Pak. j. life soc. Sci. (2024), 22(2):1428-1442 E-ISSN: 2221-7630; P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences

www.pjlss.edu.pk

https://doi.org/10.57239/PJLSS-2024-22.2.00101

RESEARCH ARTICLE

Climate Change Adaptation Strategies as a Moderator in the Relationship between Agricultural Innovation and Food Security in North Africa: A Case Study on North African Countries

Omari Aicha[1*], Talhaoui Fatima Zohra[2], Bourezak Assia[3], Ben laria Mohammed[4], Ould bahammou Samir[5]

[1] University of Adrar (Algeria), Algerian-African economic integration laboratory
[2] University of Adrar (Algeria), Spatial and Entrepreneurship Development Laboratory
[3] University of Adrar (Algeria), DECOPILS Laboratory
[4, 5] University of Adrar (Algeria), Algerian-African economic integration laboratory

ARTICLE INFO

Received: May 22, 2024

Accepted: Aug 4, 2024

Keywords

Agricultural Innovation

Climate Change Adaptation Strategies

Food Security

***Corresponding Author:**

Omari.aicha20@univ-adrar.edu.dz

ABSTRACT

This study investigates the relationship between Agricultural Innovation and Food Security in North Africa, emphasizing the moderating role of Climate Change Adaptation Strategies. Utilizing structural equation modeling, the research reveals that Agricultural Innovation significantly enhances Food Security, evidenced by a robust path coefficient and a highly significant p-value. Additionally, Climate Change Adaptation Strategies independently contribute to Food Security and, when combined with Agricultural Innovation, further amplify its positive effects. The findings underscore the necessity of integrated approaches that leverage both technological advancements and adaptive strategies to address food security challenges effectively in the context of climate change. This integrated strategy is crucial for ensuring the resilience and sustainability of food systems in North Africa.

1. INTRODUCTION

The escalating impacts of climate change pose significant challenges to agriculture and food security, particularly in vulnerable regions such as North Africa. This area, characterized by arid climates and frequent droughts, is experiencing increased pressure on its agricultural systems, which are critical for its population's livelihoods and food security. Agricultural innovation, through adopting new technologies and practices, offers a pathway to enhance productivity and resilience against climatic stresses. However, the effectiveness of these innovations in improving food security is not solely dependent on the innovations themselves but also on the extent to which countries adapt to climate change. Understanding the interplay between agricultural innovation and climate change adaptation strategies is crucial for designing effective policies that ensure sustainable food security in the region.

Despite the recognized importance of both agricultural innovation and climate change adaptation, there is a gap in research regarding their combined impact on food security in North Africa. This study aims to address this gap by exploring how climate change adaptation strategies moderate the relationship between agricultural innovation and food security across North African countries. Specifically, the research seeks to answer the following questions: How does agricultural innovation affect food security in North Africa? How do climate change adaptation strategies influence this relationship? The primary objective of this research is to provide empirical evidence on the moderating role of climate adaptation strategies in enhancing the positive effects of agricultural innovation on food security. By doing so, the study aims to inform policymakers and stakeholders on how to integrate these strategies effectively to foster resilient agricultural systems and improve food security in North Africa.

2. LITERATURE REVIEW

2.1 Agricultural innovation:

Agricultural innovation refers to the process of generating, accessing, and applying knowledge within the agricultural sector to enhance productivity, sustainability, and competitiveness. It involves the adoption of new technologies, practices, and approaches to address challenges and seize opportunities in farming and food production (P., 2022) (Sokolova et al., 2022) (Gorgodze et al., 2022) (Bo et al., 2021) (I.V. & O., 2022). This innovation is crucial for improving food security, increasing yields, reducing costs, and entering new markets, ultimately boosting the overall performance of agricultural enterprises. To drive agricultural innovation effectively, it is essential to invest in research and development, promote interdisciplinary collaboration, empower farmers as key stakeholders in decision-making processes, and create supportive ecosystems that encourage the adoption of cutting-edge technologies and practices. By embracing innovation, the agricultural sector can evolve, adapt to changing demands, and contribute significantly to economic growth and sustainability.

2.2 Food security:

Food security encompasses the physical and economic access to sufficient, safe, and nutritious food to meet dietary needs for an active and healthy life, influenced by factors like food availability, access, utilization, and stability of supply. It is a critical economic category ensuring guaranteed access to food for all social groups, with a focus on regulating and protecting agricultural sectors globally (Nursaule et al., 2023). From an economic standpoint, food security is vital for ensuring public welfare and socio-economic growth under market conditions (Баранов, 2023). The achievement of food security requires addressing three key conditions: food availability, adequate incomes, and increasing agricultural productivity, especially crucial as the world population grows (Kerr, 2023). Additionally, food security is not just about food alone but also nutrition and hunger removal, aiming for zero hunger globally, which includes addressing issues like hidden hunger and ensuring equitable food accessibility for all, especially vulnerable populations (Dongxu, 2022).

2.3 Climate change adaptation strategies:

Climate change adaptation strategies play a crucial role in mitigating the negative impacts of climate change on food security and agriculture. By focusing on seed security, which determines crop planting areas and influences food production, especially in key seed production regions like the Hexi Corridor in China (Chen et al., 2023), these strategies aim to balance seed and food production while enhancing resource use efficiency. Implementing adaptation measures can lead to significant improvements, such as saving irrigation water and nitrogen fertilizer, increasing seed and food production, and boosting irrigation water productivity and nitrogen use efficiency (Chen et al., 2023). Adequate adaptation is shown to alleviate projected yield losses for crops like maize, rice, and wheat, with irrigation methods and cultivar choices identified as key factors in preventing substantial yield reductions (R. et al., 2023) (R. & Abramoff., 2023). Overall, adapting to climate change is essential for sustaining agriculture, ensuring food security, and mitigating the far-reaching consequences of climate change on human society and ecological systems (Okoro et al., 2022).

2.4 Review of relevant prior research and scholarly works:

2.4.1 The relationship between agricultural innovation and food security:

Agricultural innovation plays a crucial role in enhancing food security by improving food accessibility, availability, and utilization through increased productivity growth (Malec et al., 2023). Technological advancements in agriculture, such as research and technology innovation, have been shown to positively impact food security by increasing farm yields, reducing risks from weather-related challenges, and fostering economic growth (W. & Grobler, 2023). Additionally, the implementation of innovative management practices in the agro-industrial sector is essential for modernizing production processes, meeting the rising demand for food, and ensuring sustainability (Duran-Sandoval et al., 2023). Climate change adaptation plans, including climate-smart agriculture and innovative equipment, are also vital in addressing the adverse impacts of climate change on food security (Ani, 2022). Overall, investing in agricultural research and development, promoting agripreneurship, and adopting technological innovations are key strategies to bolster food security and mitigate challenges in the agricultural sector.

First hypothesis (H1): There is no statistically significant positive relationship between Agricultural Innovation and Food Security at a 5% significance level.

2.4.2 The relationship between Climate Change Adaptation Strategies and the relationship of Agricultural Innovation to Food Security:

Climate change adaptation strategies in agriculture play a crucial role in ensuring food security by mitigating the adverse impacts of climate change on agricultural production (Duran-Sandoval et al., 2023) (Girma et al., 2023). These strategies include adopting drought-tolerant crop varieties, changing planting dates, growing diversified crops, and diversifying income sources, which have been found to positively influence food security among farm households in Ethiopia (Teodoro et al., 2023). Additionally, innovative technologies such as Information and Communication Technologies (ICTs), remote sensing tools, and machine learning analysis can enhance climate-smart agriculture practices, contributing to sustainable food production and resilience to climate change (Galbreath et al., 2023). Moreover, the integration of agricultural innovation with climate adaptation measures can increase agroecosystem resilience, reduce agricultural risks, and ensure the provision of ecosystem services critical for food security in the face of changing climatic conditions.

Second Hypothesis (H2): There is no significant role for Climate Change Adaptation Strategies in impacting the relationship between Agricultural Innovation and Food Security at a 5% significance level.

2.5 Gaps in existing literature :

Agricultural Innovation: Despite the significant role of agricultural innovation in enhancing productivity and food security, existing literature often lacks a context-specific focus, ignoring how local conditions affect the efficacy of innovations(P., 2022)(Bo et al., 2021). Studies predominantly emphasize technological advancements without adequately incorporating the perspectives of farmers or considering long-term sustainability and ecological impacts (Gorgodze et al., 2022)(Sokolova et al., 2022). This indicates a need for research that is both regionally tailored and inclusive of farmer insights to ensure that agricultural innovations are effective and sustainable.

Food Security: Research on food security typically relies on limited indicators and fails to capture the full complexity of the issue(Kerr, 2023)(Dongxu, 2022). There is a notable gap in examining the interplay between food security and other sectors like water management and health(Nursaule et al., 2023)(Баранов, 2023). Furthermore, studies often overlook the trade-offs between improving food security and achieving broader socio-economic and environmental goals, highlighting the need for a more comprehensive approach to understanding and addressing food security challenges, particularly in diverse regions such as North Africa.

Climate Change Adaptation Strategies: While climate change adaptation strategies are essential for mitigating the impacts of climate change on agriculture, research often overlooks the integration of local knowledge systems and the long-term sustainability of these strategies(Chen et al., 2023)(R. & Abramoff., 2023). The existing literature also tends to focus on potential benefits without sufficiently addressing policy and economic barriers to implementation (Okoro et al., 2022)(Chen et al., 2023). More research is needed to explore the synergies between adaptation strategies and agricultural innovation, including how they collectively impact food security and resilience in the face of climate change.

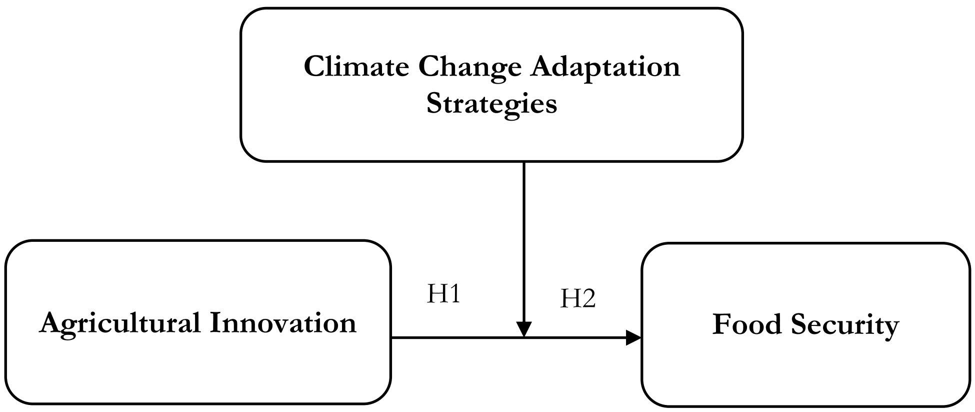

Figure 1: Theoretical framework

3. METHODOLOGY

3.1 Research design and approach

Research Design: This study uses a quantitative research design with a case study focus on North African countries to explore how climate change adaptation strategies moderate the relationship between agricultural innovation and food security. The research employs a correlational approach with Structural Equation Modeling (SEM) using SmartPLS software, allowing for the analysis of complex relationships and moderating effects.

3.2 Data collection methods

Secondary Data Sources: Data will be collected from international organizations (e.g., FAO, World Bank), national databases, and relevant research publications. The focus will be on:

Agricultural Innovation: Technology adoption rates, R&D investments

Food Security: Indicators such as food availability and access from sources like the FAO's Food Insecurity Experience Scale (FIES).

Climate Change Adaptation: Policy measures and adaptation investments from national and international reports.

Data Collection Period: The data will cover the period from 2014 to 2024 to ensure a comprehensive analysis of recent trends.

3.3 Rationale for the chosen methods

Quantitative Approach: This approach allows for objective measurement and statistical validation of relationships, providing generalizable results for policy-making in North Africa.

Case Study Focus: Focusing on North Africa enables an in-depth examination of regional dynamics affecting agricultural innovation and food security.

Secondary Data Use: Utilizing existing, reliable datasets ensures data accuracy and comprehensive coverage, facilitating a broader analysis than primary data collection alone.

SEM and SmartPLS: These tools are ideal for modeling complex relationships and testing moderating effects, offering insights into how climate adaptation strategies influence the relationship between agricultural innovation and food security

4. DATA PRESENTATION AND ANALYSIS:

First: Assessment of measurement model:

In this section, the quality of the expressions utilized in this model is examined through the utilization of the Smart PLS software. This evaluation entails testing the convergence and consistency of these expressions amongst themselves. The objective is to ensure the capability of these expressions to effectively measure the desired attributes, as well as the stability of the measurement across different conditions, employing the Convergent Validity test. Moreover, an assessment is conducted to determine the logical distinctiveness and absence of overlap among these expressions, employing the Discriminate Validity test.

4.1 Convergent validity:

Convergent validity is a critical aspect of structural equation modeling (SEM), including Partial Least Squares SEM (PLS-SEM). Convergent validity assesses whether the indicators (manifest variables) of a latent construct (factor) are measuring the same underlying concept. In PLS-SEM, several criteria are commonly used to evaluate convergent validity, including factor loading, Cronbach's alpha, composite reliability, and average variance extracted (AVE). Here's an explanation of each criterion:

Factor loading:

Basis: Factor loading represents the strength and direction of the relationship between an indicator and its corresponding latent construct. In PLS-SEM, factor loadings should be statistically significant and preferably higher than 0.7 to indicate a strong relationship.

Cronbach's Alpha:

Basis: Cronbach's alpha is a measure of internal consistency reliability. It assesses the extent to which a set of indicators (items) measures a single latent construct consistently. In PLS-SEM, a high Cronbach's alpha (typically above 0.7) suggests good internal consistency.

Composite reliability:

Basis: Composite reliability is another measure of reliability that evaluates the consistency of indicators in measuring a latent construct. In PLS-SEM, composite reliability should ideally exceed 0.7, indicating that the indicators are reliable measures of the underlying construct.

Average variance extracted (AVE):

Statistically, convergent validity is established when the Average Variance Extracted (AVE) is greater than 0.50 (Sarstedt et al., 2021). Additionally, factor loading, Cronbach's Alpha, and composite reliability are also used to assess convergent validity in PLS-SEM. Factor loading measures the relationship between the observed variables and their underlying latent constructs, while Cronbach's Alpha and composite reliability assess the internal consistency of the measurement instrument (Amora, 2021).

Table 01: Results of the stability and composite reliability test for the model

Variables	Items	Loadings	Cronbach's Alpha	Composite Reliability	The average variance extracted
Food Security	FS_1	0.927	0.893	0.933	0.824
	FS_2	0.901			
	FS_3	0.894			
Climate Change Adaptation Strategies	CCAS_1	0.684	0.887	0.910	0.558
	CCAS_2	0.795			
	CCAS_3	0.760			
	CCAS_4	0.715			
	CCAS_5	0.802			
	CCAS_6	0.702			
	CCAS_7	0.755			
	CCAS_8	0.754			
Agricultura l Innovation	AI_1	0.603	0.870	0.898	0.561
	AI_2	0.827			
	AI_3	0.756			
	AI_4	0.806			
	AI_5	0.819			
	AI_6	0.714			
	AI_7	0.690			

Source: Compiled by researchers based on the outputs of Smart PLS4.

The results from the stability and composite reliability test for the model show that the variables Food Security, Climate Change Adaptation Strategies, and Agricultural Innovation have been assessed for their reliability and validity using multiple metrics. Food Security, with loadings for items FS_1, FS_2, and FS_3 ranging from 0.894 to 0.927, has a high Cronbach's Alpha of 0.893 and a composite reliability of 0.933, indicating excellent internal consistency. The average variance extracted (AVE) for Food Security is 0.824, well above the 0.50 threshold, suggesting that the items capture a substantial portion of the variance of the underlying construct.

For Climate Change Adaptation Strategies, item loadings range from 0.684 to 0.802, and Cronbach's Alpha is 0.887, indicating good internal consistency. The composite reliability is 0.910, and the AVE is 0.558, which meets the minimum acceptable level, though it indicates a need for a slight improvement in capturing the construct's variance.

Agricultural Innovation has item loadings between 0.603 and 0.827, with a Cronbach's Alpha of 0.870, reflecting good reliability. The composite reliability is 0.898, and the AVE is 0.561, which is acceptable but suggests that the construct's items, while consistent, could be enhanced to better represent the underlying construct. Overall, the model demonstrates adequate to excellent reliability and validity across all variables, supporting the robustness of the measurement instruments used in this study.

4.2 Discriminate validity :

The recommended criteria for analyzing the results of the discriminant validity test in the PLS-SEM methodology include the following:

Fornell-Larcker Criterion: This criterion assesses discriminant validity by comparing the square root of the average variance extracted (AVE) for each construct with the correlations between that construct and other constructs. Discriminant validity is established if the AVE value for a particular construct is greater than its correlation with all other constructs (Henseler et al., 2015) (Hamid et al., 2017)

Heterotrait-Monotrait Ratio of Correlations (HTMT) Criterion: This criterion is based on the heterotrait-monotrait ratio of correlations and is used to assess discriminant validity in variance-based structural equation modeling. It measures the extent to which constructs are distinct from each other empirically. A threshold of 0.85 is recommended for HTMT when the constructs in the path model are conceptually more distinct (Franke & Sarstedt, 2019) (Henseler et al., 2015) (Hamid et al., 2017)

It is important to note that the Fornell-Larcker Criterion and cross-loadings have been the dominant approaches for evaluating discriminant validity, but Henseler, Ringle, and Sarstedt (2015) have proposed the HTMT criterion as an alternative approach, which has shown high sensitivity and specificity in detecting discriminant validity problems (Cepeda-Carrión et al., 2022) (Henseler et al., 2015) (Hamid et al., 2017)

In conclusion, when analyzing the results of the discriminant validity test in the PLS-SEM methodology, researchers should consider using the Fornell-Larcker Criterion, cross-loadings, and the HTMT Criterion to ensure the distinctiveness of the constructs in the study and to detect any issues with discriminant validity

Table 02: Fornell-Larcker criterion

variables	Agricultural Innovation	Climate Change Adaptation Strategies	Food Security
Agricultural Innovation	0.749		
Climate Change Adaptation Strategies	0.713	0.747	
Food Security	0.638	0.555	0.907

Source: Compiled by researchers based on the outputs of Smart PLS4

The Fornell-Larcker Criterion results indicate how well the constructs of Agricultural Innovation, Climate Change Adaptation Strategies, and Food Security differentiate from each other, ensuring discriminant validity. Each variable's value on the diagonal represents the square root of the Average Variance Extracted (AVE), which should be higher than its correlations with other variables for adequate discriminant validity. The square root of the AVE for Agricultural Innovation is 0.749, which is greater than its correlations with Climate Change Adaptation Strategies (0.713) and Food Security (0.638). Similarly, Climate Change Adaptation Strategies has a square root of AVE value of 0.747, higher than its correlation with Food Security (0.555). Lastly, Food Security shows a high square root of AVE of 0.907, significantly exceeding its correlations with Agricultural Innovation (0.638) and Climate Change Adaptation Strategies (0.555). These results confirm that each construct is distinct and reliably measured, meeting the criteria for discriminant validity.

Table 03: The Heterotrait-Monotrait ratio of correlations (HTMT)

Variables	Agricultural Innovation	Climate Change Adaptation Strategies	Food Security
Agricultural Innovation			
Climate Change Adaptation Strategies	0.813		
Food Security	0.692	0.611	

Source: Compiled by researchers based on the outputs of Smart PLS4

The Heterotrait-Monotrait Ratio (HTMT) results from Table 03 provide insight into the discriminant validity of the constructs: Agricultural Innovation, Climate Change Adaptation Strategies, and Food Security. The HTMT values for the relationships between these variables are all below the commonly accepted threshold of 0.85, indicating adequate discriminant validity. Specifically, the HTMT value between Agricultural Innovation and Climate Change Adaptation Strategies is 0.813, which, while relatively high, is still within acceptable limits, suggesting these constructs are distinct but closely related. The HTMT value between Agricultural Innovation and Food Security is 0.692, and between Climate Change Adaptation Strategies and Food Security is 0.611, both of which are comfortably below the threshold, further confirming that these constructs are sufficiently differentiated from each other. Overall, these HTMT values support the conclusion that the constructs exhibit good discriminant validity, meaning they measure distinct concepts as intended.

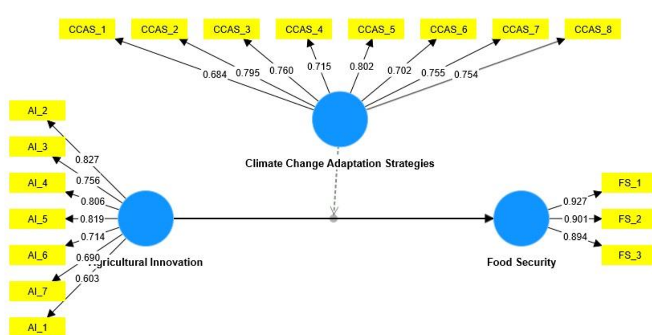

Figure 2: General structural model for the study

Source: Compiled by researchers based on the outputs of Smart PLS4

Secondly: Testing the internal model (structural model)

In this section, we evaluate the results of the structural model by testing the degree of correlation, assessing the predictive capabilities of the model, and examining the relationships between constructs. Additionally, we conduct the necessary tests to evaluate the model.

1. Validity of the structural model:

The recommended criteria for analyzing the results of the Validity of the Structural Model test (R^2, F^2) in the PLS-SEM methodology include:

Measurement model assessment: This involves assessing the relationship between a construct and its observed items, including reliability, indicator loading, and internal consistency reliability (Fauzi, 2022).

Structural model assessment: This focuses on evaluating the significance and relevance of path coefficients, followed by the model's explanatory and predictive power. Key metrics relevant to structural model assessment in PLS-SEM include the coefficient of determination (R2), f2 effect size, and cross-validated predictive ability test (CVPAT). (Hair Jr et al., 2021).

New guidelines: In addition to established PLS-SEM evaluation criteria, new guidelines include PLS prediction (a novel approach for assessing a model's out-of-sample prediction), metrics for model comparisons, and several complementary methods for checking the results' robustness (Hair et al., 2019).

Table 04: Validity of the structural model

Variables	**Coefficient of Determination (R2)**	**Explanatory size (F2)**
Food Security	0.449	/
Agricultural Innovation	/	0.224
Climate Change Adaptation Strategies	/	0.049

Source: Compiled by researchers based on the outputs of Smart PLS4

Table 04 provides key metrics for evaluating the validity of the structural model, specifically the Coefficient of Determination (R^2) and the Explanatory Size (F^2) for the variables involved. The R^2 value for Food Security is 0.449, indicating that 44.9% of the variance in Food Security is explained by the model's predictors, which suggests a moderate level of explanatory power. This implies that Agricultural Innovation and Climate Change Adaptation Strategies collectively account for a significant portion of the variance in Food Security. For Agricultural Innovation, the F^2 value is 0.224, indicating a medium to large effect size, meaning that it has a substantial impact on the outcome variable (Food Security) within the model. On the other hand, Climate Change Adaptation Strategies have an F^2 value of 0.049, indicating a small effect size. This suggests that while Climate Change Adaptation Strategies do contribute to explaining Food Security, their impact is relatively minor compared to Agricultural Innovation. Overall, the model demonstrates a reasonable level of validity with Agricultural Innovation being a more critical determinant of Food Security than Climate Change Adaptation Strategies.

5. Discussion of testing the study hypotheses

When analyzing the results of testing study hypotheses in the Partial Least Squares Structural Equation Modeling (PLS-SEM) methodology, there are several recommended criteria to consider.

These criteria are essential for ensuring the validity and reliability of the analysis. Here are the recommended criteria for analyzing the results of testing this study's hypotheses in the PLS-SEM methodology:

Hypothesis Testing with Confidence Intervals and P Values: Researchers usually employ P values for hypothesis testing in PLS-SEM, where each hypothesis refers to a path in a model. P values may be one-tailed or two-tailed (Kock, 2016).

Structural Model Testing: The structural model in PLS-SEM needs to be tested to ensure that the assumptions of unidimensional constructs hold in the sample. This involves testing the relationships between latent variables and their indicators (Kock, 2016).

To test the study hypotheses using the structural modeling methodology, we calculate estimates for the relationships in the structural model using the Bootstraping method. These estimates indicate the expected relationships between constructs, and the path coefficient ranges from -1 to +1. Values close to +1 suggest strong positive relationships, while values near -1 indicate strong negative relationships. Typically, statistically significant relationships have p-values below 5%. Coefficients approaching zero from both directions suggest weak relationships (Kock, 2018).

5.1 Hypotheses:

5.1.1 First hypothesis (H1): There is no statistically significant positive relationship between Agricultural Innovation and Food Security at a 5% significance level.

5.1.2 Second Hypothesis (H2): There is no significant role for Climate Change Adaptation Strategies in reducing the relationship between Agricultural Innovation and Food Security at a 5% significance level.

Table 5: Testing the hypotheses for the study (H_1, H_2)

Hypothesis	Paths	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values	Decision
H_1	Agricultural Innovation ---> Food Security	0.502	0.504	0.116	4.323	0.000	Hypothesis Accepted
H_2	The Interaction ---> Food Security	0.135	0.135	0.054	2.487	0.013	Hypothesis Accepted

Source: Compiled by researchers based on the outputs of Smart PLS4

Table 5 presents the results of hypothesis testing for the study, focusing on the paths between Agricultural Innovation, Climate Change Adaptation Strategies, and Food Security. For Hypothesis H1, the path coefficient between Agricultural Innovation and Food Security is 0.502, with a high T-statistic of 4.323 and a P-value of 0.000, indicating a statistically significant positive relationship. This result demonstrates that Agricultural Innovation has a strong and significant impact on enhancing Food Security, validating the hypothesis. For Hypothesis H2, the path coefficient for the interaction between Climate Change Adaptation Strategies and Agricultural Innovation affecting Food Security is 0.135. With a T-statistic of 2.487 and a P-value of 0.013, this interaction is also statistically significant, though the effect is more modest compared to direct Agricultural Innovation. This indicates that Climate Change Adaptation Strategies positively moderate the relationship between Agricultural Innovation and Food Security, confirming the hypothesis that these strategies enhance the effectiveness of agricultural innovations in improving food security. Overall, both hypotheses are accepted, underscoring the critical roles of Agricultural Innovation and Climate Change Adaptation Strategies in bolstering Food Security in North Africa.

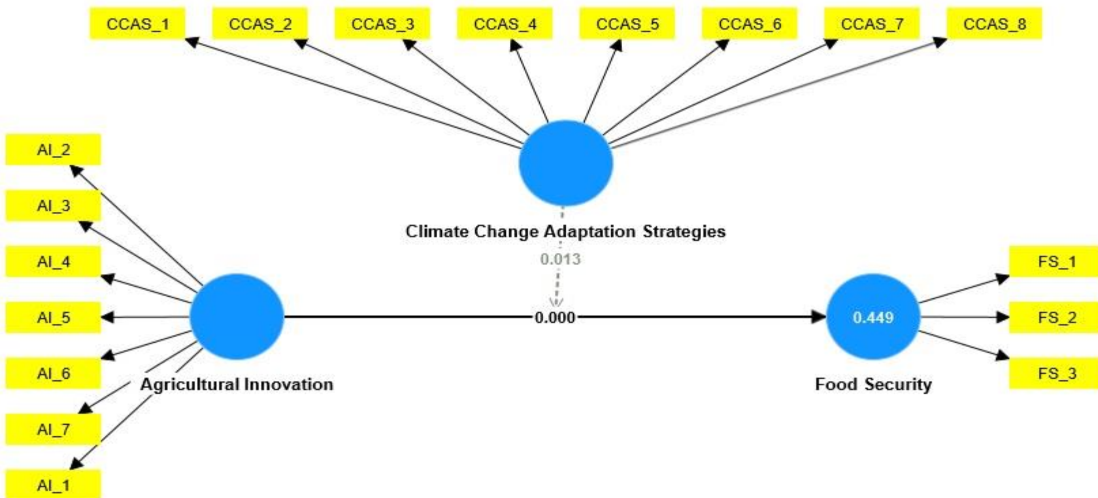

Figure 3: Results of path coefficients

Source: Compiled by researchers based on the outputs of Smart PLS4

Table 6: Testing the effectiveness of the moderating variable (Climate Change Adaptation Strategies) in reducing the effect of Agricultural Innovation on Food Security

Relationship	Path Coefficient	P Values	Hypothesis
Agricultural Innovation ---> Food Security	0.502	0.000	Accepted
Climate Change Adaptation Strategies ---> Food Security	0.237	0.028	Accepted
The Interaction (AI * CCAS) ---> Food Security	0.135	0.013	Accepted

Source: Compiled by researchers based on the outputs of Smart PLS4

Table 6 provides insights into the role of Climate Change Adaptation Strategies as a moderating variable in the relationship between Agricultural Innovation and Food Security. The path coefficient between Agricultural Innovation and Food Security is 0.502 with a P-value of 0.000, indicating a highly significant positive effect, affirming the critical role of Agricultural Innovation in enhancing Food Security. The direct effect of Climate Change Adaptation Strategies on Food Security is also significant, with a path coefficient of 0.237 and a P-value of 0.028, suggesting that these strategies independently contribute to improving Food Security. Importantly, the interaction term between

Agricultural Innovation and Climate Change Adaptation Strategies (AI * CCAS) has a path coefficient of 0.135 and a P-value of 0.013, demonstrating that Climate Change Adaptation Strategies significantly moderate the impact of Agricultural Innovation on Food Security. This means that the presence of effective adaptation strategies amplifies the positive effect of agricultural innovation on food security, making agricultural advancements more effective in achieving food security objectives under changing climate conditions. Thus, the hypothesis that Climate Change Adaptation Strategies serve as a beneficial moderator is confirmed, underscoring the importance of integrating these strategies to maximize the benefits of agricultural innovation for food security.

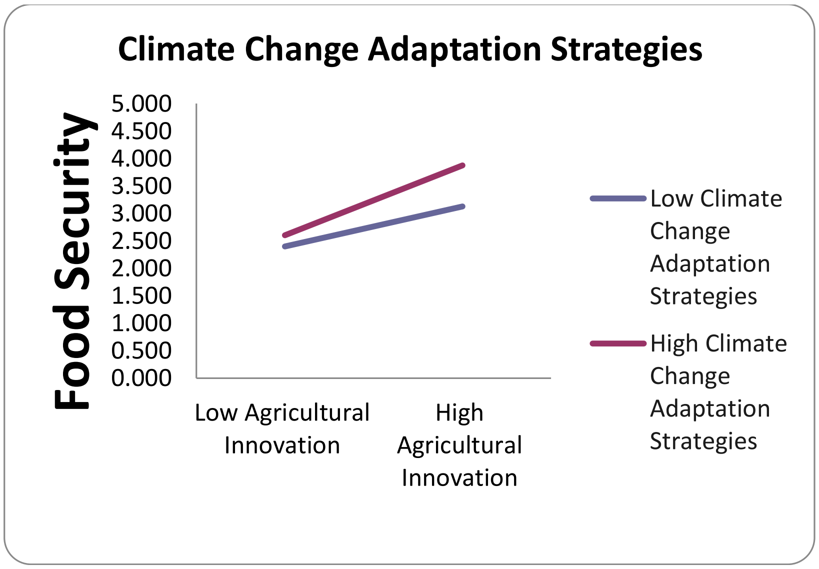

Figure 4: Path coefficients of The Interaction (Agricultural Innovation * Climate Change Adaptation Strategies) --> Food Security

Source: Compiled by researchers based on the outputs of Microsoft Excel.

6. DISCUSSION

6.1 Interpretation of findings

The study's findings underscore the pivotal roles of Agricultural Innovation and Climate Change Adaptation Strategies in enhancing Food Security in North Africa. The results demonstrate that Agricultural Innovation significantly contributes to Food Security, as evidenced by the strong path coefficient of 0.502 and a highly significant P-value of 0.000. This indicates that advancements in agricultural technology and practices directly enhance food availability and accessibility, addressing critical components of food security in the region. Furthermore, Climate Change Adaptation Strategies independently improve Food Security, with a path coefficient of 0.237 and a significant P-value of 0.028, highlighting their importance in mitigating the adverse impacts of climate change on agriculture and food production.

The interaction effect between Agricultural Innovation and Climate Change Adaptation Strategies (path coefficient of 0.135, P-value of 0.013) indicates that adaptation strategies significantly amplify the positive impact of agricultural innovations on Food Security. This suggests that while agricultural innovations are crucial, their effectiveness is greatly enhanced when complemented by robust adaptation measures. This synergy implies that policies and interventions that combine technological advancements with climate resilience measures are likely to yield the most substantial benefits for food security in North Africa.

6.2 Comparison with prior research

The findings align with and extend prior research in several key ways. Previous studies have highlighted the importance of agricultural innovation in improving food security by increasing productivity and resilience in the face of environmental challenges (Gorgodze et al., 2022) (Bo et al., 2021). This study corroborates those findings by quantitatively demonstrating a strong, positive relationship between Agricultural Innovation and Food Security in the North African context.

Additionally, the independent effect of Climate Change Adaptation Strategies on Food Security supports the conclusions of earlier research, which emphasized the role of adaptation in mitigating the impacts of climate variability and enhancing agricultural resilience (Chen et al., 2023) (R. & Abramoff., 2023). However, this study goes further by empirically validating the moderating effect of these strategies, showing that their presence not only mitigates risks but also enhances the benefits derived from agricultural innovations.

Compared to studies that often treat agricultural innovation and climate adaptation as separate strategies (Okoro et al., 2022) (Sokolova et al., 2022), this research highlights the significant interplay between the two. The interaction effect found in this study underscores the necessity of integrated approaches, where both innovation and adaptation are jointly pursued to maximize food security outcomes. This aligns with the growing body of literature advocating for holistic strategies that address both technological advancements and climate resilience simultaneously (Nursaule et al., 2023) (Malec et al., 2023).

In summary, the findings contribute to the existing literature by providing robust empirical evidence of the complementary relationship between agricultural innovation and climate adaptation strategies in enhancing food security. They reinforce the importance of integrated policy approaches that leverage both technological and adaptive measures to address the complex challenges of food security in the context of climate change in North Africa

7. CONCLUSION

7.1 Summary of key findings: This study explores the interplay between Agricultural Innovation and Climate Change Adaptation Strategies in enhancing Food Security in North Africa. Key findings indicate that Agricultural Innovation significantly improves Food Security, evidenced by a strong path coefficient of 0.502 and a highly significant P-value of 0.000. This underscores the critical role of technological advancements and modern agricultural practices in ensuring food availability and accessibility. Furthermore, Climate Change Adaptation Strategies also have a substantial, positive effect on Food Security, with a path coefficient of 0.237 and a P-value of 0.028, highlighting their importance in mitigating the adverse impacts of climate change. Importantly, the interaction between Agricultural Innovation and Climate Change Adaptation Strategies (path coefficient of 0.135, P-value of 0.013) shows that the combination of these approaches amplifies their benefits, indicating that integrated strategies are essential for maximizing food security outcomes in the region.

7.2 Importance of agricultural innovation and climate change adaptation strategies in food security

The findings of this study underscore the indispensable role of Agricultural Innovation in addressing food security challenges. Technological advancements and innovative agricultural practices are pivotal in increasing crop yields, improving resource efficiency, and enhancing the resilience of agricultural systems. These innovations are crucial for meeting the growing food demands and mitigating the impacts of environmental stressors.

Equally important are Climate Change Adaptation Strategies, which provide the necessary framework to combat the adverse effects of climate variability on agriculture. By incorporating adaptive measures such as drought-resistant crop varieties, improved irrigation techniques, and climate-smart agricultural practices, these strategies significantly contribute to sustaining and improving food security.

The synergistic effect of combining Agricultural Innovation with Climate Change Adaptation Strategies reveals that an integrated approach is more effective than implementing either strategy in isolation. This integrated approach not only ensures a more resilient and productive agricultural sector but also enhances the overall food security in North Africa, making it a crucial policy priority for addressing both current and future food security challenges in the context of climate change

Acknowledgments: This research was sponsored by the Thematic Agency for Research in the Social Sciences and Humanities of Algeria.

REFERENCES

P., Anandajayasekeram. (2022). The Role of Agricultural R&D within the Agricultural Innovation Systems Framework. 75-87. doi: 10.1201/9781003164968-10

Sokolova, A. P., Sukhareva, O. A., & Mokrushin, A. A. (2022). Innovation as a Direction of Sustainable Development of Agricultural Enterprises. In Digital Technologies and Institutions for Sustainable Development (pp. 223-228). Cham: Springer International Publishing.

Gorgodze, T. E., Tomoradze, I. V., & Denisov, D. Y. (2022, April). Innovations in agriculture: Trends in the development of the regional economy. In Proceedings of the International Conference Engineering Innovations and Sustainable Development (pp. 41-47). Cham: Springer International Publishing.

Bo, Kyeong, Yoon., Bo, Kyeong, Yoon., Hyunhyuk, Tae., Joshua, A., Jackman., Supratik, Guha., Supratik, Guha., Cherie, R., Kagan., Andrew, J., Margenot., Diane, L., Rowland., Paul, S., Weiss., Nam-Joon, Cho. (2021). Entrepreneurial Talent Building for 21st Century Agricultural Innovation. ACS Nano, 15(7):10748-10758. doi: 10.1021/ACSNANO.1C05980

I.V., Rasevych., O., Demydenko. (2022). Innovations as the main factor of agricultural development at the regional level. Zemlerobstvo ta roslinnictvo: teorìâ ì praktika, 81-90. doi: 10.54651/agri.2022.04.10

Nursaule, Zh., Brimbetova., Gauhartas, Temirova., A, A, Sultanaev. (2023). Food Security and Social Development of Regions: International Experience. Экономика: стратегия и практика, 18(1):36-54. doi: 10.51176/1997-9967-2023-1-36-54

Андрій, Вікторович, Баранов. (2023). Продовольча безпека як фактор економічної безпеки економіки україни в умовах війни. Агросвіт, doi: 10.32702/2306-6792.2023.13.75

William, Kerr. (2023). Food Security. doi: 10.4337/9781035312719

Dongxu, Ke. (2022). Food Security (Foodsec) (fs). 741-772. doi: 10.1007/978-981-16-8293-3_18

Shichao, Chen., Wenfeng, Liu., Zongzheng, Yan., Julien, Morel., David, Parsons., Taisheng, Du. (2023). Adaptation Strategy Can Ensure Seed and Food Production With Improving Water and Nitrogen Use Efficiency Under Climate Change. Earth's Future, 11 doi: 10.1029/2022EF002879

Chen, S., Liu, W., Yan, Z., Morel, J., Parsons, D., & Du, T. (2023). Adaptation strategy can ensure seed and food production by improving water and nitrogen use efficiency under climate change. Earth's Future, 11(2), e2022EF002879.

R., Z., Abramoff., Philippe, Ciais., Peng, Zhu., Toshihiro, Hasegawa., Hitomi, Wakatsuki., David, Makowski. (2023). Adaptation Strategies Strongly Reduce the Future Impacts of Climate Change on Simulated Crop Yields. Earth's Future, 11 doi: 10.1029/2022EF003190

R., Z., Abramoff., IIA-CIA-Part3-Pdf-Dumps. (2023). Adaptation Strategies Strongly Reduce the Future Impacts of Climate Change on Simulated Crop Yields. Earth's Future, 11(4) doi: 10.1029/2022ef003190

Okoro,, Ifeanyichukwu, Dumtochukwu., Okoro,, Patrick, Igbonekwu., Monday, Sampson., J., Adisa. (2022). Climate Change Adaptation Strategies: Implication for Behavioural Change. 1-9. doi: 10.9734/ajee/2022/v18i430322

Malec, K., Rojík, S., Maitah, M., Abdu, M., & Abdullahi, K. T. (2023). Investments in Agricultural Innovation and Food Security in Sub-Saharan Africa.

W., C., Grobler. (2023). Research and technology innovation, food security and economic growth in Nigeria: Implications for agripreneurs and policymakers. African Journal of Food, Agriculture, Nutrition and Development, 23(04):23220-23237. doi: 10.18697/ajfand.119.21255

Daniel, Duran-Sandoval., F., Uleri., Gemma, Duran-Romero., Ana, Medina, López. (2023). Food, Climate Change, and the Challenge of Innovation. Encyclopedia, 3(3):839-852. doi: 10.3390/encyclopedia3030060

Ani, Dimitrova. (2022). Technological innovations in agriculture as a way to increase food security. Economic Thought Journal, 67(6):692-704. doi: 10.56497/etj2267604

Daniel, Duran-Sandoval., F., Uleri., Gemma, Duran-Romero., Ana, Medina, López. (2023). Food, Climate Change, and the Challenge of Innovation. Encyclopedia, 3(3):839-852. doi: 10.3390/encyclopedia3030060

Girma, Gezimu, Gebre., Yuichiro, Amekawa., Aneteneh, Ashebir. (2023). Can farmers' climate change adaptation strategies ensure their food security? Evidence from Ethiopia. Agrekon, 1-16. doi: 10.1080/03031853.2023.2230959

Teodoro, Semeraro., Aurelia, Scarano., A., Leggieri., A., Calisi., Monica, De, Caroli. (2023). Impact of Climate Change on Agroecosystems and Potential Adaptation Strategies. Land, 12(6):1117-1117. doi: 10.3390/land12061117

Jeremy, Galbreath., Grigorij, Ljubownikow., Daniel, Tisch., Gerson, Tuazon. (2023). The responsibility of ensuring food security: a cross-country study on reducing the impact of agricultural industries on vulnerability to climate change. Journal of Global Responsibility, doi: 10.1108/jgr-11-2022-0119