

Impact of Institutional Risk Management, Technological Adoption, and Climate Change Adaptation on Ghana's Crop Productivity

*Dexter Senanu Kofi Hewlett^a, Evans Tee^b,
Kojo Essel-Mensah^c, Janet Owusu Asabre^d

^aDepartment of Banking and Finance, University of Professional Studies, Accra, Ghana

^bDepartment of Economics and Actuarial Science, University of Professional Studies, Accra, Ghana,

^cDepartment of Mathematical Statistics and Actuarial Science, University of the Free State, South Africa,

^d The International Institute of Tropical Agriculture (IITA)

Corresponding author: dhewlett@upsamail.edu.gh,

evans.tee@upsamail.edu.gh, EsselMensahKA@ufs.ac.za, ^d J.Owusu-Asabre@cgiar.org

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Abstract

This study investigated the impact of Agricultural Technology Adoption (ATA), Climate Change Adaptation Measures (CCAM), and Institutional Risk Management (IRM) on crop production (CP). The purpose of this study is to assess how these variables influence agricultural productivity and identify the key drivers of successful crop production in the context of climate change and institutional challenges. A quantitative research design was employed utilising survey data collected from farmers across different agricultural regions. Structural equation modelling (SEM) was used for data analysis to examine the relationships between ATA, CCAM, IRM, and CP. The findings indicated that ATA, CCAM, and IRM had a positive and statistically significant effect on crop production. This study highlights that adopting advanced technologies, implementing effective climate change adaptation strategies, and strengthening institutional risk management can significantly enhance crop productivity. This study contributes to the literature by emphasising the importance of technological adoption and risk management strategies in agriculture. These practical implications suggest that policymakers should prioritise the integration of ATA and IRM into agricultural policies to promote sustainable and resilient agricultural practices, thereby improving overall crop production and food security.

Keywords: Agricultural Technology Adoption, Climate Change Adaptation, Institutional Risk Management, Crop Production, Policy Implications.

JEL Codes: Q12, O33, Q54.

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1. Introduction

Ghana's economy is dependent on agriculture, which is essential for export revenue, food security, and employment (Nkansah-Dwamena, 2024; Asare-Nuamah et al. 2023). Several risk factors, such as the effects of climate change, institutional inefficiencies, and the inadequate incorporation of contemporary technology, have contributed to the fact that crop productivity has not reached its potential (Agyei-Holmes et al., 2023; Ayojimi et al., 2023). The necessity for comprehensive solutions to resolve these issues is underscored by the ongoing productivity disparity. A comprehensive method for overcoming these obstacles and attaining sustainable agricultural development is provided by the amalgamation of institutional risk management, technical implementation, and climate change adaptation strategies (Afriyie et al., 2023; Grigorieva et al., 2023).

The agricultural industry's resilience, which has faced numerous challenges, is inextricably linked to crop productivity in Ghana. These consist of market volatility, financial uncertainty, inadequate infrastructure, and erratic weather conditions (Sekyi et al. 2023). Addressing these challenges necessitates effective institutional risk management, particularly through policies that provide financial protection, extension services, and regulatory frameworks (Eghan & Adjasi, 2023). However, bureaucratic inefficiencies and resource constraints have frequently impeded the effectiveness of these endeavours.

The integration of technology is a critical component of agricultural development. In numerous developing nations, mechanisation, precision agriculture, and mobile information systems are acknowledged as critical factors that increase productivity (Tham-Agyekum et al., 2024; Redclift, 2023). However, the adoption of these technologies in Ghana is restricted due to their high costs, insufficient technical expertise, and limited access to financing (Jones et al., 2023). These challenges are further complicated by the escalating effects of climate change, which include insect infestations, elevated temperatures, and irregular rainfall patterns (Campbell et al., 2023). A unified framework that integrates institutional, technological, and adaptive strategies is necessary to resolve these interconnected difficulties.

Empirical research that investigates the combined impact of institutional risk management, technological adoption, and climate change adaptation on crop output is still scarce, despite the growing recognition of the intricate nature of agricultural hazards. The majority of research conducted in Ghana has focused solely on one or two variables. Torsu et al. (2024) examined the role of extension services in reducing production hazards, while Antwi-Agyei and Amanor (2023) examined the challenges associated with technology adoption. Asante et al. (2024) assessed the effectiveness of climate-smart agriculture; however, they did not establish a direct correlation between it and technological and institutional challenges. The interplay of various variables on agricultural productivity is significantly compromised by this disparate methodology, which leads to significant deficiencies in comprehension. It is imperative to rectify this research deficiency in order to develop comprehensive policies that enhance the productivity and resilience of Ghanaian agriculture.

The objective of this investigation was to evaluate the synergistic effects of institutional risk management, technological implementation, and climate change adaptation strategies on agricultural productivity in Ghana. The objective of this investigation is to

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- i. Evaluate the influence of institutional risk management techniques on crop productivity.
- ii. To examine the impact of technological adoption on crop productivity.
- iii. Assessment of the efficacy of climate change adaptation strategies on crop productivity.

The following research questions guide this study:

- i. To what extent does institutional risk management influence Ghana's crop productivity?
- ii. How does technological adoption enhance crop productivity?
- iii. What role do climate change adaptation measures play in mitigating crop productivity loss?

For various reasons, it is imperative to investigate the correlation between institutional risk management, technological adoption, and climate change adaptation measures. This study provides empirical evidence to inform policy decisions that prioritise developing agricultural resilience. Effective risk management policies can significantly reduce farmers' vulnerability to market and environmental disruptions, as Aduhene-Chinbuah et al. (2024) emphasized. Ghana's strategic objectives for agricultural modernization under the "Planting for Food and Jobs" initiative are consistent with the role of technology in addressing the productivity gap, as emphasized in this study (Ministry of Food and Agriculture, 2022). Third, the research combines climate change adaptation into the analysis, acknowledging the existential threat that global warming poses to food security and livelihoods (Tham-Agyekum et al., 2024). Significant implications for farmers, policymakers, and researchers will result from the findings of this study, which will offer actionable insights for the promotion of sustainable agricultural development.

A fragmented approach has been primarily used in previous studies on agricultural productivity in Ghana, with a focus on individual variables rather than comprehensive frameworks. The impact of technological innovations was not taken into account by Batung et al. (2023), who demonstrated that institutional support, such as access to credit and insurance, mitigates production risks. Financial and knowledge barriers to technology adoption were identified by Osei et al. (2023); however, they neglected to consider the influence of institutional frameworks and environmental factors.

The importance of climate-smart agricultural practices was emphasised by Anang and Dagunga (2024); however, they did not investigate their interaction with technological and institutional factors. The necessity of a comprehensive approach that considers the interconnections among risk management, technology, and adaptation strategies is underscored by the identified limitations.

Addressing the increasing complexity of agricultural challenges in Ghana, this research is both timely and pertinent. By transcending fragmentary analyses, this investigation offers a comprehensive evaluation of the factors that influence crop productivity. This investigation investigates the dynamics that influence agricultural outcomes by examining the intersections of environmental, technological, and institutional dimensions. The practical solutions provided by these findings will enhance the resilience and productivity of Ghanaian farmers, as well as contribute to academic discourse.

2 Literature Review

2.1 Theoretical Framework

The interconnections between institutional risk management, technological adoption and climate change adaptation strategies are investigated in this study through the application of a variety of

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theoretical frameworks. The Resource-Based View (RBV) posits that the efficient utilisation of resources by institutions, including agricultural systems, results in a competitive advantage (Malhotra et al., 2024). Institutional frameworks, technologies, and adaptive measures are indispensable resources in agriculture that necessitate strategic management to enhance productivity. In order to achieve stability and growth,

Risk Management Theory provides a framework for understanding how producers and institutions can anticipate, assess, and mitigate risks (Jankensgard & Kapstad, 2021).

The interconnections between the institutional, technological, and adaptive dimensions are underscored by the synthesis of these theories. The financial risks associated with the adoption of advanced technologies can be mitigated through institutional support, while adaptive measures can promote technological innovation by resolving environmental uncertainties. The exhaustive examination of factors that affect crop productivity is guided by this theoretical framework.

The current literature on agricultural productivity in Ghana reveals significant deficiencies in the comprehension of the interplay between institutional risk management, technological adoption, and climate change adaptation strategies. There is a scarcity of research on the collective impact of these factors, despite the fact that they have been examined separately. Batung et al. (2023) investigate the obstacles to technology adoption; however, they fail to recognise the importance of institutional support and climate adaptation. The advantages of CSA practices are underscored by Osei et al. (2023); however, they fail to integrate these discoveries with technological and institutional factors. The identified deficiencies underscore the importance of a comprehensive framework that evaluates the synergies and trade-offs between these dimensions.

2.2 Institutional Risk Management

It is imperative to implement institutional risk management in order to mitigate uncertainties and improve the stability of agricultural systems. This encompasses credit facilities, regulatory policies, extension services, and agricultural insurance schemes. Aigbavboa et al. (2023) states that effective institutional frameworks are essential for mitigating production risks, particularly in the presence of environmental uncertainties and market volatility. The availability of credit enables producers to invest in contemporary inputs that increase productivity. Acheampong et al. (2023) argue that bureaucratic inefficiencies and insufficient transparency in their distribution methods diminish the potential benefits of institutional support. The evidence from Kenya has shown that agricultural output is considerably increased by well-structured institutional interventions, such as cooperative farming schemes (Borter and Malik 2023). The prerequisite for context-specific assessments of institutional risk management in Ghana is emphasized by these constructing results. Additionally, institutional risk management functions as a catalyst for innovation and adaptation and as a protective mechanism. Effective policies can facilitate the adoption of sophisticated agricultural practices (Aigbavboa et al. 2023). In Ghana, the effectiveness of these interventions is frequently diminished due to the disparity between policy design and implementation, which is frequently the result of fragmented institutional frameworks. This investigation aims to evaluate the optimization of institutional risk management in conjunction with technological and adaptive strategies to address existing gaps.

2.3 Technological Adoption

The adoption of technology in agriculture has become fundamental to improving productivity and resilience. Innovations, including precision farming, mechanisation, and mobile-based advisory services, have shown considerable potential in addressing productivity gaps in sub-Saharan Africa (Anang & Dagunga, 2024). Mobile platforms providing real-time weather updates and market prices have facilitated informed decision making among farmers, resulting in increased yields. Ghana's adoption rates are low, primarily because of financial constraints, limited technical expertise, and insufficient infrastructural support (Aduhene-Chinbuah et al., 2024).

Although research has demonstrated the beneficial effects of technology on agricultural productivity, it has frequently overlooked the interaction between technology and additional elements, including institutional frameworks and climate adaptation strategies. Anang and Dagunga, (2024) assert that supportive institutional policies are essential for technological interventions to realise their full potential. Borter and Malik (2023) indicated that the lack of risk-sharing mechanisms, including insurance, discourages farmers from utilising high-cost technologies. This study seeks to address this gap by analysing the role of technological adoption within a comprehensive framework that incorporates institutional and environmental factors.

2.4 Climate Change Adaptation Measures

Climate change poses a significant risk to agricultural productivity, especially in nations such as Ghana, where agricultural systems rely heavily on natural weather patterns. Measures for adaptation, including crop diversification, water conservation, and implementation of drought-resistant seeds, have been extensively advocated as effective solutions (Gyamerah et al., 2023). Erekaló and Yadda (2023) assert that climate-smart agriculture (CSA) practices mitigate the negative impacts of climate variability while simultaneously improving long-term productivity. However, the success of these measures often depends on their compatibility with local conditions and availability of institutional support.

The adoption of climate change adaptation measures in Ghana has been inconsistent despite their apparent benefits. Amankwah (2019) identified lack of awareness, restricted access to climate-resilient technologies, and insufficient funding as contributing factors. Acheampong et al. (2023) contended that the majority of adaptation strategies are reactive, prioritising short-term gains over the development of long-term resilience. This study aimed to evaluate the effectiveness of climate change adaptation measures alongside institutional and technological factors to address existing shortcomings.

The literature highlights the significance of institutional risk management, technological adoption, and climate change adaptation measures for improving crop productivity. Existing studies have frequently employed a fragmented approach, neglecting the interdependencies among these factors. This study aims to overcome this limitation by employing an integrated framework that analyzes the interactions between these dimensions and their impact on agricultural outcomes in Ghana. The efficacy of climate change adaptation strategies alongside institutional and technological influences.

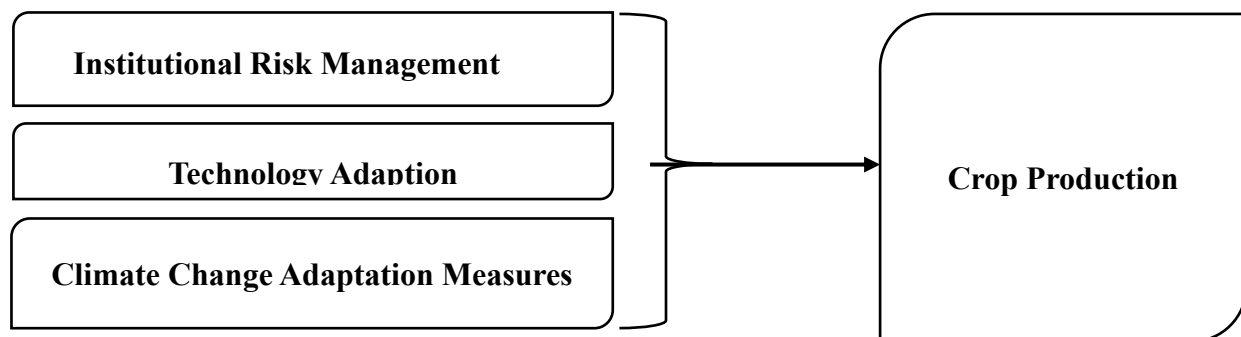


Figure 1 Conceptual Framework

3. Research Method

3.1 Research Design

This study employed a quantitative design to examine the effects of institutional risk management, technological adoption, and climate change adaptation on crop productivity in Ghana. This study employed a quantitative approach to facilitate the systematic collection, analysis, and interpretation of numerical data to examine the relationships among the variables of interest. This design enables the application of statistical tools to evaluate the magnitude and direction of relationships, yielding robust and generalizable findings (Creswell, 2017). The survey methodology was chosen for its efficiency in gathering data from a substantial sample of respondents (Bryman, 2016), especially in geographically dispersed areas, such as Ghana's agricultural zones.

3.2 Study Population and Sampling

The study's target population comprised crop farmers from key agricultural regions in Ghana. This population was chosen because farmers are the main stakeholders directly affected by institutional, technological, and environmental factors that affect crop productivity. This study examines farmers involved in crop production interacting with institutional risk management systems, technological tools, or climate adaptation measures. These characteristics ensure that respondents have the necessary knowledge and experience to offer pertinent insights for the study. A stratified random sampling technique was used to ensure representation across various farming regions and farm sizes, thus reducing selection bias and improving the generalisability of the findings (Flick, 2018). The sample size was calculated using Cochran's formula, achieving a 95% confidence level and 5% margin of error, resulting in 1,054 respondents. The sample size was adequate to detect significant relationships and maintain statistical power (Cochran, 1977).

3.3 Data Collection Methods

A structured questionnaire was used as the primary data-collection instrument for this study. The questionnaire comprised two primary sections. Section A presents demographic data on the participants, including age, gender, educational qualifications, and farming experience.

Section B includes items intended to assess the study's primary variables: institutional risk management, technological adoption, climate change adaptation measures, and crop productivity. The items were evaluated using a five-point Likert scale, with 1 indicating Strongly Disagree and

5 indicating Strongly Agree. The scale promotes clarity, consistency, and ease of response, facilitating the use of advanced statistical methods for data analysis (Likert, 1932). Each construct was represented by several indicators obtained from validated scales in previous studies, adjusted to fit the Ghanaian agricultural context.

3.4 Measurement of Variables

The research utilizes A structured questionnaire was used to assess four primary variables: institutional risk management, technological adoption, climate change adaptation measures, and crop productivity. Institutional risk management is evaluated using indicators that examine access to agricultural insurance, training, extension services, and credit facilities. Technological adoption emphasises the implementation of innovations, including mechanised equipment, enhanced seed varieties, fertilisers, irrigation systems, and digital tools. Climate change adaptation measures assess practices, such as crop diversification, soil conservation, water management, and the implementation of drought-resistant crops. Crop productivity, as the dependent variable, was evaluated based on self-reported perceptions of yield enhancements and harvest quality in recent seasons. Table 3.1 presents the constructs and the measurement items. This evaluation of the variables is consistent with earlier research on risk management and agricultural productivity (Makate et al., 2019).

Table 1: Constructs and Measurement Items

Construct	Description/Measurement
ATA1	I practice crop diversification on my farm
ATA2	I use pest-resistant crop varieties to reduce production risk
ATA3	I have invested in an irrigation system to manage water-related production risks
ATA4	I use digital tools or mobile applications to monitor and manage farm activities.
ATA5	I apply precision farming techniques to optimise resource use and improve productivity.
CCAM1	I adopt new technologies in my farming practices.
CCAM2	I use irrigation to manage water availability effectively.
CCAM3	I practice sustainable farming methods (farming practices that preserve the environment like Crop rotation, planting legumes to protect and enrich the soil) to manage environmental risks
CCAM4	I diversify my crops and livestock to reduce the risks associated with climate variability.
CCAM5	I access climate-related information from reliable sources to make informed farming decisions.
CP1	My crop yield meets or exceeds my expectations.
CP2	I am satisfied with the overall productivity of my crops per yield.
CP3	My crop yield per hectare is improving over time.
CP4	The strategies I use significantly contribute to achieving high crop yield per hectare.
CP5	The quality of my crop yield is consistent and meets market or consumption standards.
IRM1	I have hired additional or seasonal workers to help manage my farm activities.

IRM2	I offer regular training programs for my workers to improve their efficiency
IRM3	I regularly hire seasonal workers during peak periods to manage labour shortages.
IRM4	I frequently utilise agricultural extension services for advice and support.
IRM5	I have established contingency plans to manage unexpected risks in my farming operations.
IRM6	I actively participate in cooperative societies or farmer associations to enhance risk-sharing and support.

Source: Authors Own Creation

3.5 Data Analysis

Structural Equation Modelling (SEM) was utilized to analyze the interrelationships among the latent variables: Human Resource Risk Management (HRRM), financial risk management, institutional support, and crop productivity. This method is suitable for evaluating intricate models involving several mediating and moderating variables (Hair et al., 2014). The analysis examined the mediating role of financial risk management and the moderating effect of institutional support through bootstrapping and multigroup analysis, thereby enhancing the robustness and reliability of the indirect and interaction effects (Preacher et al., 2007). This analytical approach guarantees that this study yields valid and reliable insights into the dynamics of risk management in agriculture.

3.6 Ethical Considerations

Ethical considerations were prioritised in this study. All participants received comprehensive information regarding the research objectives and the voluntary aspects of their involvement. All respondents provided informed consent and confidentiality was ensured through data anonymisation. The study complied with the ethical standards established by the Institutional Review Board of the University of Ghana, which safeguarded participants' rights and privacy during data collection.

4. Result and Discussion

Table 2. Descriptive Statistical Analysis Result-Demographic

		FREQUENCY	PERCENT
GENDER	Male	556	52.8
	Female	498	47.2
AGE GROUP	under 20	81	7.7
	21-30	264	25
	31-40	125	11.9
	41-50	243	23.1
	51-60	219	20.8
	above 60	122	11.6
EDUCATIONAL LEVEL	Primary education	270	25.6
	Secondary school education	195	18.5
	Tertiary education	370	35.1

	No formal education	219	20.8
YEAR OF EXPERIENCE	less than 5 years	268	25.4
	5-10 years	245	23.2
	11-20 years	268	25.4
	over 20 years	273	25.9

Source: Authors Own Creation

4.1 Descriptive Analysis

Table 4.1 presents a comprehensive descriptive statistical analysis of the respondents' demographic characteristics, encompassing variables such as age, sex, educational level, and farming experience. This analysis provides a foundational understanding of the composition of the sample and emphasises the diversity within the respondent population. The analysis systematically examined the demographic dimensions to identify patterns that may influence respondents' perspectives and practices related to risk management and crop productivity. Demographic variables are essential for contextualising the study's findings, as differences in age, educational attainment, or experience may influence individuals' perceptions and the adoption of risk management strategies. Comprehending this heterogeneity is essential for analysing variations in the effectiveness and implementation of these strategies in different agricultural contexts.

The study sample demonstrated a gender distribution of 52.8% male and 47.2% female participants. Equal representation enhances the generalisability of the findings and facilitates the analysis of gender-specific agricultural practices and risk-management strategies. Gender diversity in the sample allows for the analysis of differences in roles, decision-making, and resource access between genders, thereby improving the understanding of social dynamics in farming communities.

Age demographics revealed a diverse distribution, with the highest percentage (25%) in the 21–30 age group. This suggests a significant presence of young farmers, indicating the potential for innovation and technological adoption in agriculture. The 41–50 age group (23.1%) and the 51–60 age group (20.8%) underscored the important contribution of middle-aged and mature farmers who possess valuable experience but may face challenges in adopting contemporary practices. The low representation of individuals under 20 years of age (7.7%) highlights the need for initiatives to engage the youth in agriculture.

The educational backgrounds of the participants were diverse; 20.8% had no formal education, 35.1% completed secondary school, and 18.5% attained tertiary education, indicating that secondary education was the most prevalent level achieved. This stratification underscores the varying capacities of farmers to implement risk-management strategies. Farmers with tertiary education are better equipped to spearhead innovation, whereas those with restricted educational backgrounds may need tailored and accessible training to rectify knowledge gaps.

The largest cohort (25.9 %) had more than 20 years of farming experience, signifying a substantial reservoir of practical knowledge in the sample. In contrast, individuals with fewer than five years of experience (25.4%) highlighted the potential to integrate modern agricultural techniques. Farmers with 5–10 and 11–20 years of experience (23.2% and 25.4%, respectively) demonstrated

a notable balance between traditional and modern practices, making them crucial for fostering innovation and enabling knowledge transfer.

4.2 Measurement Model

The reliability and validity of the measurement scales were rigorously evaluated using Confirmatory Factor Analysis (CFA), an advanced statistical method for assessing the structure of latent constructs (Kyriazos 2018). This assessment was aimed at ensuring the reliability and validity of the elements and scales used in the study. The evaluation utilised key metrics such as Cronbach's alpha (CA), Composite Reliability (CR), and construct-specific factor loadings, which serve as essential indicators of the internal consistency and coherence of the measurement model.

Cronbach's alpha was employed to assess the reliability of the individual constructs, with values surpassing the recommended threshold of 0.7, indicating high internal consistency among the items. Composite Reliability confirmed this consistency by showing values exceeding the 0.7 benchmark, indicating that the constructs effectively captured the variance of their related items in relation to measurement error. The Average Variance Extracted (AVE) was used to evaluate convergent validity, yielding results that exceeded the minimum threshold of 0.5, as recommended by Bagozzi and Yi (2012). This suggests that the latent constructs account for a significant amount of variance in their indicators.

The CFA results in Table 2 indicate that all factor loadings exceeded 0.6, signifying robust associations between individual items and their corresponding constructs. The findings demonstrate significant convergence and reliability among all constructs, highlighting the strength of the measurement framework and its appropriateness for hypothesis testing and model validation.

Table 3. Construct reliability, validity, and Multicollinearity

Construct and Items	Factor Loading	Cronbach Alpha	Composite Reliability	AVE	VIF
ATA1	0.777	0.817	0.873	0.578	1.631
ATA2	0.786				1.718
ATA3	0.722				1.453
ATA4	0.733				1.554
ATA5	0.781				1.711
CCAM1	0.730	0.775	0.848	0.527	1.489
CCAM2	0.731				1.509
CCAM3	0.665				1.290
CCAM4	0.735				1.499
CCAM5	0.765				1.568
CP1	0.726	0.811	0.869	0.57	1.433
CP2	0.772				1.622
CP3	0.751				1.603
CP4	0.771				1.728
CP5	0.754				1.600
IRM1	0.742	0.809	0.862	0.513	1.574

IRM2	0.657	1.502
IRM3	0.745	1.676
IRM4	0.752	1.670
IRM5	0.617	1.464
IRM6	0.769	1.836

Source: Authors Own Creation

Table 2 presents the reliability of all constructs, as evidenced by the Cronbach's alpha (CA) values exceeding the accepted threshold of 0.70. This indicates robust internal consistency, suggesting that the items within each construct are well-aligned and effectively assess the intended underlying concept. Furthermore, the Composite Reliability (CR) values significantly improved, highlighting the robustness of internal consistency among the constructs. The results confirm that the constructs effectively represent the shared variance of their associated indicators, thereby strengthening the reliability of the measurement model.

The Average Variance Extracted (AVE), which indicates convergent validity, met the minimum threshold of 0.50, as recommended in the literature. The results indicate that the indicators collectively explained a substantial portion of the variance within their respective constructs, underscoring the validity of these constructs in reflecting their intended dimensions.

Discriminant validity was evaluated by comparing the correlations among constructs with the square root of the Average Variance Extracted (AVE) for each construct in accordance with the Fornell-Larcker criterion (Fornell & Larcker, 1981). Discriminant validity establishes that each construct is conceptually distinct and empirically independent of the other constructs (Ramayah et al., 2018).

Table 4. Discriminant validity Fornell-Larker criteria

	ATA	CCAM	CP	IRM
ATA	0.760			
CCAM	0.748	0.726		
CP	0.650	0.625	0.755	
IRM	0.702	0.685	0.662	0.716

Source: Authors Own Creation

Table 3 indicates that the square root of the Average Variance Extracted (AVE) for each construct consistently exceeded the highest correlation observed with any other construct. This demonstrates that the constructs were separate and did not overlap significantly, which is crucial for preserving the accuracy of the structural model. The results validate the reliability of the measurement model, providing a strong foundation for subsequent hypothesis testing and structural analysis.

The discriminant validity analysis yielded satisfactory results, confirming that the constructs employed in this study were adequately distinct. This distinction is crucial for validating the utility of constructs in subsequent analyses, ensuring that each construct represents a unique and significant aspect of the data. Through this differentiation, the research framework effectively represents the theoretical concepts under investigation, thus enhancing the model's reliability and

robustness. Validation is crucial to confirm the relevance and appropriateness of the constructs in relation to the objectives of the study.

The heterotrait–monotrait (HTMT) ratio was used to evaluate discriminant validity. The HTMT metric is a recognised criterion for assessing the empirical distinctiveness of constructs (Henseler et al., 2015). This method offers a more sensitive and rigorous evaluation of discriminant validity than the traditional approaches. This study's literature indicates varying thresholds for HTMT values: Kline (2011) proposed a conservative threshold of 0.85 or lower, while Teo et al. (2008) recommended a more lenient threshold of 0.90 or below.

The results in Table 4 demonstrate that the HTMT ratios for all constructs were below 0.90, thus satisfying the criterion for adequate discriminant validity. These findings indicate that the constructs are both theoretically and empirically distinct, thereby enhancing the validity of the measurement model. This study adhered to stringent criteria and established a robust basis for the dependable hypothesis testing and interpretation of causal relationships within the structural model.

Table 5. Discriminant validity-HTMT

	ATA	CCAM	CP	IRM
ATA				
CCAM	0.884			
CP	0.794	0.785		
IRM	0.852	0.852	0.811	

Source: Authors Own Creation

The next phase evaluated the degree to which the independent variable accounted for variance in the dependent variable. This study established a measurement model to ascertain the degree to which the independent variable explained the variance of the dependent variable.

Table 6. Model Fit – R Square

	R-square	R-square adjusted
CP	0.520	0.518

Source: Authors Own Creation

The analysis demonstrated an R² value of 0.520 for Crop Production (CP), indicating that 52% of the variance in CP was explained by agricultural technology adaptation (ATA), climate change adaptation measures (CCAM), and institutional risk management (IRM).

4.3 Structure Assessment Model

Table 6 Structure Model Result

	Beta Coefficient	Standard deviation	T statistics	P values
ATA -> CP	0.265	0.046	5.714	0.000
CCAM -> CP	0.189	0.040	4.729	0.000
IRM -> CP	0.347	0.042	8.216	0.000

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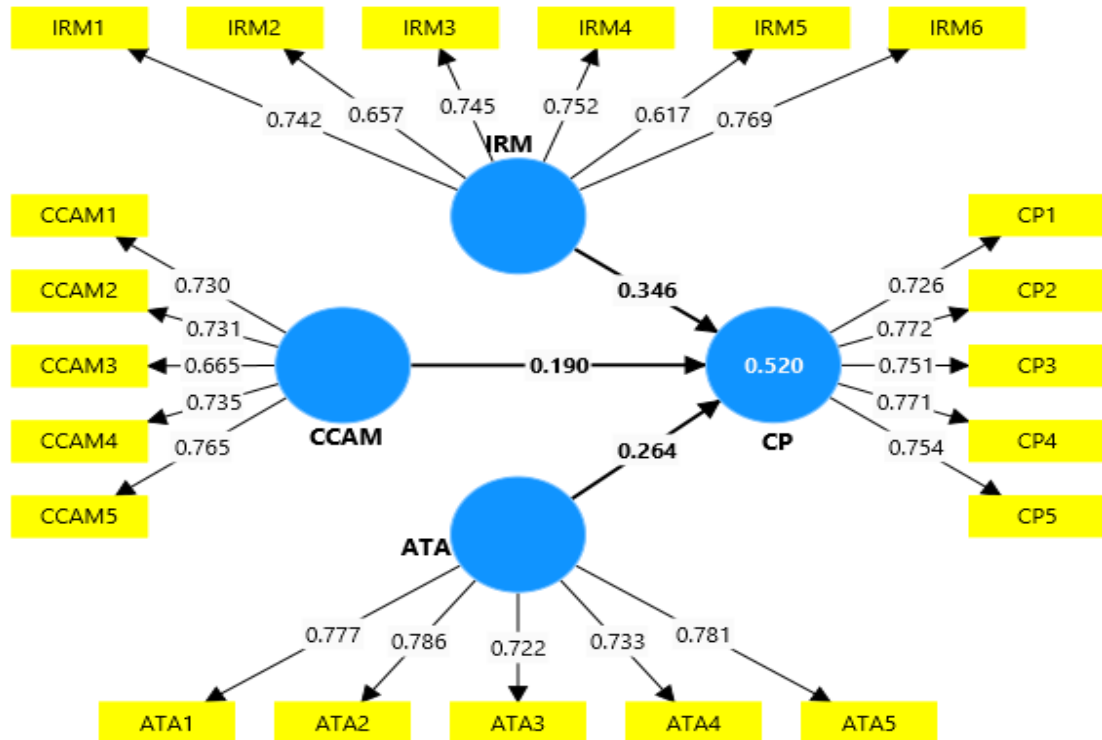


Figure 2 Measurement Assessment Model

The analysis indicates a positive and statistically significant correlation between agricultural technological adoption (ATA) and crop productivity (CP), as demonstrated by the coefficient ($\beta = 0.265$, $t = 5.714$, $p < 0.000$). A 1% increase in ATA correlated with a 26.5% increase in CP, underscoring the significant impact of technological advancements in agriculture. Innovations, including precision farming, mechanisation, and enhanced seed varieties, improve efficiency, decrease resource wastage, and reduce environmental and production risks. This finding highlights the importance of enhancing access to, and adoption of, agricultural technologies to attain sustainable productivity and food security.

The results demonstrated a statistically significant impact of climate change adaptation measures (CCAM) on crop productivity (CP), with a coefficient of ($\beta = 0.189$, $t = 4.729$, $p < 0.000$). This indicates that a 1% enhancement in CCAM may result in an 18.9% increase in CP, highlighting the significance of proactive measures in alleviating the negative impacts of climate variability. Soil conservation, crop diversification, and implementation of drought-resistant varieties improve resilience, optimise resource use, and maintain agricultural productivity. These findings underscore the necessity for focused investments and policy actions to enhance adaptive strategies for sustained agricultural productivity.

The analysis indicates a positive and statistically significant impact of institutional risk management (IRM) on crop productivity (CP), with a coefficient of ($\beta = 0.347$, $t = 8.216$, $p < 0.000$). This indicates that a 1% enhancement in IRM correlates with a 34.7% increase in CP, underscoring the essential function of IRM in stabilising agricultural systems. Effective integrated risk management strategies, including insurance programs, access to financial services, and strong institutional frameworks, reduce production risks and improve farmers' abilities to address market and environmental uncertainties. This highlights the need to enhance institutional support to foster resilience and maximise agricultural productivity.

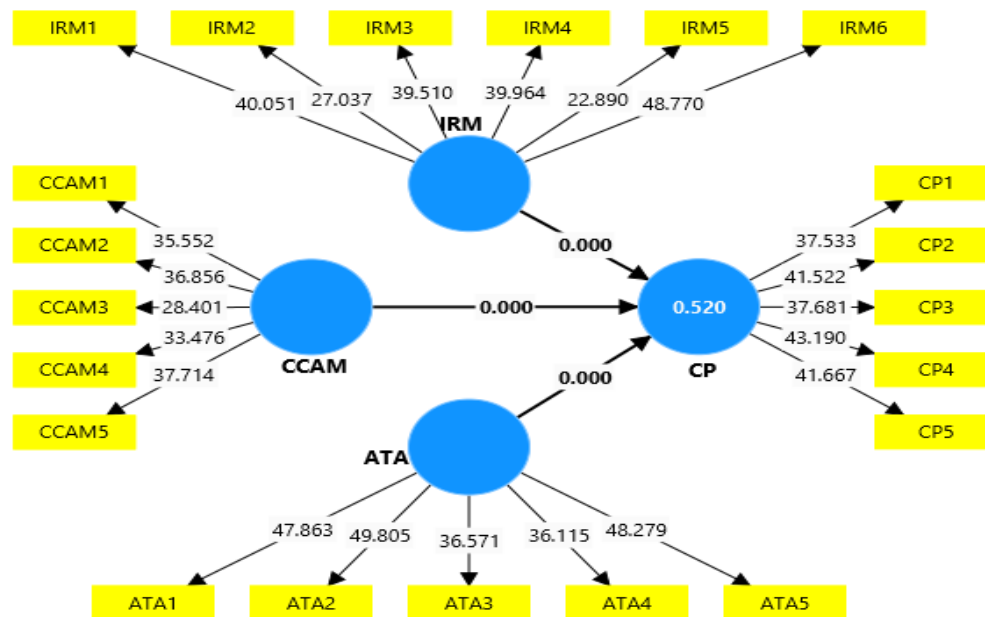


Figure 3 Structure Assessment Model

4.4. Discussion

This study highlights the substantial influence of agricultural technology adoption, climate change adaptation measures, and institutional risk management on crop productivity. The positive correlation between ATA and CP illustrates the significant impact of technology in enhancing agricultural efficiency and productivity. This finding is consistent with research highlighting the significance of mechanisation, precision agriculture, and enhanced seed varieties in boosting agricultural productivity (Jones et al. 2019). Some studies indicate that the benefits of technological adoption may be limited by challenges, including restricted access to resources, insufficient training, and elevated initial costs, especially in developing regions (Smith & Brown, 2020).

This research emphasises the impact of CCAM on CP, suggesting that proactive measures such as sustainable irrigation, soil conservation, and climate-resilient cropping patterns improve agricultural resilience. These findings support previous research, indicating that the adaptive capacity of farmers is essential for alleviating the negative impacts of climate variability (Kumar

et al., 2021). In contrast, other studies indicate that CCAM adoption is inconsistent due to insufficient institutional support, implying that these measures may not consistently lead to substantial productivity improvements (Taylor et al., 2020).

IRM has emerged as the most significant variable, underscoring the critical role of institutional frameworks in the management of agricultural risks and maintenance of sustained productivity. This underscores the research highlighting the importance of effective policies, credit systems, and insurance schemes in mitigating farmers' risk exposure and promoting innovation. Critics contend that institutional inefficiencies, corruption, and inadequate governance structures may diminish the effectiveness of risk management initiatives, consequently restricting their impact on productivity (Williams 2021).

This study illustrates that the ATA, CCAM, and IRM are essential for enhancing CP, highlighting the necessity for integrated strategies to improve agricultural results. Policymakers must prioritise technology dissemination, enhance adaptive measures, and foster institutional development to promote sustainable productivity. Future research should investigate the obstacles to the effective implementation of these interventions and the contextual factors that affect their scalability.

5. Conclusion

5.1 Theoretical Contribution

This study offers important insights into the theoretical framework governing crop production (CP) dynamics. The findings support the principles of the Diffusion of Innovation Theory, highlighting that the adoption of new agricultural technologies (ATA) results in enhanced productivity. The beneficial impact of the ATA on CP supports the theory that innovation disseminates and yields economic advantages over time. These findings support Resilience Theory, emphasising the significance of climate change adaptation measures (CCAM) in improving the capacity of agricultural systems to endure environmental shocks. This highlights the adaptive capacities developed through systematic risk-reduction strategies, which is consistent with theory.

This study is consistent with Institutional Theory, which asserts that strong institutional frameworks improve operational efficiency. The impact of institutional risk management (IRM) on CP illustrates that formalised structures mitigate uncertainties, thereby enhancing productivity. Nonetheless, the results contrast with conventional Production Function Theories, which frequently neglect non-technical elements, such as institutional management and adaptive strategies. The findings enhance theoretical discussions by incorporating socio-institutional dynamics along with production outcomes, underscoring their essential role in agricultural development.

5.2 Policy and Practical Implications

The findings of this study have substantial implications for agricultural development in terms of policies and practices. Policymakers must prioritise the promotion of agricultural technology adoption and institutional risk management as essential elements of sustainable crop production strategies. Incentivising ATA can enhance productivity, while strengthening IRM frameworks can reduce risks and improve agricultural resilience. Integrating climate change adaptation measures (CCAM) into national agricultural policies enhances the capacity of the sector to address

environmental challenges. These insights can guide agricultural policies designed to promote innovation and reinforce institutional frameworks for improved crop production.

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