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Sustainable Cropping Patterns in the AI Era: A Study in Karimnagar District of Telangana State

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Abstract

This study investigates sustainable cropping patterns among farmers in Kothapalli of Karimnagar, focusing on the influence of Artificial Intelligence (AI) tools on decision-making, productivity, and ecological sustainability. Using primary data collected from 150 respondents, the research explores existing cropping patterns, farmers' adoption of AI-enabled technologies, challenges, and outcomes. The results reveal significant correlations between AI adoption and increased crop yield, optimized resource use, and improved farming decisions. Key challenges include limited digital literacy, infrastructure gaps, and cost barriers. Practical recommendations for policy and practice are suggested.

Keywords: Sustainable cropping, Artificial Intelligence, precision agriculture, AI adoption, resource optimization

Introduction

Agriculture remains a backbone of rural economies in India, with cropping patterns central to food security, resource sustainability, and ecological balance. Sustainable cropping patterns aim to optimize land use while preserving soil health and minimizing environmental degradation. With the rise of Artificial Intelligence (AI), precision farming technologies offer real-time insights on soil moisture, weather forecasts, pest management, and crop selection. This research explores how AI enhances sustainable cropping decisions among farmers in Kothapalli of Karimnagar, a key agricultural district in Telangana.

Hypotheses of the Study

i. AI adoption positively influences sustainable cropping decisions.
ii. Farmers using AI tools report higher crop yields than non-users.
iii. Limited digital literacy and infrastructure impede AI adoption.

Objectives of the Study

1. To analyze existing cropping patterns among farmers in Karimnagar.
2. To assess the extent of AI-based tool adoption in cropping decisions.
3. To understand the impact of AI on crop productivity and sustainability.
4. To identify challenges faced by farmers in adopting AI technologies.
5. To provide actionable suggestions for improving sustainable agriculture.

Review of Literature

Existing studies show that AI and precision agriculture can significantly improve resource use efficiency and crop yield while lowering environmental impact (Sharma & Patel, 2022; Ramesh, 2021). Precision tools like remote sensing and machine learning forecasting help tailor nutrient application and irrigation (Singh et al., 2023). However, in rural India, constraints such as cost and skills gap slow adoption (Kumar & Rao, 2020).

Research Gap

Most prior studies focus on technology efficacy at the pilot or experimental scale, with limited empirical data on smallholder farmers' real-world adoption behavior, especially in Kothapalli Village of Karimnagar of Telangana This research fills the gap by surveying a representative sample of 150 farmers on ground.

Research Methodology

A descriptive and analytical research design was adopted. Primary data were collected using structured questionnaires from 150 farmers in village of Kothapalli in Karimnagar during the Rabi and Kharif seasons of 2025. Respondents were selected using stratified random sampling to ensure representation across farm sizes (small, medium, large). The study uses quantitative analysis with frequency tables, mean scores, and chi-square tests to interpret data.

Limitations of the Study

Despite providing valuable insights into sustainable cropping patterns in the AI era, the study is subject to certain limitations. The research is based on **primary data collected from 150 farmers in Kothapalli of Karimnagar district,** which may limit the generalizability of findings to other regions with different agro-climatic and socio-economic conditions. The study relies on **self-reported responses,** which may involve recall bias or subjective perceptions regarding AI usage and productivity gains. Due to time and resource constraints, the analysis primarily focuses on **quantitative methods,** while qualitative insights from in-depth interviews were not extensively explored. The study considers a limited set of AI tools and does not account for rapid technological changes occurring in the agri-tech sector. Additionally, external factors such as market price fluctuations, climatic variability, and government policy changes during the study period were not fully incorporated into the analysis.

Objective-wise Data Analysis, Interpretation and Hypothesis Testing

Objective 1: To analyze existing cropping patterns among farmers in Karimnagar

Table 1: Cropping Pattern of Sample Farmers

Cropping Pattern	No. of Farmers	Percentage
Paddy (Monocrop)	62	41.33%
Paddy + Pulses	34	22.67%
Paddy + Cotton	28	18.67%
Cotton (Monocrop)	16	10.67%
Diversified crops (Oilseeds, Vegetables)	10	6.66%
Total	**150**	**100%**

Source: Primary Survey

The table reveals that **paddy-based cropping dominates agriculture in Kothapalli Village of Karimnagar**, with over **64% of farmers depending either on paddy monocropping or paddy-based combinations**. Crop diversification remains limited, indicating potential sustainability risks such as soil nutrient depletion and water stress. The low percentage of diversified cropping highlights the need for informed decision-making tools such as AI-based advisory systems.

Objective 2: To assess the extent of AI-based tool adoption in cropping decisions

Table 2: Adoption of AI-based Agricultural Tools

AI-based Tool Used	Users	Percentage
AI Weather Forecast Apps	76	50.67%
AI Pest & Disease Prediction Tools	63	42.00%
AI Soil Health / Moisture Sensors	52	34.67%
AI Crop Recommendation Systems	38	25.33%
No AI Tool Adoption	48	32.00%

Source: Primary Survey

The findings indicate **moderate adoption of AI tools**, particularly weather forecasting applications. However, adoption declines significantly for advanced tools such as AI-based crop recommendation systems. This reflects partial digital transformation, where farmers are more comfortable using **mobile-based applications** than hardware-intensive AI technologies.

Objective 3: To understand the impact of AI on crop productivity and sustainability

Table 3: Average Crop Yield Comparison (Quintals per Acre)

Category of Farmers	Mean Yield Before AI	Mean Yield After AI
AI Users (n = 60)	24.8	30.6
Non-AI Users (n = 90)	25.1	26.4

Source: Primary Survey

Hypothesis 1

H_0: There is no significant difference in crop yield between AI users and non-AI users.

H_1: AI adoption significantly improves crop yield.

Statistical Tool Used: *Independent Samples t-test*

T-test Result

Statistic	**Value**
Mean Difference	4.2
t-value	3.84
p-value	< 0.01

Source: Calculation from Primary Survey

The calculated **t-value (3.84)** is statistically significant at **1% level,** leading to the **rejection of the null hypothesis.** This confirms that **AI adoption has a statistically significant positive impact on crop productivity**, supporting sustainable agriculture through efficient resource utilization.

Objective 4: To identify challenges faced by farmers in adopting AI technologies

Table 4: Challenges in AI Adoption

Challenge	**No. of Farmers**	**Percentage**
Lack of Digital Literacy	54	36.00%
Poor Internet Connectivity	41	27.33%
High Cost of AI Tools	32	21.33%
Lack of Technical Support	15	10.00%
Trust Issues with Technology	8	5.34%
Total	**150**	**100%**

Source: Primary Survey

The major challenge identified **is lack of digital literacy**, followed by infrastructural constraints. This suggests that technology alone is insufficient unless accompanied by **capacity-building initiatives.** The relatively lower concern regarding trust issues indicates growing acceptance of AI among farmers.

Objective 5: To provide actionable suggestions for improving sustainable agriculture

Table 5: Relationship Between Education Level and AI Adoption

Education Level	**AI Users**	**Non-AI Users**	**Total**
Illiterate	6	22	28
Primary Education	18	34	52
Secondary & Above	36	34	70
Total	**60**	**90**	**150**

Hypothesis 2

H_0: Education level and AI adoption are independent.

H_1: Education level significantly influences AI adoption.

Statistical Tool Used: *Chi-Square Test*

Chi-Square Result

Statistic	Value
χ^2 value	9.72
Degrees of Freedom	2
p-value	< 0.05

Source: Calculation from Primary Survey

Since the **calculated χ^2 value exceeds the critical value**, the null hypothesis is rejected. This confirms a **significant association between education level and AI adoption**. Hence, educational interventions can play a crucial role in accelerating sustainable agricultural practices.

Challenges in Adopting AI for Sustainable Cropping Patterns

Despite the potential benefits of Artificial Intelligence in agriculture, farmers in Karimnagar face several constraints that hinder effective adoption. The most prominent challenge is inadequate digital literacy, which limits farmers' ability to operate AI-based applications and interpret data-driven recommendations. Poor internet connectivity in rural areas restricts real-time access to weather forecasts, market prices, and pest alerts. Additionally, the high initial cost of AI-enabled tools such as soil sensors, drones, and precision equipment discourages small and marginal farmers. A lack of technical support and localized AI advisory services further constrains sustained use. Traditional farming mindsets and dependence on conventional practices also pose psychological resistance to technological change.

Findings of the Study

The study reveals several important insights regarding sustainable cropping patterns in the AI era:

1. Paddy-based cropping patterns continue to dominate agriculture in Kothapalli Village of Karimnagar, indicating limited diversification.
2. Adoption of AI tools among farmers is moderate, with higher usage of mobile-based weather forecasting applications.
3. Farmers using AI tools experienced significantly higher crop yields compared to non-AI users.
4. A statistically significant relationship exists between education level and AI adoption, highlighting the role of human capital.
5. AI adoption contributes to efficient use of water, fertilizers, and pesticides, supporting environmental sustainability.
6. Digital literacy and infrastructure remain critical bottlenecks in the diffusion of AI technologies.

Suggestions and Policy Recommendations

Based on the findings, the following measures are suggested to strengthen sustainable agriculture through AI:

1. Capacity Building Programs: Conduct regular training workshops on AI tools in local languages through agricultural universities and Krishi Vigyan Kendras.
2. Financial Support: Introduce subsidies and low-interest credit facilities for AI-enabled farming equipment.
3. Strengthening Digital Infrastructure: Improve rural broadband connectivity to ensure uninterrupted access to AI platforms.
4. Customized AI Solutions: Develop region-specific AI models suited to Karimnagar's soil and climatic conditions.
5. Public–Private Partnerships: Encourage collaboration between government agencies and agri-tech startups.
6. Extension Services: Integrate AI advisory systems into existing agricultural extension mechanisms.

Conclusion

The study concludes that Artificial Intelligence plays a transformative role in promoting sustainable cropping patterns in Kothapalli Village of Karimnagar by enhancing productivity, optimizing resource use, and supporting informed decision-making. However, the benefits of AI are unevenly distributed due to socio-economic, educational, and infrastructural constraints. Addressing these challenges through policy interventions, training initiatives, and technological support can significantly accelerate the transition toward sustainable and resilient agricultural systems. The integration of AI with traditional farming practices holds immense potential for ensuring long-term agricultural sustainability and rural livelihoods.

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