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Determinants of Millet-Based Agri-Entrepreneurship and Adoption Behaviour for Sustainable Rural Development: An Empirical Study in the Rayalaseema Region

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Abstract

As the global agricultural sector moves toward climate-resilient and sustainable food systems, millets have become a key solution for enhancing food security, environmental health, and supporting rural livelihoods. This study investigated the factors driving millet-based agri-entrepreneurship and their effects on adoption behaviour to promote sustainable rural development in the Rayalaseema region of Andhra Pradesh, India. This study analysed the role of perceived benefits of government support, financial access, and market access in shaping the adoption of millet-based agripreneurial practices. Primary data were collected from 228 respondents using a multi-stage random sampling technique. The study employed correlation and multiple regression analyses in SPSS to examine the relationships among the variables. The findings revealed that financial access and market access have a positive and statistically significant influence on adoption behaviour, while perceived benefits show a negative and non-significant relationship. Government support demonstrated a positive association at the correlation level but did not significantly predict adoption behaviour in the regression model. Further, adoption behaviour was found to have a significant positive effect on the economic, social, and environmental dimensions of sustainable rural development. The study highlights that institutional support systems related to finance and market integration

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play a crucial role in promoting millet agri-entrepreneurship and climate-resilient rural livelihoods. The findings provide important policy implications for strengthening millet value chains, improving financial inclusion, enhancing market linkages, and promoting sustainable agripreneurship in semi-arid regions. The study contributes to the existing literature by developing an integrated empirical framework linking institutional determinants, adoption behaviour, and sustainable rural development.

Abbreviations

PB	Perceived Benefits;
GS	Government Support;
FA	Financial Access;
MA	Marketing Access;
AB	Adoption Behavior;
SRD	Sustainable Rural Development.

Introduction

The global agricultural industry is transitioning from monoculture to more diverse and sustainable food systems, highlighting millets as climate-resilient and nutrient-rich crops. Previously overlooked during the Green Revolution, millets are now recognised for their role in enhancing food security, safeguarding the environment, and achieving the Sustainable Development Goals. The International Year of Millets 2023 has further increased worldwide awareness and policy backing. In India, millets continue to be a vital part of traditional farming, particularly in semi-arid and tribal areas, although their commercial potential is still not fully exploited.[1] This research examines how perceived benefits, government initiatives, access to finance, and market opportunities affect adoption behaviours and support millet-based agri-entrepre--neurship as a means for sustainable rural growth.

The Context: Millets and Global Food Security

Millets such as sorghum, finger millet, pearl millet, and small millets are climate-resilient crops with high drought tolerance and low water requirements. Nutritionally, they are gluten-free, low-glycemic, and rich in fibre, minerals, and antioxidants. Despite these benefits, adoption remains limited due to inadequate processing infrastructure and weak market connectivity, underscoring the need for agri-entrepreneurship.

Agri-Entrepreneurship Determinants

The Four Pillars: The development of agri-entrepre--neurship in the millet sector is influenced by a complex mix of internal motivations and external factors. In this study, these are categorised into four main determinants that together shape the entrepreneurial landscape.

Perceived Benefits

Millet-based agri-entrepreneurship is influenced by perceived benefits such as agronomic resilience, health-driven consumer demand, and economic diversification through value-added products like flour, snacks, and ready-to-eat foods. Adoption depends on recognising millet's specific advantages. Studies by Jaison and Sudhagar highlight health conscious ness and environmental concern as key drivers,[2] while Kheya identify millets' climate-smart nature as reducing farming risks and encouraging adoption.[3]

Government Support

Government support plays a key role in promoting millet agri-entrepreneurship through policies such as the International Year of Millets 2023, the Minimum Support Price (MSP), subsidies for processing machinery, and Millet Hubs. These policies reduce entry barriers, encourage private investment, strengthen Farmer-Producer Organisations (FPOs), and signal the long-term viability of the sustainable millet sector.

Financial Access

Access to finance is essential for millet-based agri-entrepreneurship, including credit, crop insurance, low-interest loans, and incubation grants. Limited collateral, perceived crop risks, and inadequate infrastructure often constrain financing. Studies show that weak processing facilities and poor market connectivity hinder growth, underscoring the importance of robust credit systems and efficient value chains for entrepreneurial success in the millet sector.

Marketing Access

Traditional millet farmers commonly face "market invisibility." Agri-entrepreneurship addresses this by creating structured value chains. Marketing Access includes electronic platforms, Farmer-Producer Organisations (FPOs), and branding strategies that connect rural producers to high-value urban and international markets. Effective marketing transforms millet from a "poor man's food" into a premium health product.

Adoption Behaviour

The Psychological and Social Bridge

Adoption behaviour refers to the process by which farmers and entrepreneurs decide to integrate millet-based practices into their activities. According to the Theory of Planned Behaviour, adoption is shaped by attitudes, social norms, and perceived behavioural control rather than occurring instantly. When determinants such as perceived benefits, government support, financial access, and market access align, they reduce perceived risk and strengthen adoption decisions. Clear market opportunities and institutional backing encourage entrepreneurs to deploy sustainable millet technologies. Studies also suggest that adoption is influenced by trust, awareness, and collective participation, as farmers involved in groups such as Farmer-Producer Organisations (FPOs) are more likely to adopt innovations.

Impact on Sustainable Rural Development (SRD):

The ultimate goal of promoting millet agri-entrepre-neurship is Sustainable Rural Development. This impact is assessed across three critical dimensions.

Economic Dimension

Agri-entrepreneurship strengthens rural economies by enabling local processing, packaging, and branding of millet products. This increases village income retention, improves household earnings, supports women-led livelihoods, reduces distress migration, and strengthens overall livelihood security through value addition and agri-entrepreneurship.

Social Dimension

Millet agri-entrepreneurship promotes social equity by empowering women-led Farmer-Producer Organisations and small-scale processing units. It enhances gender equality, strengthens nutritional security, preserves traditional agricultural knowledge, and supports the empowerment of tribal women by challenging social and economic barriers in rural communities.

Environmental Dimension

Millets support environmental protection through low water requirements, a reduced carbon footprint, and minimal dependence on synthetic inputs. Their cultivation promotes biodiversity, soil health, and regenerative agriculture, enabling a more sustainable farming system aligned with long-term ecological conservation goals.

Review of Literature

Literature positions millets as strategic crops for sustainable agriculture, food security, nutrition, and rural agri-entrepreneurship. Millets are climate resilient: they sustain yields under drought, heat, and poor soils while needing less water and fewer chemical inputs than many cereals. These traits support climate adaptation and multiple Sustainable Development Goals.[3,4,5] Their high nutrient density and adaptability to marginal agro climatic zones have renewed policy and academic interest in millet-based systems. Despite its advantages, millet cultivation faces persistent limitations that hinder adoption and commercialization. Cultivation area has declined in many regions due to low economic returns, weak market incentives, fragmented value chains, and limited consumer awareness. These factors discourage farmer investment and hinder scaling of millet products.[6-8] Strengthening demand, improving price signals, and integrating supply chains are critical to reverse this trend. Women and tribal communities play a central role in conserving millet diversity and traditional knowledge. Millet enterprises can boost income, add value, diversify livelihoods, and empower women through processing, packaging, and marketing.[9,10] Tribal women particularly sustain

indigenous millet practices but face heavy labor burdens across sowing, weeding, harvesting, and processing, alongside limited access to finance, markets, technology, and institutional support. These barriers constrain entrepreneurial expansion and decrease socioeconomic benefits for rural and tribal households.[11,12] The adoption of electronic platforms, e commerce, AI, IoT, and autonomous tools can improve productivity, efficiency, and market access.[13,14] However, inadequate digital infrastructure, low awareness, restricted technical skills, affordability issues, and accessibility barriers impede uptake among rural and tribal entrepreneurs.[15] This research gap underscores the need for further investigation into the technological, social, economic, and institutional determinants shaping entrepreneurial intentions and sustainable livelihood outcomes in millet-based enterprises.

Therefore, this study evaluated the Determinants of Millet-Based Agri-Entrepreneurship and Adoption Behaviour for Sustainable Rural Development: An Empirical Study in the Rayalaseema Region of Andhra Pradesh.

Methodology

Objectives

To investigate the relationship between institutional determinants and the adoption behaviour of millet-based agripreneurship, and to evaluate its impact on sustainable rural development.

This study develops an integrated conceptual framework linking institutional determinants, adoption behaviour, and sustainable rural development. Perceived Benefits, Government Support, Financial Access, and Market Access are treated as independent variables that influence Adoption Behaviour, which in turn affects Sustainable Rural Development across economic, social, and environmental dimensions. The framework is grounded in the Theory of Planned Behaviour and the literature on sustainable agri-entrepreneurship.

The study adopted a quantitative research design to examined the determinants influencing millet-based agri-entrepreneurship and their impact on adoption behaviour and sustainable rural development in the Rayalaseema region of Andhra Pradesh. Primary data were collected from millet farmers and agri-entrepreneurs using a structured questionnaire based on a five-point Likert scale. A multi-stage random sampling technique was employed to select respondents from different districts of the Rayalaseema region. The final sample consisted of 228 respondents, which satisfies the recommended sample size for multivariate statistical analysis.[16]

The study measured four institutional determinants: Perceived Benefits, Government Support, Financial Access, and Market Access. Adoption Behaviour was treated as the mediating behavioural construct, while Sustainable Rural Development was assessed through economic, social, and environmental dimensions. Reliability of the constructs was tested using Cronbach's Alpha. Correlation and multiple regression analyses were conducted using SPSS to test the hypotheses and examine the relationships among variables.

Table 1: Reliability Analysis of Constructs

Construct	Cronbach's Alpha	Interpretation
Perceived Benefits (PB)	0.78	Acceptable Reliability
Government Support (GS)	0.81	Good Reliability
Financial Access (FA)	0.75	Acceptable Reliability
Market Access (MA)	0.77	Acceptable Reliability
Adoption Behavior (AB)	0.83	Good Reliability
Sustainable Rural Development (SRD)	0.85	Good Reliability

Source: Primary Data

Results

The reliability of the measurement constructs was assessed using Cronbach's alpha, which is presented in Table 1. The results indicate that all constructs demonstrate acceptable to good internal consistency, with values ranging from 0.75 to 0.85. Constructs such as Government Support (α = 0.81), Adoption Behavior (α = 0.83), and Sustainable Rural Development (α = 0.85) exhibit strong reliability, while the remaining constructs meet the acceptable threshold (α > 0.70). These findings confirm that the measurement scales are consistent and reliable, thereby supporting the validity of subsequent correlation and regression analyses.

Table 2: Relationship between institutional determinants and the adoption of millet-based Agripreneurial Practices-Correlation Matrix.

Variables	Mean PB	Mean GS	Mean FA	Mean MA	Mean SR	Mean AB
Mean PB	—					
Mean GS	-0.095	—				
Mean FA	-0.157*	0.816***	—			
Mean MA	-0.151*	0.765***	0.797***	—		
Mean SR	0.064	0.633***	0.613***	0.699***	—	
Mean AB	-0.145*	0.671***	0.743***	0.719***	0.726***	—

Note: * $p < 0.05$, *** $p < 0.001$; N ≈ 228

The correlation results indicated that institutional determinants have mixed effects on the adoption of millet-based agripreneurial practices. Government Support (GS) shows a strong, positive, and significant relationship with Adoption Behaviour (AB) ($r = 0.671$, $p < 0.001$), indicating that subsidies, training, and policy support encourage adoption. Financial Access (FA) also has a strong, positive relationship with Adoption Behaviour ($r = 0.743$, $p < 0.001$), showing that access to financial resources improves adoption levels. Similarly, Market Access (MA) is positively and significantly related to Adoption Behaviour ($r = 0.719$, $p < 0.001$), suggesting that better market opportunities promote adoption. Perceived Benefits (PB) shows a weak, significant negative relationship with Adoption Behaviour ($r = -0.145$, $p < 0.05$), contrary to the proposed hypothesis. This suggests that perceived benefits alone may not be sufficient to influence adoption decisions due to possible awareness gaps or practical challenges.

The results partially support Hypothesis H1. Government Support, Financial Access, and Market Access significantly and positively influence the adoption of millet-based agripreneurial practices, whereas Perceived Benefits do not show the expected positive relationship.

Table 3: Model Fit Measures

Model	R	R^2	Adjusted R^2	RMSE	F	df1	df2	P
1	0.776	0.602	0.594	0.499	84.2	4	223	<.001

Source: Primary Data

Impact of Institutional Determinants on the Adoption Behaviour-Regression Analysis

The regression model is statistically significant and shows a good fit. The correlation coefficient (R = 0.776) indicates a strong relationship between institutional determinants and adoption behaviour. The R^2 value (0.602) shows that 60.2% of the variation in adoption behaviour is explained by

Perceived Benefits, Government Support, Financial Access, and Market Access. The adjusted R^2 (0.594) confirms the model's reliability. The overall model is significant ($F = 84.2$, $p < 0.001$), indicating that the predictors collectively affect adoption behaviour.

Table 4 reveals the individual contribution of each predictor to the model. Financial Access (FA) ($F = 21.9565$, $p < 0.001$) and Market Access (MA) ($F = 21.7699$, $p < 0.001$) have a significant impact on adoption behaviour. In contrast, Perceived Benefits (PB) ($p = 0.779$) and Government Support (GS) ($p = 0.286$) do not show statistically significant effects in this model. This indicates that while some institutional factors strongly influence adoption, others may not directly contribute when all variables are considered simultaneously.

Table 4: ANOVA

Source	Sum of Squares	Df	Mean Square	F	p
Mean PB	0.0201	1	0.0201	0.0787	.779
Mean GS	0.2917	1	0.2917	1.1455	.286
Mean FA	5.5919	1	5.5919	21.9565	<.001
Mean MA	5.5444	1	5.5444	21.7699	<.001
Residuals	56.7939	223	0.2547		

Source: Primary Data

Table 5: Regression Coefficients

Predictor	Estimate (β)	SE	T	P
Intercept	1.6810	0.2391	7.029	<.001
Mean PB	-0.0146	0.0522	-0.281	.779
Mean GS	0.0737	0.0689	1.070	.286
Mean FA	0.2805	0.0599	4.686	<.001
Mean MA	0.2507	0.0537	4.666	<.001

Source: Primary Data

The regression coefficients in the above table 5 indicate that Financial Access ($\beta = 0.2805$, $p < 0.001$) and Market Access ($\beta = 0.2507$, $p < 0.001$) have positive and statistically significant effects on adoption behaviour, showing that improved financial resources and market opportunities increase the adoption of millet-based agripreneurial practices. Government Support ($\beta = 0.0737$, $p = 0.286$) has a positive but non-significant effect, while Perceived Benefits ($\beta = -0.0146$, $p = 0.779$) shows a negative and non-significant influence on adoption behaviour. The significant intercept ($p < 0.001$) indicates the existence of a baseline level of adoption behaviour. Overall, Financial Access and Market Access emerge as the most influential determinants of adoption behaviour.

The correlation matrix indicates relatively high inter-correlations among Government Support, Financial Access, and Market Access. This suggests possible multicollinearity among institutional variables. However, the regression results indicate that Financial Access and Market Access remain the strongest independent predictors of adoption behaviour. Future studies may employ Variance Inflation Factor (VIF) analysis and Structural Equation Modelling (SEM) to further validate the relationships among constructs.

Impact of Adoption Behaviour on Sustainable Rural Development-Regression Analysis

The regression model is statistically significant and shows a strong relationship between Adoption Behaviour and Sustainable Rural Development (R

= 0.726). The R^2 value (0.527) indicates that 52.7% of the variation in Sustainable Rural Development is explained by Adoption Behaviour. The adjusted R^2 (0.525) confirms the model's reliability. The overall model significance (F = 254, p < 0.001) shows that Adoption Behaviour is a significant predictor of Sustainable Rural Development.

Table 6: Model Fit Measures

Model	R	R^2	Adjusted R^2	RMSE	F	df1	df2	P
1	0.726	0.527	0.525	0.493	254	1	228	<.001

Source: Primary Data

Table 7: ANOVA

Source	Sum of Squares	Df	Mean Square	F	P
Mean AB	62.2	1	62.230	254	<.001
Residuals	55.8	228	0.245		

Source: Primary Data

The results show that the regression model is statistically significant (F = 254, p < 0.001). Adoption Behaviour makes a significant contribution to explaining sustainable rural development, indicating that the model effectively predicts these outcomes.

Table 8: Regression Coefficients

Predictor	Estimate	SE	T	p
Intercept	1.439	0.1339	10.7	<.001
MEAN AB	0.655	0.0411	15.9	<.001

Source: Primary Data

The regression coefficient indicates that Adoption Behaviour (β = 0.655, p < 0.001) has a positive and significant effect on Sustainable Rural Development. This shows that an increase in adoption behaviour leads to improvement in sustainable rural development outcomes. The significant intercept also indicates the existence of a baseline level of sustainable rural development. The results show that Adoption Behaviour has a significant positive effect on the economic, social, and environmental dimensions of sustainable rural development. The findings indicate that increased adoption of millet-based agripreneurial practices improves income and livelihood opportunities, enhances social well-being, and supports environmental sustainability through better resource conservation and resilience.

Discussion

The reliability analysis confirmed that all constructs showed acceptable to good internal consistency, indicating that the measurement scales were reliable for analysis. Correlation analysis revealed that Government Support, Financial Access, and Market Access have positive and significant relationships

with Adoption Behaviour. Financial Access and Market Access showed the strongest association with adoption behaviour.

Perceived Benefits showed a weak negative relationship with Adoption Behaviour, suggesting that awareness of benefits alone may not ensure adoption without institutional and market support. Regression analysis identified Financial Access and Market Access as the most significant predictors of millet-based agripreneurial adoption. Government Support and Perceived Benefits were not statistically significant in the regression model.

The study found that Adoption Behaviour has a strong positive effect on Sustainable Rural Development by improving economic opportunities, social well-being, and environmental sustainability. The findings indicate that practical support systems such as finance and market connectivity are more influential than perceptual or policy-related factors in promoting millet-based agripreneurship.

The findings of the study revealed that institutional support systems significantly influence millet-based agripreneurial adoption, although their effects vary across dimensions. Financial Access and Market Access emerged as the strongest determinants of adoption behaviour, indicating that practical economic support mechanisms are more influential than perceptual or policy-related factors. These findings are consistent with the studies of Pandey and Bolia, Grovermann and Badatya emphasised the importance of financial systems, market integration, and economic incentives in promoting millet entrepreneurship.[7,8,17]

The non-significant influence of Government Support in regression analysis suggests that policy availability alone may not ensure adoption unless implementation mechanisms effectively reach farmers and entrepreneurs. Similarly, the negative relationship of Perceived Benefits with adoption behaviour may reflect an awareness–implementation gap, where farmers recognise the advantages of millets but hesitate to adopt due to uncertainty, risk perception, and infrastructural limitations.

The study also confirms that adoption behaviour strongly contributes to sustainable rural development by improving economic opportunities, social empowerment, and environmental sustainability. These findings support the Triple Bottom Line framework proposed by Sargani which highlights the integration of economic, social, and environmental sustainability in agricultural entrepreneurship.[18]

Suggestions

1. Expand affordable credit facilities, subsidies, and crop insurance schemes to improve financial access for millet farmers and agripreneurs.
2. Strengthen market linkages through Farmer-Producer Organisations (FPOs), digital platforms, value-chain development, and assured procurement systems.
3. Improve the effectiveness of government schemes through better awareness programmes, training, and last-mile implementation.
4. Conduct field demonstrations, extension activities, and peer-learning programmes to increase confidence in millet-based entrepreneurship.
5. Promote value addition, processing, branding, and packaging of millet products to improve rural income and employment opportunities.
6. Develop integrated policies combining financial support, market access, entrepreneurship development, and climate-resilient agricultural practices for sustainable rural development.

Policy Implications

The findings of the study have important implications for policymakers, financial institutions, Farmer-Producer Organisations (FPOs), and rural development agencies. Strengthening institutional credit systems, expanding millet procurement mechanisms, and improving market connectivity can significantly enhance millet entrepreneurship. Policies should focus on integrating financial assistance, training programmes, digital marketing support, and infrastructure development to create sustainable millet value chains. The government should also improve awareness of and access to existing millet promotion schemes through effective extension services and last-mile implementation strategies.

Limitations and Future Research

The study is limited to the Rayalaseema region of Andhra Pradesh and therefore the findings may not be generalisable to other regions with different socio-

economic and agricultural conditions. The study adopted a cross-sectional research design and relied primarily on perception-based responses collected through structured questionnaires. Future studies may employ longitudinal approaches, comparative regional analysis, and Structural Equation Modelling (SEM) to obtain deeper insights into behavioural and institutional relationships. Further research may also explore the mediating and moderating effects of digital literacy, climate awareness, and entrepreneurial orientation on millet-based agripreneurship.

Conclusion

The study concluded that institutional determinants significantly influence the adoption of millet-based agripreneurial practices, though their effects vary in strength and statistical significance. Government support and perceived benefits showed positive correlations with adoption behaviour, but were not statistically significant in the regression analysis. This suggests that awareness and policy support alone are insufficient to ensure adoption. In contrast, financial access and market access emerged as the strongest and most significant determinants, indicating that affordable credit, financial services, and reliable market opportunities are essential for encouraging farmers to adopt millet-based enterprises. These factors reduce risk, improve profitability, and provide economic security. The study further revealed that adoption behaviour strongly contributes to sustainable rural development by improving income, enhancing social well-being, and supporting environmentally sustainable farming practices. Overall, the findings emphasise the need to strengthen financial systems, improve market linkages, enhance institutional effectiveness, and build farmers' capacities through an integrated approach to achieve long-term sustainable rural development through millet-based agripreneurship.

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Conflict of Interest

The authors do not have any conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

The present study followed standard ethical guidelines for conducting field-based research involving human participants. Prior informed consent was obtained from all respondents before administering the survey. Participation was entirely voluntary, and respondent confidentiality and anonymity were strictly maintained throughout the research process.

Clinical Trial Registration

This research does not involve any clinical trials.

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Not Applicable.

Author Contributions

- **Malathi Gottumukkala:** Data Analysis, Findings and Conclusion.
- **Ramineni Sivarama Prasad:** Funding Acquis--ition and Resource Supervision.
- **Ranganatham Gangineni:** Conceptualization and Research Framework.
- **MSR Anjaneyulu:** Research Methodology.
- **Dommari Anjaneyulu:** Introduction and Literature Review.

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