), Lupogo and Mkuna (2023), Safdar et al. (2024), and Gemtou et al. (2024), all of whom emphasize the critical role of sustainable governance and policymaking on the development of agricultural technologies. Additionally, the shortage of extension training courses and skilled human resources was found as another institutional barrier. Farmers often lack access to practical CSA training, which not only limits their awareness but also diminishes their motivation to adopt new technologies.

The results indicate that weaknesses in knowledge transfer and the absence of pilot projects have hindered farmers' trust in adopting climate-smart technologies. Similarly, File and Nhamo (2023) and Murugesan (2024) have noted the importance of educational and pilot programs to demonstrate the effectiveness of CSA. The lack of collaboration between researchers and farmers and the absence of effective knowledge-transfer systems further exacerbate this gap.

Poor communication infrastructure, the unavailability of modern equipment, and the lack of precise climatic and agronomic data are additional critical challenges identified in this research. Since CSA relies heavily on advanced technologies and climate data monitoring systems, their scarcity in the Sistan plain significantly hinders its implementation. This finding supports the reports of Hussein (2024), Gemtou et al. (2024), and Mabhaudhi et al. (2025) regarding the need for developing robust technical and communication infrastructure to support the promotion of sustainable agriculture.

Harsh climatic conditions in the Sistan plain, including frequent droughts and severe winds, have created substantial environmental challenges, restricting farmers' ability to effectively utilize climate-smart technologies. Extreme climate fluctuations not only reduce agricultural productivity but also intensify the need for advanced systems to manage water and soil resources. These results are consistent with those reported by Komba and Muchapondwa (2018), Mehta et al. (2022), Zhao et al. (2023), and Oteng and Egbendewe (2024).

Farmers' low literacy and awareness in the Sistan plain, combined with their older age and the migration of young workers, have significantly hindered the adoption of new technologies. These findings corroborate the reports of Kom et al. (2022), Naveen et al. (2024), and Bhatnagar et al. (2024), which emphasize the influence of educational level and demographic characteristics on the adoption of climate-smart technologies. Additionally, the restricted role of women in CSA due to sociocultural barriers presents another challenge identified in this research.

Crop price fluctuations and the absence of a well-developed value chain are other obstacles detected in this research. These challenges discourage farmers from investing in new technologies and limit their access to consumption markets. Similar findings have been reported by George and Rwegasira (2017), Makkar et al. (2023), and Gemtou et al. (2024), who emphasize the importance of market stability in facilitating CSA expansion.

According to the results, policymakers should take measures to cope with these challenges, considering the local conditions in the Sistan plain, provide integrated approaches for infrastructure development, provide practical training, create sustainable financial and institutional support systems, and, most critically, strengthen political diplomacy to reclaim the Hirmand River water rights from Afghanistan. Investing in communication infrastructure and advanced technologies, enhancing cooperation among stakeholders, and developing crop value chains will further contribute to advancing CSA adoption. These measures will not only improve agricultural productivity but also play a crucial role in promoting sustainable development and reducing vulnerability to climate change.

The improvement of CSA adoption depends on implementing pragmatic solutions. Providing operational training to farmers and experts, with a focus on modern technologies and resource productivity, can be instrumental in building trust and motivation. Establishing local centers to offer consulting services, necessary equipment, and technical support is another essential measure. In addition, pilot projects at the village level and across other regions of the Sistan plain can be used to effectively demonstrate the tangible benefits of CSA. These initiatives can pave the way for expanding modern technologies by presenting real-world results and fostering greater farmer engagement. Strengthening communication networks, including access to the Internet and digital services, can further support farmers in using new information and data.

From a policymaking perspective, it is imperative to develop national strategies for CSA development. These strategies should incorporate financial incentives, targeted subsidies, and accessible credit facilities for smallholders. Furthermore, policies must be established to strengthen collaboration among the public sector, private sector, and educational institutions. Enacting supportive regulations for natural resource management, encouraging the use of modern technologies, and minimizing bureaucratic obstacles are other critical measures. The government must play a central role in achieving sustainable development goals by allocating sufficient funds for CSA-related research and development, as well as enhancing economic diplomacy to attract foreign investment. Focusing on deprived regions and leveraging local potential in policymaking can significantly improve the effectiveness of these initiatives.

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Authors′ contributions

The authors equally contributed to the preparation of this article.

Conflict of interest

The authors declare no conflict of interest.

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Original Article

تحلیل موانع و چالش‌های ترویج کشاورزی اقلیم هوشمند در مناطق روستایی دشت سیستان: یک رویکرد کیفی

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چکیده مبسوط

۱. مقدمه

کشاورزی اقلیم هوشمند به‌عنوان یکی از راهبردهای کلیدی برای مقابله با اثرات تغییرات اقلیمی در بخش کشاورزی معرفی شده است. این رویکرد با تمرکز بر افزایش بهره‌وری، سازگاری با تغییرات اقلیمی و کاهش انتشار گازهای گلخانه‌ای، می‌تواند نقشی حیاتی در تأمین امنیت غذایی و پایداری کشاورزی در مناطق روستایی ایفا کند. در مناطق خشک و نیمه‌خشک مانند دشت سیستان، تغییرات اقلیمی اثرات شدیدی بر منابع آبی، کیفیت خاک و معیشت کشاورزان داشته و ضرورت استفاده از فناوری‌های اقلیم هوشمند را دوچندان کرده است. با این حال، ترویج و پذیرش این رویکرد در چنین مناطقی با چالش‌ها و موانع متعددی مواجه است که نیازمند شناسایی و تحلیل دقیق است. بنابراین، پژوهش حاضر با هدف شناسایی این موانع و ارائه راهکارهای عملی برای بهبود پذیرش کشاورزی اقلیم هوشمند انجام شده است. هدف اصلی این پژوهش، شناسایی و تحلیل چالش‌ها و موانع ترویج کشاورزی اقلیم هوشمند در مناطق روستایی دشت سیستان بوده است. کشاورزی اقلیم هوشمند به‌عنوان یک رویکرد پایدار و جامع، ظرفیت بالقوه‌ای برای مقابله با اثرات تغییرات اقلیمی و بهبود بهره‌وری کشاورزی در مناطق خشک و نیمه‌خشک دارد. با این حال، این پژوهش بر آن است تا با شناسایی موانع و چالش‌های موجود، راهکارهایی موثر برای افزایش پذیرش و کاربرد این روش‌ها توسط کشاورزان و سیاست‌گذاران ارائه دهد. اهمیت این موضوع در شرایطی که مناطق روستایی دشت سیستان به دلیل اقلیم سخت و زیرساخت‌های محدود به شدت آسیب‌پذیر هستند، دوچندان می‌شود.

۲. مبانی نظری تحقیق

مبانی نظری این پژوهش بر اصول و مفاهیم کشاورزی اقلیم هوشمند استوار است. کشاورزی اقلیم هوشمند به عنوان رویکردی سه‌گانه مطرح شده است که شامل افزایش بهره‌وری، کاهش آسیب‌پذیری در برابر تغییرات اقلیمی و کاهش انتشار گازهای گلخانه‌ای می‌باشد. اگرچه کشاورزی اقلیم هوشمند بر اساس دانش کشاورزی موجود، فن‌آوری‌ها و اصول پایداری ساخته شده است، اما این نوع نظام از چندین جهت متمایز است: اول، تمرکز صریح بر پرداختن به تغییرات اقلیمی در سیستم کشاورزی است. دوم، کشاورزی اقلیم هوشمند به طور سیستماتیک هم‌افزایی و مبادله‌ای را که بین بهره‌وری، سازگاری و کاهش اثرات وجود دارد، در نظر می‌گیرد و سوم، کشاورزی اقلیم هوشمند شامل طیف وسیعی از شیوه‌ها و فن‌آوری‌هایی است که برای شرایط خاص زراعی-اکولوژیکی و زمینه‌های اجتماعی- اقتصادی از جمله اتخاذ گونه‌های گیاهی مقاوم در برابر آب و هوا، تکنیک‌های کشاورزی حفاظتی، جنگل-زراعی، کشاورزی دقیق، استراتژی‌های مدیریت آب و بهبود مدیریت دام ترویج یافته‌اند.

۳. روش تحقیق

این پژوهش از رویکرد کیفی برای شناسایی موانع و چالش‌های ترویج کشاورزی اقلیم هوشمند بهره گرفته است. داده‌ها از طریق تکنیک گروه متمرکز از ۵۴ مشارکت‌کننده شامل کشاورزان و کارشناسان جمع‌آوری شد. این مشارکت‌کنندگان به صورت هدفمند انتخاب شدند تا نماینده بخش‌های مختلف جامعه کشاورزی و نهادهای مرتبط باشند. برای تحلیل داده‌ها، از روش تحلیل محتوای استقرایی استفاده شد که شامل مراحل کدگذاری باز، محوری و انتخابی می‌باشد. این روش امکان شناسایی مقوله‌های اصلی و زیرمقوله‌های مرتبط با چالش‌ها و موانع ترویج کشاورزی اقلیم هوشمند را فراهم کرد. ابزارهای مورد استفاده شامل ضبط گفتگوها، یادداشت‌برداری دقیق، و تحلیل سیستماتیک داده‌ها بود.

۴. یافته‌های تحقیق

تحلیل داده‌های به‌دست‌آمده نشان داد که چالش‌های ترویج کشاورزی اقلیم هوشمند در دشت سیستان در هفت دسته اصلی شامل

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چالش‌های مالی، نهادی، فنی و زیرساختی، شکاف‌های دانشی، جمعیت‌شناختی، محیط‌زیستی و بازار دسته‌بندی می‌شوند. از میان این چالش‌ها، موانع مالی و نهادی بیشترین تأثیر را بر کندی پذیرش این رویکرد داشته‌اند. هزینه‌های اولیه بالا برای تهیه فناوری‌های اقلیم هوشمند، کمبود منابع اعتباری و حمایت‌های مالی محدود از سوی دولت، از مهم‌ترین موانع مالی شناسایی‌شده بودند. کشاورزان خرد، که بخش عمده‌ای از تولید کشاورزی در این منطقه را به خود اختصاص می‌دهند، به دلیل نبود یارانه‌های هدفمند و دسترسی نابرابر به منابع مالی، قادر به سرمایه‌گذاری در فناوری‌های نوین نیستند. کمبود سیاست‌های مشخص و برنامه‌های راهبردی برای حمایت از کشاورزی اقلیم هوشمند در سطح ملی و منطقه‌ای از دیگر موانع شناسایی‌شده بود. سیاست‌های موجود بیشتر بر مناطق برخوردار متمرکز بوده و استان‌های محرومی مانند سیستان و بلوچستان از اولویت کمتری برخوردار هستند. ضعف در آموزش‌های کاربردی و نبود نیروی انسانی متخصص نیز بر شدت این چالش‌ها افزوده است. نبود تجهیزات مدرن، ضعف زیرساخت‌های ارتباطی و فنی، و محدودیت در دسترسی به فناوری‌های نوین از دیگر موانع مهم بودند. بسیاری از فناوری‌های اقلیم هوشمند نیازمند دسترسی به اینترنت پرسرعت و ابزارهای پیشرفته هستند که در این منطقه به‌طور قابل‌توجهی محدود است. کمبود پروژه‌های پایلوت و آزمایشی برای نمایش کارایی فناوری‌های اقلیم هوشمند و نبود سیستم‌های مؤثر انتقال دانش از محققان به کشاورزان، مانع اعتمادسازی و افزایش آگاهی کشاورزان شده است. بسیاری از کشاورزان از مزایای این فناوری‌ها آگاهی کافی ندارند. ویژگی‌های جمعیت‌شناختی، از جمله سطح پایین سواد کشاورزان، سن بالا و مهاجرت نیروی کار جوان، از موانع مهم در پذیرش فناوری‌های نوین بودند.

۵. بحث و نتیجه‌گیری

نشان داد که این منطقه با طیف گسترده‌ای از محدودیت‌های ساختاری، اجتماعی و اقتصادی مواجه است. برای بهبود پذیرش کشاورزی اقلیم هوشمند، باید به اجرای راهکارهای عملی پرداخته شود. آموزش‌های عملیاتی برای کشاورزان و کارشناسان با تمرکز بر فناوری‌های نوین و بهره‌وری منابع، می‌تواند اعتمادسازی و انگیزه‌سازی کند. ایجاد مراکز محلی برای ارائه خدمات مشاوره‌ای، تأمین تجهیزات مورد نیاز، و پشتیبانی‌های فنی نیز از اقدامات ضروری است. همچنین، ایجاد پروژه‌های پایلوت در سطح روستاها و مناطق مختلف دشت سیستان، می‌تواند نشان‌دهنده مزایای واقعی کشاورزی اقلیم هوشمند باشد. از منظر سیاست‌گذاری، تدوین استراتژی‌های ملی برای توسعه کشاورزی اقلیم هوشمند ضروری است. این استراتژی‌ها باید شامل مشوق‌های مالی، مانند یارانه‌های هدفمند، و تسهیلات اعتباری برای کشاورزان خرد باشد. همچنین، باید سیاست‌هایی برای تقویت همکاری میان بخش‌های دولتی، خصوصی و نهادهای آموزشی تدوین شود. ایجاد قوانین حمایتی برای مدیریت منابع طبیعی، تشویق به استفاده از فناوری‌های نوین، و کاهش موانع بروکراتیک از دیگر اقدامات کلیدی است. دولت باید با اختصاص بودجه‌های کافی به تحقیق و توسعه در حوزه کشاورزی اقلیم هوشمند، و تقویت دیپلماسی اقتصادی برای جذب سرمایه‌گذاری خارجی، نقش مهمی در تحقق اهداف توسعه پایدار ایفا کند. تمرکز بر مناطق محروم و استفاده از ظرفیت‌های بومی در سیاست‌گذاری‌ها، می‌تواند اثربخشی برنامه‌ها را افزایش دهد.

کلیدواژه‌ها: کشاورزی اقلیم هوشمند، بهره‌وری کشاورزی، تاب-آوری کشاورزان، توسعه روستایی، دشت سیستان.

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