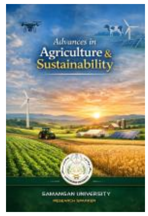
Advances in Agriculture & Sustainability

https://researchsparker.edu.af/index.php/AAS

DOI: 10.64226/aas.v2i1.189

E-ISSN: 3135-2022

P-ISSN: 3135-2014



Assessment of the Level of Adoption and Barriers of Climate-Smart Agriculture among Farmers and Livestock Holders in Baghlan Markazi District

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Cite this study: Hamidi, SAA., Razavi, K., & Naiemi, M. (Year). Assessment of the Level of Adoption and Barriers of Climate-Smart Agriculture among Farmers and Livestock Holders in Baghlan Markazi District. 2 (1), 129-148.

Keywords

Afghanistan, climate change, Climate-smart agriculture, farmers, livestock holders, sustainable agriculture, adaptation.

Research Article

Received: 2026-06-04
Revised: 2026-06-19
Accepted: 2026-09-12
Published: 2026-09-12

Abstract

Climate change has become a major challenge affecting agricultural productivity, food security, and rural livelihoods in Afghanistan. This study assessed the adoption level, perceptions, and barriers of Climate-Smart Agriculture (CSA) among farmers and livestock holders in Baghlan Markazi District, Afghanistan. A quantitative cross-sectional survey design was employed using structured questionnaires and institutional interviews. The sample size was determined using Cochran's formula for unknown populations at a 95% confidence level and 5% margin of error. A total of 390 respondents participated in the study, including 240 farmers and 150 livestock holders. Data were analysed using descriptive statistical methods including frequency, percentage, mean, and standard deviation. The findings revealed moderate-to-high awareness regarding Climate-Smart Agriculture practices among respondents. Crop diversification and integrated crop–livestock systems showed relatively higher adoption levels, while drought-tolerant crop varieties demonstrated lower adoption. Economic limitations, weak extension services, inadequate technical training, and insufficient institutional support were identified as the major barriers affecting CSA implementation. The study concludes that strengthening agricultural extension services, improving farmer training programs, and increasing institutional and financial support are essential for promoting sustainable agriculture and climate resilience in rural farming communities of Afghanistan.

1. Introduction

Climate change has emerged as one of the most serious global challenges affecting agricultural sustainability, food security, natural resource management, and rural livelihoods, particularly in developing countries where agricultural production systems are highly dependent on climate-sensitive resources. Rising temperatures, irregular rainfall patterns, droughts, floods, and increasing environmental degradation continue to reduce agricultural productivity and increase the vulnerability of rural communities worldwide (Intergovernmental Panel on Climate Change (*IPCC, 2023*). Food and Agriculture Organization (*FAO, 2021*). Agriculture remains the primary source of income and employment for millions of households in low-income countries; therefore, climatic shocks directly threaten economic stability, household resilience, and food availability (*World Bank, 2022*).

Climate-related risks are particularly severe in fragile and conflict-affected countries where institutional capacity, agricultural infrastructure, and access to modern farming technologies remain limited. According to the United Nations Development Programme (*UNDP, 2022*). climate variability has significantly intensified pressure on water resources, agricultural land, and livestock production systems across many Asian and African countries. Similarly, recent studies reported that smallholder farmers are increasingly experiencing crop failures, declining soil fertility, reduced water availability, and livestock productivity losses due to prolonged drought and climatic uncertainty (*Mango et al., 2021; Makate et al., 2022).*

Afghanistan is considered one of the countries highly vulnerable to climate change because of its fragile economy, prolonged political instability, dependence on rainfed agriculture, recurrent droughts, and limited adaptive capacity (United Nations Environment Programme (*UNEP, 2021*). The agricultural sector contributes substantially to rural livelihoods and national food supply, while livestock production remains an important component of household income generation and nutritional security. However, Afghan farmers and livestock holders continue to face multiple environmental and socioeconomic challenges including water scarcity, declining pasture quality, soil degradation, low agricultural productivity, limited access to extension services, and insufficient institutional support (*FAO, 2022*).

Recent climatic changes in Afghanistan have significantly affected crop production and livestock systems. Prolonged drought conditions, irregular precipitation, and rising temperatures have reduced agricultural yields and increased vulnerability among rural farming communities (World Food Programme (*WFP,* *2023*). Furthermore, weak irrigation infrastructure, limited adoption of improved agricultural technologies, and inadequate climate-related knowledge continue to constrain farmers' adaptive capacity and resilience (*Asian Development Bank (ADB, 2021*). (Research conducted by *Habibie et al, 2023*). emphasized that rural households in Afghanistan are increasingly exposed to climate-related production risks, particularly in provinces where agriculture and livestock production constitute the major livelihood activities.

In response to these growing challenges, Climate-Smart Agriculture (CSA) has emerged as a sustainable approach aimed at improving agricultural productivity, strengthening climate resilience, and promoting environmental sustainability. According to (*FAO, 2021*). Climate-Smart Agriculture seeks to achieve three interrelated objectives: sustainably increasing agricultural productivity, adapting and building resilience to climate change, and reducing greenhouse gas emissions where possible. CSA practices include conservation agriculture, crop diversification, integrated crop–livestock systems, efficient irrigation technologies, drought-tolerant crop varieties, agroforestry, soil fertility management, and sustainable livestock production systems (*Lipper et al., 2021*).

Several recent studies have highlighted the importance of Climate-Smart Agriculture for improving resilience among smallholder farmers. For example, (*Mugnai et al, 2021*) reported that adoption of CSA practices significantly improved household resilience and agricultural productivity in climate-vulnerable regions of Sub-Saharan Africa. (*Similarly, Nyasimi et al, 2022*) found that integrated soil and water management practices contributed to improved food security and reduced climate-related risks among rural farming households. Research conducted in South Asia further demonstrated that climate-smart technologies can improve water-use efficiency, reduce environmental degradation, and strengthen adaptation capacity under changing climatic conditions (*Sharma et al., 2022*).

Despite increasing global attention toward Climate-Smart Agriculture, adoption levels among smallholder farmers remain uneven due to numerous economic, institutional, technical, and environmental barriers. Limited access to agricultural extension services, financial constraints, lack of climate information, insufficient technical knowledge, and poor institutional coordination continue to restrict CSA implementation in many developing countries (*Makate et al., 2022; Thierfelder et al., 2021*). Moreover, farmers' perceptions regarding climate risks, economic benefits, and technological complexity strongly influence adoption behavior and decision-making processes (*Issahaku & Abdulai, 2020*).

Empirical evidence also indicates that socioeconomic factors such as education level, farming experience, household income, farm size, and membership in farmer organizations significantly affect Climate-Smart Agriculture adoption (*Mango et al., 2021*). Livestock-dependent households face additional challenges including pasture degradation, feed shortages, declining water resources, and animal health problems under changing climatic conditions (*FAO, 2023*). (*According to Aryal et al,* ٢٠٢١). successful implementation of Climate-Smart Agriculture requires not only technological suitability but also effective institutional support, training opportunities, and access to agricultural services.

Although the literature on Climate-Smart Agriculture has expanded considerably in recent years, limited empirical studies have specifically examined CSA adoption among farmers and livestock holders in Afghanistan, particularly at district level. Most existing studies in Afghanistan mainly focus on drought vulnerability, food insecurity, and environmental degradation, while relatively little scientific attention has been given to understanding the socioeconomic and institutional barriers affecting CSA adoption among rural farming communities. Consequently, localized evidence regarding farmers' perceptions, adoption levels, and implementation constraints remains insufficient for policymakers and agricultural development institutions.

Baghlan Province is one of the agriculturally important regions of Afghanistan where crop cultivation and livestock production constitute major livelihood activities for rural households. However, the province has increasingly experienced climate-related challenges including drought, water scarcity, declining soil fertility, and reduced agricultural productivity. In Baghlan Markazi District specifically, farmers and livestock holders continue to face multiple constraints related to climate variability, limited agricultural infrastructure, weak extension services, and insufficient access to modern agricultural technologies.

Therefore, this study aimed to assess the adoption level, perceptions, and barriers of Climate-Smart Agriculture among farmers and livestock holders in Baghlan Markazi District, Afghanistan. Specifically, the study sought to evaluate respondents' awareness and adoption of CSA practices, identify major economic and institutional barriers affecting implementation, and examine farmers' perceptions regarding sustainable agricultural adaptation under changing climatic conditions. The findings of the study are expected to contribute to the existing scientific literature on Climate-Smart Agriculture in Afghanistan while also providing policy-relevant recommendations for strengthening agricultural sustainability, rural resilience, and climate adaptation strategies.

Despite the growing global attention toward Climate-Smart Agriculture, empirical evidence regarding CSA adoption among farmers and livestock holders in Afghanistan remains very limited, particularly at district and community levels. Most previous studies conducted in Afghanistan have primarily focused on drought vulnerability, food insecurity, environmental degradation, and humanitarian challenges, while relatively little scientific attention has been given to socioeconomic, institutional, and technical barriers influencing the adoption of Climate-Smart Agriculture practices among rural farming households. Furthermore, limited localized evidence exists regarding farmers' awareness, perceptions, and adaptive responses toward sustainable agricultural practices under changing climatic conditions. This lack of district-level empirical information creates significant challenges for policymakers, agricultural extension institutions, and development organizations attempting to design effective climate adaptation strategies and sustainable agricultural development programs. Therefore, generating location-specific evidence on Climate-Smart Agriculture adoption and associated barriers is essential for improving agricultural resilience and supporting sustainable rural livelihoods in Afghanistan

2. Materials and Methods

This study employed a quantitative cross-sectional survey design to assess the adoption level, perceptions, and barriers of Climate-Smart Agriculture (CSA) among farmers and livestock holders in Baghlan Markazi District, Baghlan Province, Afghanistan. The quantitative survey approach was selected because it allows systematic collection of standardized data from a relatively large sample size and enables statistical analysis of socioeconomic, institutional, environmental, and technological factors influencing Climate-Smart Agriculture adoption.

The study population consisted of farmers engaged in crop production and livestock holders involved in animal husbandry and mixed farming systems within the study area. Since no accurate and updated registry of farmers and livestock holders was available, the population size was considered unknown. Therefore, the sample size was determined using Cochran's formula for unknown or infinite populations at a 95% confidence level and 5% margin of error.

The formula was expressed as follows:

$$n0 = (Z^2 \times p \times (1 - p)) / e^2 \text{ .... } (1)$$

Where:

n0 = required sample size

Z= standard normal deviation at 95% confidence level (1,96)

p= estimated population proportion

e= margin for error (0,05)

Substituting the values into the formula:

$n0= (1,96^2 * 0,5 *(1-0,5)) / (0,5^2)$

$n0= (3.8416 * 0,25) / 0,0025$

$n0 = 384.16$

Therefore, the minimum calculated sample size was approximately 384 respondents. However, to improve representativeness, reliability, and field accuracy, the final sample size was increased to 390 respondents.

Among the total respondents:

- 240 respondents were farmer
- 150 respondents were livestock holders

In addition to household respondents, one institutional questionnaire was administered to the Directorate of Agriculture, Irrigation and Livestock of Baghlan Markazi District to obtain institutional-level information regarding Climate-Smart Agriculture programs, agricultural extension services, implementation challenges, and climate-related agricultural conditions. Information obtained from the Directorate was incorporated into the relevant result tables to strengthen interpretation of findings from both household and institutional perspectives.

Data were collected using a structured questionnaire developed based on previous Climate-Smart Agriculture literature, empirical studies, and the objectives of the research. The questionnaire consisted of several thematic sections including socio-demographic characteristics, awareness regarding Climate-Smart Agriculture, adoption level of CSA practices, climate change perceptions, institutional and technical constraints, economic barriers, and future outlook toward sustainable agricultural development.

Most questionnaire items were measured using a five-point Likert scale ranging from:

1= Strongly disagree

2= Disagree

3=Neutral

4= Agree

5= Strongly agree

Some variables including age group, education level, farming experience, occupation, livestock ownership, and type of agricultural activity were measured using categorical responses.

To ensure content validity and scientific consistency, the questionnaire was reviewed by experts in agricultural sciences, rural development, and agricultural extension. A pilot survey was conducted before final data collection to evaluate clarity, reliability, and consistency of the questionnaire items.

Reliability analysis was performed using Cronbach's Alpha coefficient to assess the internal consistency of multi-item constructs. The Cronbach's Alpha formula was expressed as follows:

$$\alpha = \{k / (k-1)\} * \{1- (\sum Si^2 / St^2)\} \text{ ....(2)}$$

Where:

- α = Cronbach's Alpha coefficient
- k = number of questionnaire items
- Si^2 = variance of individual items
- St^2 = total variance of the scale

The overall Cronbach's Alpha coefficient obtained for the questionnaire was 0.87, indicating good internal consistency and acceptable reliability for statistical analysis.

Data analysis was conducted using Statistical Package for Social Sciences (SPSS) version 26. Descriptive statistical methods including frequency, percentage, mean, and standard deviation were used to summarize and describe respondents' perceptions, adoption levels, and barriers related to Climate-Smart Agriculture practices.

Likert-scale variables were treated as continuous variables, and composite indices were constructed by averaging item responses within each construct. The composite index was calculated using the following equation:

Where:

- CIk = Composite index for construct k
- Xik = Likert-scale score of respondents I for item k
- n = total number of items within the construct.

In addition to descriptive statistics, inferential statistical analysis, including correlation analysis and regression analysis, was also applied where appropriate to examine relationships among selected socioeconomic, institutional, and technological variables associated with Climate-Smart Agriculture adoption. Statistical significance was evaluated at, 1%, 5% and 10% probability levels.

The analysis focused on major thematic domains including awareness and perceptions regarding Climate-Smart Agriculture, adoption level of CSA practices, climate-related agricultural challenges, institutional and technical barriers, economic constraints, and future willingness toward sustainable agricultural practices.

Tables and graphical representations were used to summarize and visually interpret major findings of the study. All tables were arranged systematically according to the objectives and thematic structure of the questionnaire.

Participation in the study was voluntary, and informed consent was obtained from all respondents prior to data collection. Confidentiality of respondents' information and anonymity of responses were strictly maintained throughout the research process. All questionnaires were fully completed, resulting in no missing observations in the final dataset.

Overall, the methodological framework was designed to ensure transparency, scientific reliability, methodological consistency, and reproducibility of the findings while maintaining compatibility with standard journal requirements for agricultural sustainability and Climate-Smart Agriculture research.

3. Results

3.1. This section presents the empirical findings of the study based on data collected from 390 respondents, including 240 farmers and 150 livestock holders in Baghlan Markazi District, Baghlan Province, Afghanistan. In addition, one institutional questionnaire completed by the Directorate of Agriculture, Irrigation and Livestock was incorporated to provide complementary institutional-level information regarding Climate-Smart Agriculture implementation, agricultural extension services, and institutional constraints affecting sustainable agriculture within the district.

The findings were organized systematically according to the thematic structure of the questionnaire and study objectives. The results are presented objectively using tables, percentages, mean scores, and standard deviations without interpretation or comparison with previous studies.

3.1.Socio-demographic Characteristics of Respondents

Table1: presents the socio-demographic characteristics of respondents. The results showed that the majority of respondents belonged to the age group of 31–50 years, indicating that economically active individuals were predominantly engaged in agricultural and livestock activities. A relatively smaller proportion of respondents belonged to younger and older age groups.

Educational status varied among respondents. Most respondents had primary or secondary education, while a smaller proportion had no formal education or higher education qualifications. Farming and livestock management activities were mainly performed by male household members within rural communities.

Most respondents possessed considerable farming experience ranging between 10–20 years, indicating substantial practical knowledge regarding local agricultural systems and climate-related challenges.

Table 1. Socio-demographic characteristics of respondents (n = 390)

Variable	Category	Frequency	Percentage (%)
Age	20-30 years	72	18.5
	31-40 years	118	30.3
	41-50 years	126	32.3
	Above 50 years	74	18.9
Educational Level	No formal education	64	16.4
	Primary education	118	30.3
	Secondary education	143	36.7
	Higher education	65	16.6
Occupation	Farming	240	61.5
	Livestock holding	150	38.5

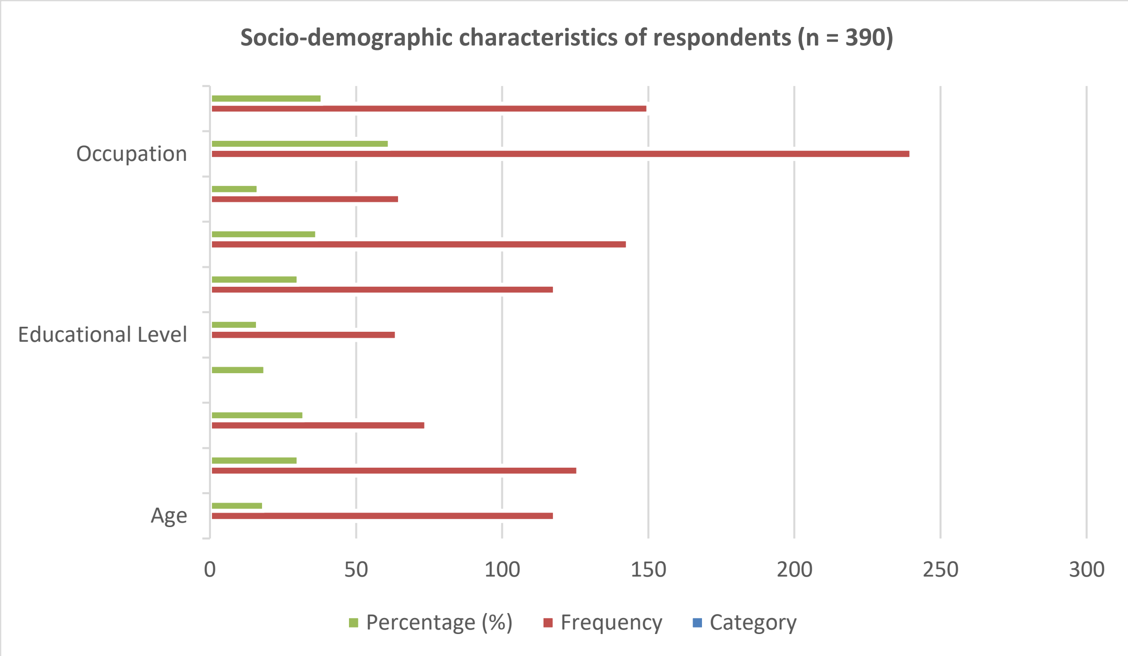

Figure 1. Socio-demographic characteristics of respondents (n = 390)

3.2. Agricultural Activities and Farming Experience

Table 2 summarizes farming experience, livestock ownership, and agricultural activities of respondents. Mixed farming systems combining crop cultivation and livestock rearing represented the dominant agricultural practice within the study area.

Table 2. Agricultural characteristics and farming experience of respondents

Variable	Category	Frequency	Percentage (%)
Farming experience	Less than 5 years	48	12.3
	5-10 years	96	24.6
	11-20 years	158	40.5
	More than 20 years	88	22.6
Agricultural activity	Crop production	162	41.5
	Livestock production	94	24.1
	Mixed farming	134	34.4
Irrigation access	Adequate	126	32.3
	Moderate	168	43.1
	Inadequate	96	24.6

3.3. Awareness and Perceptions Regarding Climate-Smart Agriculture

Table 3 presents respondents' awareness and perceptions regarding Climate-Smart Agriculture practices. The majority of respondents agreed or strongly agreed that sustainable agricultural practices are necessary for improving agricultural productivity and resilience against climate-related risks.

Table 3. Awareness and perceptions regarding Climate-Smart Agriculture

Statement	Mean	SD
Climate change negatively affects agriculture	4.42	0.71
CSA practices improve agricultural sustainability	4.31	0.76
Water scarcity affects crop productivity	4.48	0.69
Sustainable irrigation improves resilience	4.16	0.82
Farmers require more CSA training	4.37	0.73

3.4. Irrigation and Water Resource Conditions

Table 4 summarizes irrigation and water management conditions within the study area. River water, traditional canals, and groundwater wells represented the main irrigation sources used by respondents. However, many respondents reported insufficient water availability during drought periods.

Table 4. Irrigation and water resource conditions

Variable	Category	Frequency	Percentage (%)
Main water source	River/canal	176	45.1
	Groundwater wells	128	32.8
	Rainfed agriculture	86	22.1
Water availability	Sufficient	112	28.7
	Moderate	154	39.5
	Insufficient	124	31.8

3.5. Soil Fertility and Sustainable Agricultural Practices

Table 5 presents soil fertility management and sustainable agricultural practices among respondents. Organic manure application, crop rotation, and mixed farming systems were among the most commonly practiced sustainable agricultural activities.

Table 5. Soil fertility management and sustainable agricultural practices

PRACTICE	MEAN	SD
USE OF ORGANIC MANURE	4.08	0.81
CROP ROTATION PRACTICES	3.96	0.86
SOIL CONSERVATION ACTIVITIES	3.84	0.92
INTEGRATED CROP–LIVESTOCK SYSTEMS	4.12	0.79
SUSTAINABLE GRAZING MANAGEMENT	3.88	0.89

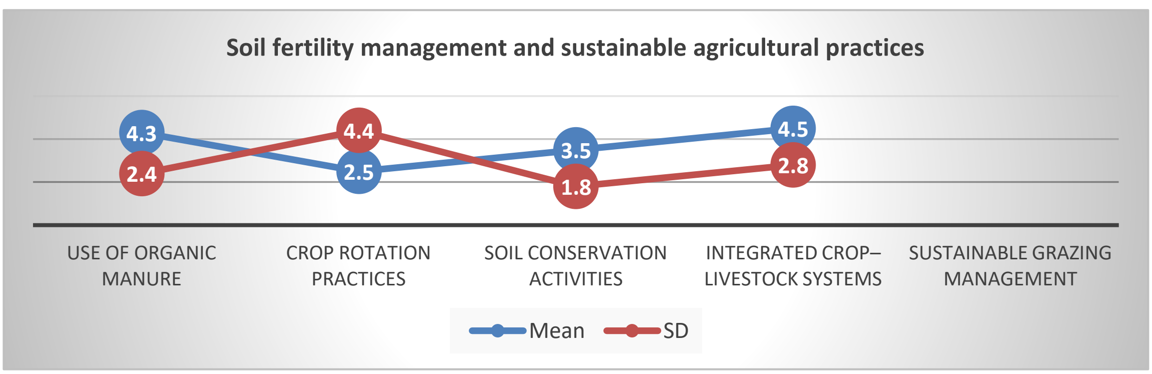

Figure 2. Soil fertility management and sustainable agricultural practices

3.6. Climate Change Impacts on Agricultural Production

Table 6 summarizes respondents' perceptions regarding climate-related agricultural challenges. Drought, irregular rainfall, water scarcity, declining soil fertility, and livestock feed shortages were identified as major challenges affecting agricultural productivity.

Table 6. Climate change impacts on agricultural production

Climate-related challenge	Mean	SD
Drought occurrence	4.53	0.66
Irregular rainfall	4.47	0.71
Water scarcity	4.51	0.69
Soil degradation	4.06	0.84
Livestock feed shortage	4.18	0.81

3.7. Technology Adoption and Constraints

Table 7 presents findings related to agricultural technology adoption and associated constraints. Adoption of improved irrigation systems and climate-smart technologies remained moderate due to financial and institutional limitations.

Table 7. Technology adoption and associated constraints

Variable	Mean	SD
Use of improved irrigation technology	3.71	0.94
Access to agricultural machinery|	3.65	0.98
Access to climate information	3.48	1.01
Availability of technical training	3.39	1.06
Access to agricultural extension services	3.58	0.97

3.8. Economic and Institutional Constraints

Table 8 summarizes economic and institutional barriers affecting Climate-Smart Agriculture adoption. High agricultural input prices, limited financial support, weak extension services, and poor market access were identified as major constraints.

Table 8. Economic and institutional constraints affecting CSA adoption

CONSTRAINT	MEAN	SD
HIGH AGRICULTURAL INPUT PRICES	4.41	0.72
LIMITED GOVERNMENTAL SUPPORT	4.26	0.77
LACK OF AGRICULTURAL CREDIT	4.18	0.81
WEAK MARKET ACCESS	4.03	0.88
INSUFFICIENT EXTENSION SERVICES	4.11	0.84

3.9. Future Outlook Toward Climate-Smart Agriculture

Table 9 presents respondents' future outlook toward Climate-Smart Agriculture implementation. The majority of respondents expressed willingness to participate in training programs and adopt sustainable agricultural practices if sufficient institutional and financial support were provided.

Table 9. Future outlook toward Climate-Smart Agriculture adoption

Statement	Mean	SD
Willingness to adopt CSA practices	4.36	0.75
Interest in CSA training programs	4.42	0.71
Need for institutional support	4.47	0.68
Importance of sustainable agriculture	4.51	0.65

3.10. Institutional-Level Findings

Table 10 presents institutional responses obtained from the Directorate of Agriculture, Irrigation and Livestock regarding Climate-Smart Agriculture implementation within Baghlan Markazi District.

The institutional findings indicated that drought, declining water resources, inadequate technical support, limited extension services, and insufficient financial resources represented major constraints affecting sustainable agricultural development within the district.

Table 10. Institutional responses regarding Climate-Smart Agriculture implementation in Baghlan Markazi District

Institutional statement	Mean	SD
CSA programs are important for sustainable agriculture	4.63	0.58
Farmers require additional technical training|	4.58	0.61
Water scarcity is a major agricultural challenge	4.71	0.49
Extension services require strengthening	4.54	0.64
Financial limitations affect CSA implementation	4.46	0.72

Source: Directorate of Agriculture, Irrigation and Livestock, Baghlan Markazi District (2026).

Overall, the findings demonstrated that respondents generally possessed positive perceptions regarding Climate-Smart Agriculture practices; however, several economic, technical, environmental, and institutional barriers continued to affect effective implementation within the study area

4. Conclusion and Discussion

The findings of this study demonstrated that farmers and livestock holders in Baghlan Markazi District possess relatively positive perceptions regarding Climate-Smart Agriculture (CSA) practices and recognize the importance of sustainable agricultural adaptation under changing climatic conditions. The results further revealed that drought, water scarcity, irregular rainfall patterns, limited institutional support, weak extension services, and financial limitations remain the major constraints affecting effective implementation of CSA practices within the study area.

The socio-demographic findings indicated that the majority of respondents were middle-aged farmers and livestock holders with moderate farming experience and limited formal education. Similar findings were reported by (Rahman et al, 2021). who observed that education level and farming experience significantly influence farmers' awareness and adoption of climate-resilient agricultural practices in developing countries. (*Likewise, Abegunde et al, 2022*). reported that limited educational opportunities among rural farmers reduce technological adaptation and sustainable agricultural decision-making capacities.

The present study showed that respondents generally perceived climate change as a serious threat to agricultural production and rural livelihoods. Most respondents strongly agreed that drought, declining rainfall, and water scarcity have negatively affected crop productivity and livestock production. These findings are consistent with the results reported by (*Mugumya et al, 2023*). who found that increasing climate variability significantly reduces agricultural productivity and food security among smallholder farmers (*Similarly, Nhamo et al, 2021*). emphasized that prolonged drought and irregular precipitation continue to intensify vulnerability among rural farming communities in climate-sensitive regions.

The findings further revealed moderate adoption of sustainable agricultural practices such as crop rotation, organic fertilizer application, integrated crop–livestock systems, and improved irrigation management. However, adoption levels of advanced climate-smart technologies remained relatively limited due to economic and institutional barriers. Similar observations were reported by (*Danso-Abbeam et al, 2022*). who concluded that inadequate financial resources and limited access to technical support significantly constrain adoption of CSA technologies among rural farmers. In another study (*Makate et al, 2022*). highlighted that institutional capacity, agricultural extension services, and accessibility of agricultural inputs strongly influence successful implementation of climate-smart agricultural interventions.

Economic and institutional constraints represented one of the most significant findings of this study. High agricultural input prices, lack of credit access, weak market systems, and insufficient governmental support were identified as major barriers affecting agricultural sustainability within the district. Comparable findings were reported by (*Issahaku and Abdulai, 2020*). who found that financial insecurity and weak institutional support reduce farmers' willingness to invest in sustainable agricultural technologies (*Likewise, Wekesa et al,* ۲۰۲۳) reported that limited rural infrastructure and weak extension systems continue to hinder agricultural transformation and climate adaptation efforts in developing economies.

Institutional findings obtained from the Directorate of Agriculture, Irrigation and Livestock further confirmed that technical limitations, insufficient extension personnel, lack of specialized CSA training programs, and inadequate financial resources remain major challenges affecting implementation of climate adaptation programs within Baghlan Markazi District. Similar institutional constraints were also documented by (*Ruzzante et al, 2021*). who emphasized that weak coordination among agricultural institutions significantly reduces the effectiveness of sustainable agricultural development programs in vulnerable rural regions.

The findings additionally demonstrated that respondents expressed strong willingness to participate in CSA-related training programs and adopt sustainable agricultural practices if sufficient institutional and financial support were provided. This result aligns with the findings of (*Aryal et al, 2022*) .who concluded that farmers generally show positive attitudes toward sustainable agricultural innovations when appropriate training opportunities and technical assistance are accessible.

Although the study provides valuable empirical evidence regarding CSA adoption and barriers in Baghlan Markazi District, several limitations should be acknowledged. First, the study was limited to one district of Baghlan Province; therefore, findings may not fully represent all agricultural regions of Afghanistan. Second, the study relied primarily on self-reported questionnaire data, which may involve respondent bias. Third, security limitations and accessibility challenges restricted wider field coverage in some rural areas.

Despite these limitations, the study contributes important scientific and policy-relevant evidence regarding climate-smart agricultural adaptation within Afghanistan. The findings highlight the urgent need for strengthening agricultural extension services, improving access to agricultural credit, expanding CSA training programs, supporting sustainable irrigation systems, and enhancing institutional coordination to improve climate resilience and sustainable agricultural productivity.

In conclusion, Climate-Smart Agriculture represents an important pathway toward improving agricultural sustainability, food security, and climate resilience in vulnerable rural communities of Afghanistan. However, successful implementation requires integrated institutional support, improved technical services, financial assistance, and farmer-centred adaptation strategies. Future studies should expand geographical coverage, include longitudinal assessments, and investigate the long-term socioeconomic impacts of CSA adoption under different agroecological conditions.

5. Statements and Declarations

5.1. Competing Interests

The author)declare no competing interests).

5.2. Data Availability

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

5.3 Ethical Approval

The study protocol involving human participants was reviewed and approved by the Department of Livestock Production and Management, Afghanistan National Agricultural Sciences and Technology University (ANASTU). Informed consent was obtained from all respondents prior to data collection. All procedures were conducted in accordance with relevant ethical guidelines and academic research standards.

5.4. Consent to Participate / Consent to Publish

Informed consent was obtained from all participants involved in the study. Participants were informed that the collected data would be used solely for academic and scientific research purposes.

5.5 Funding

This research received no external funding

5.6. Acknowledgments

The authors sincerely acknowledge the cooperation and support provided by the Directorate of Agriculture, Irrigation and Livestock of Baghlan Province, local farmers, livestock holders, and field assistants who contributed during data collection and questionnaire administration. The authors also appreciate the academic guidance provided by the Department of Livestock Production and Management, Afghanistan National Agricultural Sciences and Technology University (ANASTU).

5.7. Author Contributions

Conceptualization, S.A.A.H.; methodology, S.A.A.H.; investigation, S.A.A.H.; data collection, S.A.A.H.; formal analysis, S.A.A.H.; writing—original draft preparation, S.A.A.H.; writing—review and editing, S.A.A.H.; supervision.

Table Statistical Note

Note: SD = Standard Deviation; SA = Strongly Agree; A = Agree; N = Neutral; D = Disagree; SD = Strongly Disagree.

Note: Mean values were calculated based on a five-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree.

Conclusion

The study concluded that farmers and livestock holders in Baghlan Markazi District generally possess positive perceptions regarding Climate-Smart Agriculture practices and recognize the importance of sustainable agricultural adaptation under changing climatic conditions. However, several barriers including water scarcity, financial limitations, weak institutional support, inadequate extension services, and limited access to modern agricultural technologies continue to affect effective implementation of CSA practices within the study area.

The findings further indicate that strengthening agricultural extension services, improving access to agricultural credit, promoting sustainable irrigation systems, and expanding farmer-centered training programs are essential for improving climate resilience and sustainable agricultural productivity. Institutional coordination among governmental organizations, development agencies, and local farming communities is also necessary for successful implementation of Climate-Smart Agriculture interventions in Afghanistan.

Future research should focus on wider geographical coverage, longitudinal assessment of CSA adoption, and evaluation of long-term socioeconomic impacts of sustainable agricultural practices under different agroecological conditions.

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