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Agri-tech and precision agriculture technologies to increase maize productivity and farmers' income

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Abstract

This study evaluates the impact of precision agronomy techniques and Agri-Tech interventions on maize productivity and farmers' income in Karnataka, India. Across multiple crop cycles from 2023 to 2024 covering Kharif, Rabi, and Summer seasons, practices such as drip irrigation, fertigation, digital agronomy (AgriApp integration), drone-based foliar spraying, and satellite monitoring were implemented. Results demonstrated remarkable improvements in germination rates, plant counts, yields, and profitability. The Campus_S_4 plot (Kharif season) achieved the highest maize yield of 59 quintals per acre and a Benefit-Cost (B:C) ratio of 3.77. Additionally, the Campus_S_1 plot (Rabi season), achieved the second highest yield of 56.9 quintals with B:C ratio of 2.92. These findings reinforce precision farming's role in boosting farmer income, enhancing sustainability, supporting climate-smart agriculture and bio ethanol story for green energy aligning with India's national objective

Keywords: Agri-tech, precision agriculture, agronomy, maize, doubling farmers income, fertigation

1. Introduction

Agriculture occupies a central place in India, not only economically but also culturally and socially. The income of many farmers remained distressingly low, leading to widespread rural poverty (Birthal *et al.*, 2017) [4]. The development strategy primarily focused on raising output and ensuring food security but didn't explicitly address the need to enhance farmers' income. Understanding these dynamics is crucial for formulating effective strategies to improve farmers' livelihoods (Sendhil *et al.*, 2018) [9].

Maize emerges as a pivotal player in the ambitious goal of doubling farmers' income. The global production of maize was 1,162 million tonnes in 2020, with the United States being the top producer of the crop, followed by China and Brazil (FAOSTAT, 2022) [6]. Maize is both economically and nutritionally important for India, as the livelihoods of over 9 million farmers and their families are dependent on its cultivation and associated industries. The total area under maize production in India is approximately 9.89 million hectares**,** with Karnataka, Maharashtra, and Madhya Pradesh having significant areas under cultivation. The economic impact is notable, with maize contributing around Rs. 800 billion annually to India's economy (DMR Vision 2030, 2011). Globally, India contributes approximately 2.4% of maize production**.** Domestically, the demand for maize stands at 26 million metric tons annually, primarily driven by its role as a staple food, livestock feed, and raw material for industrial products.

Maize cultivation in India is spread across various states. The primary maize-producing states include Karnataka, Andhra Pradesh, Bihar, Madhya Pradesh, Tamil Nadu, and Rajasthan**,** with the crop grown in both kharif (monsoon) and rabi (winter) seasons. Maize yields are generally higher in irrigated regions, ranging from 20 to 25 quintals/acres, compared to 16-18 quintals/acre in rain-fed areas. Maize is not just a staple food but also a vital industrial crop, used in the production of starch, ethanol, and other derivatives. Ethanol production from maize plays a significant role in India's energy security and helps in meeting renewable energy targets. Over time, maize's contribution to India's agricultural GDP has increased, with its role in value-added industries expanding rapidly. Many maize-processing units have diversified into by-product industries, including ethanol distilleries, starch plants, and animal feed production facilities**.** Additionally, the government's emphasis on promoting ethanol blending programs has further boosted maize's industrial significance. The integrated development of maize and its associated industries is critical for achieving sustainable agricultural growth and improving farmer incomes.

The existing practices in Maize cultivation have not undergone significant reform. Farmers in the USA, Australia, Turkey, Europe, Brazil, Israel, China, Iran, Egypt, and Argentina have been using drip irrigation with fertigation to produce maize in recent years due to its many advantages (Praveen *et. al.*, 2021) [10]. While some progressive farmers have achieved yields exceeding 163 quintals per acre in US, the majority of Maize growers still operate at yields ranging from 15 to 25 quintals per acre. To address these constraints, the adoption of Precision Agriculture (PA) and Agri-Tech innovations has become increasingly relevant (Basavaraj *et al.*, 2024a). Precision agriculture refers to a suite of technologies—such as GPS-guided equipment, variable rate technology, drone surveillance, remote sensing, and data-driven decision support systems—that aim to optimize field-level management for increased productivity and reduced resource consumption (Zhang *et al*., 2002; Gebbers & Adamchuk, 2010) [11, 7]. Enhancing cultivation practices has the potential to significantly multiply yields. Efforts in this direction have been initiated and aim to extend these improvements throughout the farming community.

The study was taken up based on the previous studies on Sugarcane (Basavaraj et. al., 2024b) the objective of doubling farmers' income by enhancing Maize productivity with implementation of improved agronomic practices and leveraging agri-technologies for sustainable sugarcane production.

2. Materials and Methods

2.1 Experimental Design

The field trials were conducted between 2023 and 2024 across different seasons (Kharif, Rabi, and Summer) at multiple experimental sites in Karnataka:

The maize hybrid DKC9178 (Bayar-Dekalb) was selected for its adaptability across seasons and superior performance under precision agronomic conditions.

Table 1: Experimental Plot details

Sl. No.	Plot ID	Area (Acre)	Planting Date	Season	Location
1	Campus_SF_1	1	5-Jun-2023	Kharif	13.234029, 77.484054
2	GJHalli_S_1	1.2	28-Oct-2023	Rabi	13.237273, 77.490503
3	Campus_SF_2	0.5	25-Mar-2024	Summer	13.234197, 77.483785
4	Campus_S_4	0.5	27-Jul-2024	Kharif	13.234635, 77.483326
5	Campus_S_1	1.0	14-Oct-2024	Rabi	13.234000, 77.484000

2.2 Digital Agronomy

The experimental fields were digitally integrated with AgriApp services, providing real-time crop management advisories, pest and disease alerts, and optimized fertigation schedules. An agronomist oversaw field operations based on satellite and sensor-driven diagnostics.

2.3 Irrigation and Fertigation

A drip irrigation system was used to deliver precise quantities of water and nutrients directly to the maize root zones, significantly enhancing water use efficiency and plant health. Fertigation involved the application of both chemical and organic fertilizers, including Urea, DAP, MAP, and *Criyagen biostimulants*.

2.4 Drone and Satellite Monitoring

Drones equipped with multispectral sensors were used to generate NDVI, NDRE, MSAVI, GNDVI, and LCI indices. These indices provided actionable insights on crop vigor, chlorophyll levels, and stress detection, enabling timely interventions to correct nutrient deficiencies and pest outbreaks.

2.5 Cost of Cultivation

The cost of cultivation included expenses for land preparation, drip system amortization (spread over three years), inputs (seeds, fertilizers, pesticides), drone services, and intercultural operations.

3. Results

3.1 Germination, Plant Count, and Yield: Campus_SF_4 (Kharif) recorded the highest germination rate of 98.2%, the maximum plant count at 44,100 plants per acre, and achieved the highest yield of 59 quintals per acre. Campus_S_1, despite being a Rabi season crop, also recorded excellent performance with a 95.5% germination rate and a yield of 54 quintals per acre. This comparison underscores the robustness of precision agriculture techniques across different seasons (Table 2).

Table 2: Impact of Agronomy and Agritech on seedlings, tillers and yield

Sl. No.	Plot ID	Season	Germination %	Plant Count (per acre)	Yield (Quintals/acre)
1	Campus_SF_1	Kharif	96.6%	42,480	55.2
2	GJHalli_S_1	Rabi	94.2%	41,200	52.8
3	Campus_SF_2	Summer	96.8%	43,400	51.0
4	Campus_S_4	Kharif	98.2%	44,100	59.0
5	Campus_S_1	Rabi	95.5%	43,200	54.0

3.2 Cost of Cultivation

Cost of cultivation analysis reveals that input costs formed a major share, particularly due to improved nutrient and pest management strategies. Although the initial investment in drip irrigation and high-quality inputs slightly elevated costs compared to traditional practices, the substantial yield gains made the intervention highly cost-effective (Table 3).

Table 3: Details on Cost of Cultivation (5 plots) with standard farmers practices

Sl. No.	Plot ID	Land Preparation (Rs.)	Drip Irrigation (Rs.)	Inputs (Rs.)	Total (Rs.)
1	Campus_SF_1	4500	7500	23840	35840
2	GJHalli_S_1	4500	7500	22180	34180
3	Campus_SF_2	4500	7500	26440	38440
4	GJHalli_S_1	4500	7500	24100	36100
5	Campus_S_4	4500	7500	25550	37550
6	GJHalli S	4500	7500	22980	34980
7	Standard Farmer practice (Irrigated)	4500	0	14550	19050
8	Standard Farmer practice (Rainfed)	4500	0	6500	10500

3.3 Profitability Analysis

The profitability analysis highlights that all precision agriculture plots achieved a B:C ratio above 3.0, with Campus_S_4 achieving the highest at 3.77. The lowest cost per quintal and the highest net income were realized from the Kharif season Campus_S_4 plot, further validating the economic viability of the interventions. The B:C ratios above 3.0 across all plots and seasons signify excellent economic returns compared to conventional maize farming (Table 4).

Table 4: Cost benefit ratio of four different experiment plots with standard farmer practice

Sl. No.	Plot ID	Total Cost of cultivation/ acre (Rs.)	Yield (Quintals /acre)	Price of Maize/ Quintal (Rs.)	Total Income (Rs.)	Net Income (Rs.)	B:C Ratio	Increase of income over normal farming	Cost per Quintal	Net profit per quintal
1	Campus_SF_1	35840	55.2	2400	132480	96640	3.7	2.86	649.3	1750.72
2	GJHalli_S_1	37680	52.8	2400	126720	89040	3.4	2.64	713.6	1686.36
3	Campus_SF_2	38440	51	2400	122400	83960	3.2	2.49	753.7	1646.27
4	Campus_S_4	37550	59	2400	141600	104050	3.8	3.08	636.4	1763.56
5	GJHalli_S_1	38160	56.9	2400	136560	98400	3.6	2.92	670.7	1729.35
6	Standard Farmer practice (Irrigated)	19050	22	2400	52800	33750	2.8	1.00	865.9	1534.09
7	Standard Farmer practice (Rainfed)	10500	12	2400	28800	18300	2.7	0.54	875.0	1525

4. Discussion

The findings from this study strongly support the hypothesis that integrating precision agriculture and agri-tech solutions leads to a significant improvement in maize yield and farm profitability. Across the three experimental plots, yields ranged from 51 to 59 quintals per acre, representing a 250% increase over the standard farmer practice, which yielded only 20 quintals per acre. These results underscore the productivity potential of precision agronomy when implemented at the farm level.

4.1 Yield Improvement

The higher yields achieved in the Campus plots can be attributed to a combination of digital monitoring, scientific spacing, optimized drip fertigation, and the use of high-quality inputs. Plot Campus_S_4, with the highest germination rate (98.2%) and plant count (44,100 per acre), attained the top yield of 59 quintals per acre. This is significantly higher than the national average and even exceeds many conventional irrigated farms in India, where average yields typically range from 15-25 quintals per acre (DMR Vision 2030, 2011). Such improvements are consistent with previous studies highlighting the yield-enhancing impact of drip irrigation and fertigation, which enable better nutrient uptake and uniform moisture distribution (Rao *et al*., 2021) [8]. Drip irrigation's impact on quality, yield, and growth Abd El-Hafez *et al*. (2001) [1] found that, in comparison to furrow irrigation in maize, the drip irrigation method improved field and crop water use efficiency by 35 and 9.52 percent, respectively. Similarly, real-time field insights from remote sensing tools and AgriApp-based digital agronomy allowed for timely interventions, resulting in healthier crop stands and better grain filling.

4.2 Cost of Cultivation and Profitability

Although the precision plots had higher input costs (₹35,840-₹38,440/acre) compared to the standard farmer practice (₹19,050/acre), their net income was significantly higher, reaching up to ₹1,04,050/acre in Campus_S_4. The Benefit-Cost (B:C) ratio for the best-performing precision plot stood at 3.77, compared to 2.52 for traditional practice, confirming superior economic viability. The cost per quintal of maize was also considerably lower under improved practices (₹636-753) compared to ₹952 for standard methods. This not only reflects better input-use efficiency but also aligns with findings from Gebbers & Adamchuk (2010) [7], who showed that precision farming reduces production costs per unit by optimizing resource use and reducing waste.

4.3 Efficiency of Improved Agricultural Practices

A major highlight of the study is the resource efficiency achieved through drip irrigation and precision input management. Water savings of up to 30-50% were observed in previous studies (Rao *et al*., 2021) [8], supporting the notion that drip systems outperform flood irrigation not only in conserving water but also in making irrigation a less labor-intensive and more manageable task during crop growth stages. Further, precision agriculture allowed for site-specific application of fertilizers and pesticides, minimizing environmental impact and lowering chemical usage while maximizing output (Zhang *et al*., 2002) [11]. The use of drones for foliar application ensured uniform coverage and timely disease/pest management, which significantly contributed to yield protection and quality enhancement. These practices are especially relevant in the context of Indian agriculture, where overuse of fertilizers and poor irrigation practices have led to declining soil health and water table levels. Hence, the climate-smart approach followed in this study promotes long-term sustainability, in addition to short-term economic benefits.

5. Conclusion

Precision agriculture tools, including drip irrigation, digital agronomy platforms, drone-based monitoring, and optimized nutrition management, substantially increased maize yields and profitability across Kharif, Rabi, and Summer seasons in Karnataka. The Campus_S_4 plot achieved a remarkable 59 quintals per acre yield and a B:C ratio of 3.77, while Campus_S_1 consistently demonstrated strong performance across Rabi seasons. These outcomes emphasize that precision interventions are vital for achieving national goals of doubling farmers' incomes, promoting resource conservation, and ensuring food security amidst climate challenges.

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