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Traditional vs. Modern Maize Cultivation Practices: A Comparative Study

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Abstract This study compares traditional and modern maize cultivation practices, focusing on their respective impacts on yield, sustainability, and adaptability to mechanization. Traditional practices, such as maize-soybean intercropping, often suffer from low light and radiation use efficiency, and are incompatible with modern mechanization, leading to lower yields and profitability. Conversely, modern practices, including optimized tillage, high-density planting, and balanced nutrient management, have shown significant improvements in yield and resource use efficiency. For instance, high-density planting combined with optimized nitrogen fertilization can increase maize yield by up to 28.8%. Additionally, integrated agronomic management practices have been found to enhance nitrogen use efficiency and overall crop productivity. Continuous maize cultivation without proper soil conservation measures, however, can lead to declining yields over time, highlighting the need for sustainable practices. This study underscores the importance of adopting modern, scientifically-backed cultivation techniques to achieve higher yields, better resource efficiency, and long-term sustainability in maize farming.

Keywords Maize cultivation; Traditional practices; Modern practices; Yield efficiency; Sustainable agriculture

1 Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops globally, serving as a staple food for millions of people and a critical component in animal feed and industrial products. Its cultivation spans diverse agro-ecological zones, making it a versatile crop with significant economic and nutritional value. The transformation of maize from its wild ancestors to the highly productive varieties we see today is a testament to the power of domestication and plant breeding, which have been ongoing for over 10 000 years (Hufford et al., 2012). Modern maize cultivation practices have evolved to include advanced agronomic techniques and genetically improved hybrids, which have significantly enhanced yield potential and resilience against pests and diseases (Bender et al., 2013; Pavithra et al., 2018).

Understanding the differences between traditional and modern maize cultivation practices is crucial for several reasons. Traditional practices, often characterized by low-input and sustainable methods, have been developed over centuries and are well-adapted to local conditions. However, they may not always meet the demands of increasing population and food security challenges. On the other hand, modern practices, which include the use of high-yielding hybrids, chemical fertilizers, and mechanization, have been shown to significantly boost productivity but may also lead to environmental degradation and loss of biodiversity (Norris et al., 2016; Hasan et al., 2020; Luísa et al., 2020). Comparative studies of these practices can provide insights into optimizing maize production systems that balance productivity with sustainability (Supasri et al., 2020; Veeranna et al., 2023).

This study compares the agronomic performance and environmental impacts of traditional and modern maize cultivation practices, evaluates the socio-economic benefits and challenges associated with each practice, and identifies best practices that can be integrated to enhance maize productivity while ensuring environmental sustainability and resilience to climate change. By synthesizing findings from various research studies, this study aims to provide a comprehensive understanding of how different cultivation practices affect maize production and to offer recommendations for future agricultural policies and practices.

2 Historical Background of Maize Cultivation

2.1 Traditional practices

2.1.1 Early methods of maize cultivation

Maize (*Zea mays* L.) has a rich history that dates back approximately 9 000 years when it was first domesticated from the wild grass teosinte by early Mexican farmers. This domestication process was crucial for the development of maize as a staple food source, significantly influencing Mexican culture and religion (Hake and Ross-Ibarra, 2015). Traditional cultivation methods were primarily manual and relied heavily on natural environmental conditions. Early farmers selected seeds from plants that exhibited desirable traits, such as larger kernels and higher yields, which gradually led to the maize varieties we recognize today (Hufford et al., 2012; Hake and Ross-Ibarra, 2015).

2.1.2 Cultural and regional variations in traditional practices

The traditional practices of maize cultivation varied significantly across different regions and cultures. In the southwestern United States and northern Mexico, diverse landraces of maize were cultivated primarily for human consumption. These landraces displayed a wide array of kernel colors and were often selected for their unique culinary uses and health benefits (Nankar et al., 2016). For instance, blue maize, which has gained commercial interest due to its health-promoting properties, was traditionally grown in these regions. The cultivation practices in these areas were deeply rooted in the cultural heritage and agricultural knowledge passed down through generations (Nankar et al., 2016).

2.2 Evolution to modern practices

2.2.1 Development and adoption of modern techniques

The transition from traditional to modern maize cultivation practices has been marked by significant technological advancements and scientific research. Modern breeding techniques have introduced dynamic genetic changes into the maize genome, leading to increased productivity and the development of new maize varieties with desirable traits (Jiao et al., 2012). The sequencing of numerous maize lines has revealed extensive genetic variation, which has been harnessed to improve crop yields and resilience (Jiao et al., 2012). Additionally, the adoption of mechanized farming practices and the use of synthetic fertilizers and pesticides have further enhanced maize production (Cox and Cherney, 2018).

2.2.2 Impact of technological advancements on maize farming

Technological advancements have had a profound impact on maize farming, transforming it from a labor-intensive process to a highly efficient and productive agricultural practice. The development of genetically modified (GM) hybrids, which are resistant to pests and diseases, has significantly reduced crop losses and increased yields (Cox and Cherney, 2018). Moreover, modern intercropping systems, such as the maize-soybean intercropping system (MSIS), have been developed to optimize land use and improve nutrient acquisition, making them compatible with mechanization and suitable for small-landhold farmers (Figure 1) (Iqbal et al., 2018). These advancements have not only increased the land equivalent ratio (LER) but also ensured higher light interception and nutrient uptake, leading to better overall crop performance (Iqbal et al., 2018).

In summary, the evolution from traditional to modern maize cultivation practices has been driven by a combination of genetic research, technological innovations, and the adoption of mechanized farming techniques. These changes have significantly improved maize yields and resilience, ensuring its continued importance as a staple food crop worldwide.

3 Key Differences Between Traditional and Modern Practices

3.1 Agricultural techniques

Traditional maize cultivation practices often involve low-intensity systems characterized by seed selection by farmers, plowing, and crop-animal rotation techniques. These methods are typically more sustainable and have a higher fraction of renewability compared to modern practices. For instance, traditional systems in Argentina show a renewability fraction between 28% and 63% (Rótolo et al., 2015). In contrast, modern practices, including high-intensity and GMO-based systems, rely heavily on advanced technologies such as herbicide-resistant transgenic hybrids, pesticides, higher fertilizer rates, and no-till practices. These methods, while potentially increasing yield, often result in lower sustainability and higher environmental costs (Rótolo et al., 2015).

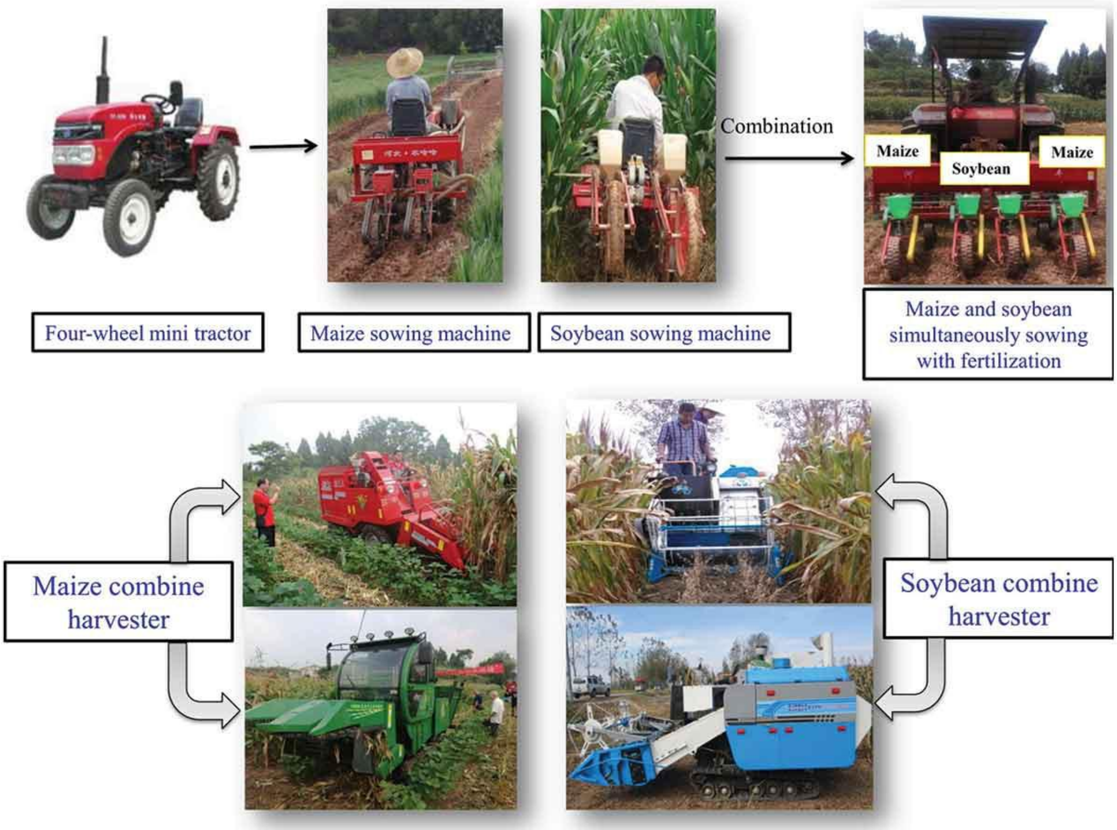

Figure 1 Mechanical operations in mechanized-based maize–soybean intercropping systems of China (Adopted from Iqbal et al., 2018)

3.2 Input use

The input use in traditional maize cultivation is generally lower and more organic. Traditional systems utilize natural fertilizers and minimal chemical inputs, which contribute to better soil health and lower environmental impact. For example, organic farming treatments have shown higher enzyme activities and nutrient content in the soil compared to conventional practices (Veeranna et al., 2023). On the other hand, modern maize cultivation practices involve the use of synthetic fertilizers, pesticides, and genetically modified seeds. These inputs are designed to maximize yield but can lead to soil degradation and increased reliance on nonrenewable resources (Rótolo et al., 2015; Cox and Cherney, 2018). The use of composted manure and mechanical weed control in organic systems during the transition phase also highlights the differences in input use between traditional and modern practices (Cox and Cherney, 2018).

3.3 Crop varieties

Traditional maize cultivation often involves the use of open-pollinated varieties that are selected and improved by farmers over generations. These varieties are typically well-adapted to local conditions and can contribute to the preservation of biodiversity. For instance, breeding programs for traditional agriculture have focused on improving open-pollinated populations for specific traits such as flour yield and bakery quality under organic conditions (Revilla et al., 2015). In contrast, modern maize cultivation frequently employs hybrid and genetically modified (GM) varieties that are engineered for specific traits such as pest resistance and higher yield. These varieties require significant investment in terms of prior knowledge and high-tech laboratory research (Rótolo et al., 2015). The use of GM hybrids treated with fungicides and insecticides is a common practice in conventional systems, further distinguishing them from traditional methods (Cox and Cherney, 2018).

4 Impact on Maize Yield

4.1 Yield comparisons

The comparison between traditional and modern maize cultivation practices reveals significant differences in yield outcomes. Modern practices, such as the adoption of improved cultivars and optimized agronomic management, have been shown to substantially increase maize yields. For instance, a study in the North China Plain demonstrated that the shift from traditional to modern cultivars increased yields by 23.9%-40.3%, while new fertilizer management practices contributed an additional 3.3%-8.6% increase in yield (Xiao and Tao, 2016). Similarly, integrated agronomic management practices, including optimized cropping systems and fertilization techniques, resulted in a 67% higher grain yield compared to traditional farming practices (Jin et al., 2012). Furthermore, no-till strip row farming with yearly maize-soybean rotation increased maize yield by 75% compared to conventional practices (Islam et al., 2015).

4.2 Factors influencing yield

Several factors influence maize yield under different cultivation practices. Modern practices often involve the use of high-yield cultivars, optimized planting densities, and advanced fertilization techniques. For example, the stay-green maize cultivar, when combined with row fertilization, significantly improved yield, especially under conditions of precipitation deficit (Jagła et al., 2019). Additionally, the adoption of sustainable agricultural practices, such as maize-legume rotation and residue retention, has been shown to enhance both maize yields and household incomes in rural Zambia (Manda et al., 2016). On the other hand, traditional practices are often limited by outdated techniques and suboptimal resource management, leading to lower yields.

4.3 Yield stability

Yield stability is a critical aspect of maize cultivation, particularly in the face of climate variability. Modern practices have been found to offer greater yield stability compared to traditional methods. For instance, the adoption of no-till strip row farming not only increased yield but also contributed to better root architecture and higher plant biomass, which are essential for maintaining yield stability (Islam et al., 2015). However, climate change poses a significant challenge, as evidenced by the reduction in maize yield due to declining solar radiation and increasing temperatures in the North China Plain (Xiao and Tao, 2016). Despite these challenges, modern practices that incorporate sustainable techniques and optimized management can mitigate some of the adverse effects of climate variability, thereby enhancing yield stability.

5 Soil Health and Fertility

5.1 Soil management practices

Soil management practices play a crucial role in maintaining soil health and fertility, especially in maize cultivation. Traditional tillage methods often involve deep plowing, which can lead to soil erosion and degradation over time. In contrast, conservation tillage practices, such as no-tillage and strip tillage, have been shown to improve soil structure and reduce erosion. For instance, a study comparing conventional tillage with non-tillage practices found that non-tillage methods, along with the implementation of herbage strips and fallow areas, contributed significantly to soil sustainability and biodiversity preservation (Luísa et al., 2020). Additionally, strip tillage has been demonstrated to enhance arthropod biodiversity by reducing the disturbed area and increasing non-crop plant richness, although it may result in lower maize yields compared to conventional methods (Norris et al., 2016).

5.2 Impact on soil fertility

The impact of different soil management practices on soil fertility is profound. Traditional agricultural practices often result in low soil fertility due to the depletion of essential nutrients. A study conducted in the Gamo Zone revealed that traditional and conventional tillage practices led to low levels of organic carbon (OC), total nitrogen (TN), and cation exchange capacity (CEC) in the soil, which are critical for crop productivity (Ayele and Petrous, 2022). In contrast, conservation agriculture (CA) practices, which include minimal soil disturbance and the use of cover crops, significantly improved soil fertility. The study reported that CA fields increased maize yield by 39% and 59% compared to conventional and traditional fields, respectively, in 2019, and by 54% and 62% in 2020

(Table 1) (Ayele and Petrous, 2022). This suggests that adopting CA practices can enhance soil fertility and, consequently, crop yields.

Table 1 Phyicochemical characteristics of the experimental site soil (0-20 cm), 2019- 2020 (Adopted from Ayele and Petrous, 2022)

	Soil characteristics										
	BD g/cm^3	Porosity %	pH(H_2O) 1:2.5	EC dS/m	OC	TN %	OM	C:N ratio	P_2O_5 mg/kg	K_2O g/kg	CEC cmol(+)/kg
					Paraso						
Initial	1.1	61.82	6.43	0.10	2.57	0.09	4.43	28.56	26.94	380.94	0.83
Rating	S1	S1	MA	SF	M	L	M	M	H	H	VL
CA	1.06	60.00	7.11	0.15	1.72	0.06	2.94	28.67	112.67	395.36	4.24
Rating	S1	S1	MA	SF	M	L	M	M	VH	VH	VL
CO	1.12	57.74	6.84	0.08	1.68	0.08	2.90	20.00	112.81	400.82	4.96
Rating	S1	S1	MA	SF	L	L	M	H	VH	VH	VL
TA	1.14	56.98	7.24	0.07	1,40	0.07	2.41	20.00	70.68	518.31	4.64
Rating	S1	S1	SA	SF	L	L	L	H	VH	VH	VL
					Ocholo						
Initial	1.03	61.13	5.75	0.20	1.54	0.03	2.65	51.33	77.75	499.13	0.61
Rating	S1	S1	N	SF	M	L	M	M	VH	VH	VL
CA	1.02	61.51	6.13	0.27	2.52	0.12	4.34	19.38	140.15	545.63	4.28
Rating	S1	S1	SAI	SF	M	L	M	H	VH	VH	VL
CO	1.04	60.75	7.54	0.27	2.24	0.11	3.86	37.33	111.88	436.34	4.92
Rating	S1	S1	SA	SF	M	L	M	M	VH	VH	VL
TA	1.00	62.26	7.65	0.21	1.68	0.08	2.40	20.00	77.78	474.59	3.30
Rating	S1	S1	N	SF	M	L	L	H	VH	VH	VL
					Bakole						
Initial	1.11	58.11	5.87	0.08	1.39	0.06	2.40	23.17	20.67	263.83	0.59
Rating	S1	S1	N	SF	M	L	M	M	H	VH	VL
CA	1.07	59.62	7.05	0.09	1.68	0.08	2.90	20.00	139.26	526.50	3.78
Rating	S1	S1	SAI	SF	M	L	M	H	VH	VH	VL
CO	1.04	60.75	6.17	0.06	1.12	0.06	1.93	18.67	127.48	318.58	2.78
Rating	S1	S1	SA	SF	L	L	L	H	VH	VH	VL
TA	1.04	60.75	6.24	0.06	1.40	0.07	2.41	20.00	136.55	395.36	4;80
Rating	S1	S1	N	SF	l	L	L	H	VH	VH	VL
					Merchie						
Initial	1.03	61.13	6.26	0.10	1.48	0.05	2.55	29.60	24.24	487.69	0.58
Rating	S1	S1	N	SF	L	L	M	M	H	VH	VL
CA	1.00	62.26	7.65	0.13	1.68	0.07	2.90	24.00	97.48	545.63	3.78
Rating	S1	S1	SAI	SF	M	L	M	M	VH	VH	VL
CO	1.02	60.75	7.11	0.09	1.40	0.08	2.41	17.50	58.01	324.43	3.34
Rating	S1	S1	SA	SF	L	L	L	H	VH	VH	VL
TA	1.01	61.89	6,95	0.10	1.40	0.07	2.41	20.00	55.08	384.30	2.70
Rating	S1	S1	N	SF	L	L	L	H	VH	VH	VL

Note: L=Low; VL=Very low; M=Moderate, and H=High; MA=moderately acidic; SA=slightly Acidic; N=Neutral SAl=Slightly Alkaline; SF=Salt Free (i.e., EC=<2dS/m). %OC x1.724=%OM; pH=power of hydrogen; OM=organic matter; TN=total nitrogen; C:N=carbon toNitrogen ratio; Av.P_2O_5=available phosphorous. 1 dS/m=1000 µS/cm (Adopted from Ayele and Petrous, 2022)

5.3 Soil biodiversity

Soil biodiversity is an essential component of soil health, influencing nutrient cycling, soil structure, and overall ecosystem function. Different maize cultivation practices have varying impacts on soil biodiversity. For example, the use of strip tillage has been shown to improve both above- and below-ground arthropod biodiversity by reducing the area disturbed by cultivation and increasing the richness of non-crop plants (Norris et al., 2016). This practice not only supports a diverse arthropod community but also contributes to the overall health of the soil ecosystem. Furthermore, the implementation of herbage strips and fallow areas in non-tillage systems has been found to preserve soil biodiversity, compensating for the negative impacts of intensive maize cultivation (Luísa et al., 2020). These findings highlight the importance of adopting sustainable soil management practices to maintain and enhance soil biodiversity.

6 Environmental Impact

6.1 Sustainability

Sustainability in maize cultivation practices is a critical concern due to the intensive nature of conventional agriculture. Traditional methods, such as continuous monoculture and conventional tillage, have been shown to degrade soil quality and reduce biodiversity. For instance, conventional tillage practices in maize cultivation have been associated with lower soil quality, as indicated by reduced organic matter and nutrient levels, and increased soil bulk density and pH (Luísa et al., 2020). Conversely, non-tillage practices and the implementation of herbage strips, non-irrigated, and fallow areas have demonstrated potential in enhancing soil sustainability and preserving biodiversity (Luísa et al., 2020). These practices contribute to improved soil physical-chemical parameters and biological activity, which are essential for long-term agricultural sustainability.

6.2 Ecological Footprint

The ecological footprint of maize cultivation varies significantly between traditional and modern practices. Traditional continuous monoculture systems have been linked to higher negative environmental impacts, including reduced habitat quality for beneficial arthropods and lower biocontrol potential of generalist predators (Puliga et al., 2023). In contrast, modern practices such as mixed cropping systems (e.g., maize-sorghum, maize-flower strips) and strip tillage have shown promise in reducing the ecological footprint. These systems provide a denser and more permanent vegetation cover, which supports higher activity density of generalist predators and enhances their biological pest control potential (Puliga et al., 2023). Additionally, strip tillage reduces the area disturbed by cultivation, thereby promoting a richer arthropod community structure and biodiversity (Norris et al., 2016).

6.3 Biodiversity

Biodiversity is a crucial indicator of the health and sustainability of agricultural ecosystems. Traditional maize cultivation practices, particularly those involving intensive monoculture and conventional tillage, have been found to negatively impact biodiversity. For example, continuous monoculture systems exhibit the lowest activity of generalist predators, which are vital for biological pest control (Puliga et al., 2023). On the other hand, modern practices such as strip tillage and mixed cropping systems have been shown to enhance biodiversity. Strip tillage, by reducing the disturbed area and increasing non-crop plant richness, significantly improves both above- and below-ground arthropod biodiversity (Norris et al., 2016). Similarly, mixed cropping systems, especially those incorporating flower strips, provide better habitats for beneficial arthropods, thereby supporting higher biodiversity and ecosystem services (Puliga et al., 2023).

In summary, while traditional maize cultivation practices tend to degrade soil quality, increase the ecological footprint, and reduce biodiversity, modern practices such as non-tillage, strip tillage, and mixed cropping systems offer more sustainable alternatives. These modern practices not only improve soil quality and reduce environmental impacts but also enhance biodiversity, contributing to more resilient and sustainable agricultural ecosystems.

7 Economic Viability

7.1 Cost-benefit analysis

The economic viability of maize cultivation practices can be significantly influenced by the choice of agricultural techniques. For instance, tied-ridging combined with mineral N and P fertilizers in semi-arid Tanzania has shown to be a potentially profitable technology. This method can increase maize grain yields up to six times compared to traditional practices, with a benefit-cost analysis supporting its profitability, especially in areas with better soil quality and market integration (Jensen et al., 2003). Similarly, the adoption of sustainable agricultural practices (SAPs) in rural Zambia, such as maize-legume rotation and residue retention, has been shown to raise both maize yields and household incomes, despite the high cost of inorganic fertilizers (Manda et al., 2016).

In Ontario, Canada, a no-till strip row farming system that involves yearly maize-soybean rotation has demonstrated a 75% increase in maize yield compared to conventional practices. This method not only enhances yield but also results in a 400% higher net return, making it a highly profitable practice (Islam et al., 2015). Additionally, a study comparing drip and conventional fertigation methods found that although the initial capital investment for drip irrigation is high, the cumulative benefits and longer system life make it economically viable. The highest income from produce was recorded for the drip fertigation treatment, indicating its superior cost-benefit ratio (Singh et al., 2017).

7.2 Financial returns

Financial returns from maize cultivation are closely tied to the adoption of improved agricultural technologies. In Ethiopia, the adoption of multiple improved maize production technologies has led to significant impacts on farm-level maize yield and production costs. The integration of these technologies has resulted in a 26.4% cost reduction per kilogram of maize output, increasing both producer and consumer surpluses and reducing poverty levels (Kassie et al., 2018). In the American Southwest, prehistoric maize farming was found to be economically comparable to local wild plants, with intensive farming practices yielding similar returns to low-ranked seeds. This suggests that financial returns from maize farming were influenced by local ecological conditions and the availability of alternative economic opportunities (Barlow, 2002).

7.3 Market access

Market access plays a crucial role in determining the economic viability of maize cultivation practices. In semi-arid Tanzania, market-oriented households that adopted tied-ridging and high fertilizer inputs were able to maximize profitability, highlighting the importance of market integration for economic success (Jensen et al., 2003). In rural Zambia, the adoption of SAPs has been shown to improve household incomes, suggesting that better market access can enhance the financial returns from sustainable agricultural practices (Manda et al., 2016). In Ethiopia, the economic impacts of improved maize production technologies at the market level have been significant, with increased producer and consumer surpluses contributing to poverty reduction (Kassie et al., 2018).

Overall, the economic viability of maize cultivation practices is influenced by a combination of cost-benefit analysis, financial returns, and market access. The adoption of improved agricultural technologies and sustainable practices can lead to higher yields, reduced production costs, and increased profitability, especially when supported by good market integration.

8 Social and Cultural Implications

8.1 Traditional knowledge

Traditional maize cultivation practices are deeply rooted in the cultural and historical contexts of farming communities. These practices often involve the use of indigenous knowledge systems that have been passed down through generations. For instance, traditional farming techniques, such as the selection of seeds and the use of organic fertilizers, are integral to maintaining biodiversity and ecological balance (Bajpai and Kumar, 2022). Additionally, cultural preferences play a significant role in the retention of landraces, which are traditional varieties of maize that have been cultivated over long periods. These landraces are not only important for their genetic diversity but also for their cultural significance, as they are often associated with traditional rituals and culinary practices (Bellon and Hellin, 2011).

8.2 Community impact

The shift from traditional to modern maize cultivation practices has profound implications for community dynamics. Modern agricultural practices, characterized by the adoption of hybrid seeds and the use of chemical fertilizers and pesticides, have led to increased yields but also to a reduction in the area planted with traditional landraces (Bellon and Hellin, 2011). This shift has been driven in part by government programs aimed at fostering commercialization and hybrid adoption. However, the abandonment of traditional practices can lead to the erosion of cultural heritage and community cohesion. On the other hand, the retention of traditional practices, supported by cultural preferences and anti-poverty programs, can empower communities, particularly women, by preserving their roles in agricultural decision-making and maintaining their cultural identity (Bellon and Hellin, 2011).

8.3 Farmer livelihoods

The livelihoods of farmers are intricately linked to the type of maize cultivation practices they adopt. Traditional farming practices, which often involve organic farming and the use of biofertilizers, can be more sustainable and environmentally friendly, potentially leading to long-term benefits for farmer livelihoods (Bajpai and Kumar, 2022). However, these practices may also result in lower immediate yields compared to modern practices, which can be a significant drawback for farmers seeking to maximize their income. Conversely, the adoption of modern practices, such as the use of genetically modified crops and advanced machinery, can lead to substantial yield increases and higher short-term profits (Bellon and Hellin, 2011). Nevertheless, these benefits must be weighed against the potential risks, including increased dependency on commercial seed suppliers and the loss of traditional knowledge and practices.

In conclusion, the social and cultural implications of maize cultivation practices are multifaceted and complex. While modern practices offer the promise of higher yields and increased income, they also pose risks to cultural heritage and community cohesion. Traditional practices, on the other hand, play a crucial role in preserving cultural identity and promoting sustainable farming, but may not always meet the economic needs of farmers. Balancing these factors is essential for the sustainable development of farming communities.

9 Case Study

9.1 Introduction to the case study

This case study aims to compare traditional and modern maize cultivation practices in a selected region. By examining the differences in methodologies, productivity, and environmental impact, we seek to provide a comprehensive understanding of how these practices influence maize cultivation outcomes. The selected region for this study is Bhavikere, where both traditional and modern farming methods are employed.

9.2 Traditional practices in the selected region

Traditional maize cultivation practices in Bhavikere typically involve natural farming methods. These methods rely on minimal external inputs and emphasize the use of organic materials and traditional knowledge passed down through generations. Key characteristics of traditional practices include: use of natural fertilizers such as compost and manure. Minimal use of chemical pesticides and herbicides. Crop rotation and intercropping to maintain soil fertility and reduce pest incidence. Manual labor for planting, weeding, and harvesting.

9.3 Modern practices in the selected region

Modern maize cultivation practices in Bhavikere are characterized by the adoption of advanced agricultural techniques and inputs to maximize yield and efficiency. These practices include: application of synthetic fertilizers and pesticides as per recommended packages. Use of high-yielding hybrid maize varieties. Mechanization of planting, weeding, and harvesting processes. Implementation of precision farming techniques to optimize resource use.

9.4 Comparative analysis

The comparative analysis of traditional and modern maize cultivation practices in Bhavikere reveals significant differences in productivity, soil health, and environmental impact. According to a field experiment conducted at the Zonal Agricultural and Horticultural Research Station, Bhavikere, modern farming practices resulted in higher growth and yield parameters for maize, including plant height, number of leaves per plant, cob length, straw yield, and grain yield (Veeranna et al., 2023). In contrast, traditional practices, particularly organic farming, showed higher enzyme activities such as dehydrogenase and urease, indicating better soil health (Veeranna et al., 2023).

9.5 Results and insights
The results of this case study highlight the trade-offs between traditional and modern maize cultivation practices. Modern practices significantly enhance maize productivity, with higher grain and straw yields compared to traditional methods (Veeranna et al., 2023). However, traditional practices contribute to better soil health, as evidenced by higher enzyme activities and nutrient content in the soil (Veeranna et al., 2023). This suggests that while modern practices are more efficient in terms of yield, traditional practices may offer long-term sustainability benefits by maintaining soil fertility and reducing chemical inputs.

In conclusion, the choice between traditional and modern maize cultivation practices depends on the specific goals of the farmers and the long-term sustainability considerations. Integrating elements of both practices could potentially offer a balanced approach, optimizing productivity while preserving soil health and environmental quality.

10 Challenges and Limitations
10.1 Traditional practices
Traditional maize cultivation practices often face several challenges and limitations. One significant issue is the low light use efficiency and radiation use efficiency in traditional intercropping systems, such as maize-soybean intercropping, which results in lower comparative profits and incompatibility with mechanization (Iqbal et al., 2018). Additionally, traditional farming practices tend to have lower water and nitrogen use efficiencies, leading to higher resource wastage and environmental impact (Li et al., 2015). The traditional methods also often fail to optimize the canopy structure and soil conditions, which are crucial for maximizing photosynthetic rates and grain yields (Piao et al., 2016). Furthermore, traditional practices are less adaptable to modern agricultural demands, such as the need for higher yields and efficient resource use (Xiao and Tao, 2016).

10.2 Modern practices
Modern maize cultivation practices, while offering numerous advantages, also come with their own set of challenges. For instance, the adoption of strip tillage, which improves arthropod biodiversity, often results in a significant reduction in maize yield, making it less appealing to farmers focused on maximizing output (Norris et al., 2016). Modern practices also require substantial technological advancements and compatible mechanization to be fully effective, which can be a barrier for smallholder farmers (Iqbal et al., 2018). Additionally, the shift to modern cultivars and agronomic management practices has been shown to increase yields, but these gains are often offset by the negative impacts of climate change, such as reduced solar radiation and increased temperatures (Xiao and Tao, 2016). Moreover, the high input costs associated with modern practices, such as optimized fertilization and irrigation, can be prohibitive for many farmers (Jin et al., 2012; Li et al., 2015).

10.3 Integration of practices
Integrating traditional and modern maize cultivation practices could potentially offer a balanced approach, but this integration is not without its challenges. One major issue is the need for technological advancements and agronomic measures to make traditional practices compatible with modern mechanization (Iqbal et al., 2018). Additionally, while integrated practices like ridge-furrow with plastic film mulching can improve water use efficiency and nitrogen uptake, they require careful management to avoid issues such as soil degradation and increased labor costs (Li et al., 2017). The integration also demands a thorough understanding of both traditional and modern techniques to optimize planting geometry, canopy structure, and nutrient management effectively (Piao et al., 2016). Furthermore, achieving a balance between enhancing biodiversity and maintaining high yields remains a significant challenge in integrated systems (Norris et al., 2016). Finally, the variability in environmental conditions and resource availability across different regions can complicate the implementation of integrated practices, necessitating region-specific adaptations and solutions (Xiao and Tao, 2016).

By addressing these challenges and limitations, it is possible to develop more sustainable and efficient maize cultivation systems that leverage the strengths of both traditional and modern practices.

11 Concluding Remarks

This comparative study on traditional and modern maize cultivation practices has revealed significant differences in methodologies and outcomes. Traditional practices, as observed in Guatemala, involve subsistence-oriented agricultural methods deeply rooted in Mayan heritage. These include drying maize cobs in direct sunlight and storing them in various forms, with a significant portion of farmers using bags and tapancos for storage. However, these methods often lead to post-harvest losses due to mishandling of grain moisture, resulting in insect and fungal infestations.

In contrast, modern practices such as no-till strip row farming and zigzag planting with deep nitrogen fertilization have shown substantial improvements in maize yield. The no-till strip row farming system in Ontario, Canada, demonstrated a 75% increase in maize yield compared to conventional methods, attributed to better root architecture, higher plant biomass, and beneficial microorganisms. Similarly, zigzag planting combined with deep nitrogen fertilization in China significantly enhanced root length density, photosynthesis rate, and dry matter accumulation, leading to higher yields compared to traditional linear planting methods.

The findings from this study suggest that integrating modern agricultural practices can significantly enhance maize productivity and sustainability. The no-till strip row farming system and zigzag planting with deep nitrogen fertilization offer promising alternatives to traditional methods, particularly in terms of yield improvement and resource utilization. These practices not only increase crop productivity but also contribute to soil health and long-term sustainability.

For regions relying on traditional methods, such as the Guatemalan Highlands, adopting elements of these modern practices could mitigate post-harvest losses and improve food security. For instance, introducing preventive pest control measures and optimizing storage conditions could reduce losses due to moisture mishandling and infestations. Additionally, the implementation of no-till farming and optimized planting techniques could be explored to enhance yield and sustainability in these regions.

In conclusion, the comparative analysis of traditional and modern maize cultivation practices underscores the potential benefits of adopting advanced agricultural techniques. While traditional methods are deeply rooted in cultural practices and provide a foundation for subsistence farming, modern practices offer substantial improvements in yield and sustainability. Future research and agricultural policies should focus on integrating these modern techniques with traditional knowledge to create a balanced approach that maximizes productivity while preserving cultural heritage and ensuring food security.

By leveraging the strengths of both traditional and modern practices, it is possible to develop a more resilient and productive agricultural system that meets the growing demand for maize without compromising environmental and cultural values.

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Conflict of Interest Disclosure

Authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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