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ARTICLE

Farmers, Chemicals and Fertility of Soil: A Quest to Sustainability

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ABSTRACT

This study examines the evolving use of synthetic chemicals in intensive agriculture over the past decade. It highlights the negative impacts of chemical inputs on soil health and ecosystem integrity and recommends knowledge-sharing platforms, soil protection laws, and collaborative efforts between regulatory agencies and agricultural experts. The study emphasizes the need for a balanced approach that includes natural methods alongside synthetic chemicals, particularly herbicides. Ten years ago, farmers primarily used urea, DAP, and potassium for nutrients. However, increased awareness, market forces, and government subsidies have led to a significant rise in herbicide use as a cost-effective weed management strategy. Over the past decade, synthetic fertilizer use for cotton cultivation has increased by 80%, leading to deteriorating soil quality. Paddy cultivation has decreased by 23%, while cotton cultivation has increased by 20.4% due to higher economic incentives. Currently, 89.1% of farmers use herbicides, compared to 97.2% who did not a decade ago. Insecticide use has also surged, with 97.8% of farmers applying 1.5 liters or more per acre. The excessive use of chemicals threatens soil fertility and disrupts the ecosystem's balance. This article explores the reasons behind the adoption of chemical-intensive farming practices and offers insights into farmers' decision-making processes. The careful use of synthetic chemicals is essential to safeguard soil health and maintain ecological balance.

Keywords: Ecosystem Integrity; Herbicides; Intensive Agriculture; Soil Health; Synthetic Chemicals

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1. Introduction

Contemporary agriculture must balance efficiency with environmental health. Intensive farming methods have led to a significant increase in dependence on synthetic chemicals (SC)[1], which are crucial for improving crop yields. However, the adverse effects of these compounds on soil health and ecosystem integrity cannot be overlooked[2]. This study investigates the factors influencing farmers' decisions to use SC and examines their perspectives on soil fertility. Our inquiry focuses on a geographic area known for its extensive agricultural operations, linked to a doctoral thesis that analyses farmers' practices over four years. Additionally, we compare current methods with farmers' practices and perceptions from ten years ago, with a specific focus on SC usage in agriculture. The research region predominantly cultivates two types of crops: paddy in wetlands and cotton in dry plains. Primary data were collected through surveys and interviews with local farmers, covering aspects such as substance use patterns, motivations, and awareness of long-term consequences. Secondary data were sourced from agricultural extension services, retailers, and scientific publications. Farmers often adopt approaches recommended by their peers; successful adopters of synthetic chemicals influence others to follow suit.

Social networks play a critical role in disseminating information about the effectiveness and productivity enhancements of chemicals[3]. Retailers and agrochemical companies actively promote SC through advertising and incentives[4], creating a perception of increased profitability that encourages farmers to integrate these chemicals into their routine practices. Agricultural producers face economic pressures to maximize crop production and financial returns[5]. The immediate appeal of higher agricultural output often outweighs concerns about the long-term health of the land[6], making profit a strong motivator[7]. Farmers recognize that fertile soil harbours a vibrant community of microorganisms, beneficial interactions, and nutrient recycling[8]. Natural soil fertility enhances plant vigor and resilience[9]. Despite this awareness, the attraction to synthetic compounds persists. Herbicides, fungicides, and pesticides offer rapid effectiveness, but their long-term effects on soil health remain a concern. Disruptions to microbial populations and nutrient availability pose potential risks to the long-term sustainability of agriculture[10]. Farmers often have limited understanding of the full repercussions of long-term chemical use[11]. Knowledge dissemination platforms, educational workshops, and extension services can bridge this gap and empower farmers with research-based insights[12].

Guiding farmers towards sustainable practices through effective policies is essential[13]. These policies should prioritize soil conservation, crop rotation, and integrated pest management[14]. Regulatory authorities should collaborate with agricultural specialists to widely disseminate best practices. The incorporation of SC in agriculture involves complex interactions between economic, social, and ecological factors[15]. Although the immediate benefits are evident, addressing long-term repercussions is crucial. Promoting knowledge exchange and adopting informed policies can help achieve a balance between productivity and soil health, ensuring the sustainability of agricultural practices for future generations.

1.1. Farmers' Motivations and Their Impact on Soil, Environment, and Health

Agriculture is crucial for ensuring food security and economic stability, particularly in emerging nations[16]. However, the extensive use of SC in agriculture has brought both benefits and challenges[17]. While these compounds enhance agricultural productivity, it is essential to conduct comprehensive research to understand their potential impact on soil health, the environment, and human well-being[18]. This study focuses on a region where farmers have traditionally grown paddy in wetlands and crops such as sorghum, flaxseeds, soybeans, pulses, and sesame in dry fields. Historically, the primary chemical inputs used were urea, Diammonium Phosphate (DAP), and potassium. Recent trends indicate a shift towards increased reliance on synthetic substances, facilitating production but also leading to soil degradation over time[18]. The long-term consequences may adversely affect future generations, exacerbating food scarcity issues[19]. Therefore, it is imperative to replace current chemical-intensive methods with sustainable agricultural practices.

1.2. Influence of Social Media and Media Availability

The rise of social media platforms and widespread availability of print and visual media have significantly improved knowledge dissemination. Agricultural practitioners now receive guidance on the proper use of SC to enhance their productivity and financial gains [20]. Governments often provide financial incentives in the form of subsidies to promote the use of SC [21], encouraging farmers to adopt these methods. Over the past decade, there has been a notable increase in chemical usage in the study region, with herbicides becoming a widely recognized tool for weed control [22]. Farmers often weigh the cost and labour of manual weed removal against the convenience, cost-effectiveness, and time-saving benefits of herbicides [23], which motivates regular use for weed management.

1.3. Consequences of Herbicides on Soil and Environment

Herbicides, though effective in weed control, disrupt essential soil microbial ecosystems [24]. These microorganisms are crucial for nutrient cycling, organic matter decomposition, and overall soil health [25]. Continuous herbicide use can reduce soil fertility and resilience [26]. Additionally, herbicides can leach into water bodies, impacting aquatic ecosystems and potentially contaminating drinking water sources [27]. Soil microorganisms enhance biodiversity, and their disruption can significantly affect the entire ecosystem [28]. Many farmers apply herbicides without adequate protective gear, posing health risks through skin contact, inhalation, or accidental ingestion [29]. Despite some farmers' awareness of these risks, the lack of comprehensive information exchange exacerbates the situation.

1.4. Influence of Chemical Fertilizers on Soil Health

SCs are vital tools in modern agriculture, driving significant advancements in crop development when used judiciously [30]. However, their extensive use poses substantial ecological risks [31]. The study found that farmers heavily depend on chemical inputs, particularly for cotton cultivation, which relies entirely on chemical fertilizers. Over the past decade, chemical use has increased by 80%, a trend that warrants caution. Farmers' pursuit of higher yields drives them to explore alternative chemicals to boost crop production.

Historically, weed management techniques promoted soil fertility and ensured long-term food production sustainability. However, widespread herbicide use has eradicated beneficial weeds along with undesirable ones [32]. These beneficial plants play a crucial role in maintaining soil nutrient and carbon balance [33]. Many farmers fail to recognize the importance of these natural resources and remain unaware of their benefits [34]. While profit-oriented chemical methods have undeniably increased output, their excessive use poses significant risks to soil health [35]. If this trend continues, agriculture's long-term viability will face considerable challenges.

This paper does not explicitly oppose synthetic chemicals but strongly cautions against their unnecessary and excessive use, particularly herbicides. These compounds adversely affect soil microbes, leading to soil degradation and diminished ecosystem health.

1.5. Threats to Our Environment and Health

The study region has witnessed a significant rise in SC use throughout crop cultivation stages. While these chemicals enhance production, their excessive use poses a severe threat to soil fertility [36]. Farmers, in response to this issue, have shifted from traditional methods to a heavy reliance on synthetic pesticides. Historically, farmers incorporated livestock dung into the soil before each crop cycle, enhancing the soil's inherent fertility [37]. Upon contact, the manure-initiated decomposition processes foster the growth of soil microbes and macrobacteria [38], which play a vital role in augmenting soil productivity.

However, the current agricultural landscape has changed dramatically. The predominant approach now involves using chemical pesticides to increase crop yield and temporarily boost soil fertility levels [39]. Unfortunately, chemical fertilizers do not genuinely enhance soil fertility; they merely facilitate crop growth for higher yields. In this scenario, plants rely entirely on artificial SC, reducing the soil to a mere growth medium [40]. Over time, persistent SC use has negatively impacted the soil's organic composition, diminishing its inherent fertility by approximately 40% [41]. Consequently, soil health is now at risk, with implications extending beyond the environment to human health, which is also vulnerable to these toxic effects.

2. Methods and Materials

This study employed an exploratory-cum-descriptive research design to investigate the socio-economic and agricultural aspects among farmers in Telangana. The research focused on several key areas, including agricultural productivity factors such as soil fertility, irrigation methods, and pest control strategies. Additionally, the study assessed the impact of SC on agricultural productivity and examined farmers' income and investment decisions, considering factors like market volatility, government subsidies, and risk management measures.

Demographic characteristics and land ownership patterns were analysed, including variables such as age, education level, family size, and caste of the farmers. Landholding patterns were also examined, highlighting differences in land size and tenure. The study focused on agricultural practices specific to the region, with cotton and paddy being the predominant crops. The research was conducted in six mandals within KB Asifabad, a prominent agricultural district in Telangana. The survey targeted 65,376 farmers registered under the Telangana government's Rythu Bandhu project, which provides financial incentives for two agricultural seasons, kharif and rabi, annually. A sample size of 382 farmers was selected using the Krejcie and Morgan (1970) sampling method at a 95% confidence level.

Data collection incorporated both quantitative and qualitative methodologies. Quantitative data on socio-economic factors were gathered through semi-structured interviews, while qualitative data were obtained via field observations and focus group discussions. Interviews and discussions were conducted in Telugu, the local language. Quantitative data were analysed using SPSS software, employing both descriptive and inferential statistics. Concurrently, qualitative data were meticulously analysed through field observations and discussions, with themes identified using deductive methods. The application of triangulation enhanced the validity and reliability of the results.

3. Results

3.1. Socio-Economic and Landholding Conditions of Farmers

The data reveal a correlation between the age and experience of farmers engaged in agriculture. A significant majority, 85.1%, are between 36 and 55 years old. Of these, 39.8% are aged 36–45, and 45.3% are aged 46–55. The remaining 14.9% are either younger than 36 or older than 56. In terms of experience, 49.2% of farmers have been working in the field for 21 to 28 years, while 37% have longer or shorter durations, and 13.8% fall in the mid-range. Education levels among farmers vary, with 18.2% holding a college or university degree and 16% lacking basic literacy.

Land ownership patterns indicate that approximately 69.6% of farmers own 2 acres or less of wetland, while 37% own between 4 and 5 acres of dry land. Additionally, 12.7% own more than 5 acres of dry land, and 21.5% possess more than 4 acres of wet property. The annual income from agricultural practices on both irrigated and non-irrigated land was analysed. The median income is ₹197,524.86, with a lower quartile of ₹150,000 and an upper quartile of ₹250,000. These quartiles represent 30.9%, 21%, and 48.1% of the farmers, respectively. Most farmers, 79.6%, believe agriculture is a lucrative industry, while 16.6% are indifferent, indicating a generally favourable perception of farming profitability. The study also examines the variables affected by land ownership and the relatively low degree of financial contentment among farmers.

Table 1 Assessments of farmers' soil management techniques during tilling reveal that 50.8% use a combination of hired and traditional land ploughing methods, including tractor tilling and bull ploughing. This indicates that half of the farmers rely on renting bulls and tractors rather than owning them. Cotton growers mainly employ conventional tillage methods, occasionally using bulls for natural weed control. Both dry land cotton farming and wet land paddy cultivation use tractors, with the latter using a single tillage procedure. Additionally, 29.8% of farmers continue to use traditional methods, with occasional tractor assistance. However, only 14.4% of farmers use mechanical methods exclusively. The remaining 2.8% and 2.2% of farmers employ a combination of self-mechanical and hired-traditional methods, and self-mechanical and self-traditional methods, respectively. These findings indicate that only 5% of farmers own tractors exclusively.

3.2. Crop Preference before 10 Years and at Present

The study collected data on the land utilization patterns of farmers for cotton and paddy crops over the past decade.

A decade ago, 60.2% of farmers cultivated 2 acres of paddy, while 11.6% and 16.6% cultivated 1 acre and 3 acres, respectively. Currently, 31.5% of farmers cultivate 3 acres or more of paddy, with 17.7% and 19.9% engaging in 1 acre and 2 acres, respectively. Comparing paddy land use from the past to the present, there is a 19.3% decrease in the total area dedicated to paddy farming. Regarding cotton cultivation, a decade ago, 56.4% of farmers cultivated 2 acres, 13.3% cultivated 1 acre, and 17.1% cultivated 3 acres. Presently, 26% of farmers cultivate 3 acres of cotton, with 19.9% and 22.1% cultivating 2 acres and 4 to 5 acres, respectively. The acreage dedicated to cotton cultivation has increased by 20.4% compared to previous years. Most farmers prefer cotton due to its higher market value compared to paddy, leading many to convert wetlands, ideal for rice, into arid regions suitable for cotton cultivation.

Table 1. Land tilling pattern adoption.

Mechanisms	C	%
Hired mechanical method (Tractors)	55	14.4
Both, hired (traditional and mechanical)	194	50.8
Both, self (Traditional and mechanical)	8	2.2
Self-traditional and hired mechanical	114	29.8
Self-mechanical and hired traditional	11	2.8
Total	**382**	**100.0**

3.3. Soil Quality, Land Fertility, and Irrigation Changes

Table 2 illustrates the changes in soil quality, land fertility, and irrigation practices over the past decade. Soil quality includes attributes such as texture, structure, and organic content. Land fertility refers to the soil's ability to provide essential nutrients and water for plant growth. Irrigation is the deliberate application of water for agricultural purposes. Four categories—less, medium, high, and very high—denote the levels of soil quality, fertility, and irrigation. The table shows the count (C) and percentage (%) of farmers in each category for both past and present conditions.

3.3.1. Soil Quality

The data indicates a significant decline in soil quality over the past decade. Ten years ago, none of the farmers reported having land with less quality, and only 2.8% (11 farmers) had medium-quality land. The majority of farmers, 97.2%, had land classified as high (70.7%) or very high quality (26.5%). In contrast, the present data shows a marked shift, with 1.1% (4 farmers) now reporting less quality land and a substantial 74.6% (285 farmers) having medium-quality land. The percentage of farmers with high-quality land has dropped to 24.3%, and none report having very high-quality land anymore. This significant decrease in soil quality can be attributed to extensive use of synthetic chemicals, low input of natural manure, and a departure from traditional soil management practices.

3.3.2. Land Fertility

Land fertility has seen a notable improvement over the past decade. Previously, 6.1% of farmers had land with less fertility, and 61.3% had medium fertility. The percentage of farmers with high fertility was 27.6%, while those with very high fertility were 5.0%. Currently, the data shows no farmers with less fertile land, and only 9.9% (38 farmers) report medium fertility. A significant 73.5% (280 farmers) have high fertility land, and 16.6% (64 farmers) report very high fertility. This increase in land fertility can be linked to the increased use of synthetic fertilizers and other nutrient inputs, which have boosted soil nutrient availability but may also raise concerns about long-term sustainability and environmental impact.

3.3.3. Irrigation

Irrigation practices have also improved considerably over the past decade. Ten years ago, 11.6% of farmers used less irrigation, and 64.6% used medium levels of irrigation. High irrigation was practiced by 18.2% of farmers, and 5.5% employed very high levels of irrigation. Presently, there are no farmers reporting less irrigation, and only 6.1% (23 farmers) use medium levels. The majority, 64.6% (247 farmers), use high levels of irrigation, and a substantial 29.3% (112 farmers) now employ very high levels of irrigation. This improvement in irrigation practices is likely due to the development of new irrigation infrastructure and projects, including canals, which have enhanced water availability for agricultural purposes.

The comparison of data over the past decade reveals significant changes in farmers' land utilization practices. While land fertility and irrigation practices have improved, indicating better nutrient management and water availability, the overall quality of soil has deteriorated. This decline in soil quality can be attributed to the extensive use of syn-

Table 2. Quality, fertility, and irrigation before 10 years and at present.

Quality before and after 10 Years	Less		Medium		High		Very High	
	C	%	C	%	C	%	C	%
Land quality: 10 years before	0	0.0%	11	2.8%	270	70.7%	101	26.5%
Land quality: present	4	1.1%	285	74.6%	93	24.3%	0	0.0%
Land fertility: 10 years before	23	6.1%	234	61.3%	106	27.6%	19	5.0%
Land fertility: present	0	0.0%	38	9.9%	280	73.5%	64	16.6%
Irrigation: 10 years-before	44	11.6%	247	64.6%	70	18.2%	21	5.5%
Irrigation: present	0	0.0%	23	6.1%	247	64.6%	112	29.3%

thetic chemicals and reduced application of natural manure and traditional soil enrichment methods. The shift in crop choices, such as the increase in cotton cultivation, which is more commercialized and offers higher economic incentives compared to paddy, has also influenced these changes. The increase in chemical usage has led to higher productivity in the short term but has raised concerns about long-term soil health and environmental sustainability. These findings emphasize the need for adopting more balanced and sustainable agricultural practices that integrate the benefits of both synthetic inputs and traditional methods. Encouraging the use of natural manure, organic farming practices, and sustainable irrigation techniques can help improve soil quality while maintaining high levels of fertility and productivity. The study emphasizes the importance of flexible and sustainable land utilization practices to address the challenges and opportunities arising from changing agricultural landscapes. Continued efforts are needed to educate farmers on sustainable practices and to develop policies that support long-term soil health and environmental protection.

3.4. Comparison of Chemical Fertilizers for Paddy and Cotton 10 Years Ago and Present

The data **Tables 3** and **4** provided presents a comparison of herbicide application in paddy and cotton fields over the past ten years, revealing substantial shifts in usage patterns. For paddy cultivation, ten years ago, 98.3% of farmers did not use any herbicides, indicating a largely herbicide-free approach. In contrast, the present data shows a dramatic shift, with only 23.2% of farmers refraining from herbicide use, while 70.7% of farmers now apply 1 liter per acre. This increase reflects a growing reliance on chemical weed control methods, likely driven by the need for more effective and efficient weed management in paddy fields. In cotton cultivation, the change is even more pronounced. A decade ago, 97.2% of farmers did not use herbicides, maintaining a minimal chemical intervention approach. Currently, only 11% of farmers avoid herbicides, with a significant 43.1% applying 2 liters per acre. Additionally, other farmers use varying amounts, indicating a broad adoption of herbicides in cotton farming. This shift highlights the intensification of cotton farming practices and the need for robust weed control measures to maintain high productivity.

Table 3. Herbicides comparison on paddy – 10 years before and at present in litres.

Before 10 Years			At Present		
Liters	Count	%	Liters	Count	%
0	376	98.3%	0.00	88	23.2%
2	4	1.1%	1	270	70.7%
3	2	0.6%	2	11	2.8%
			3	13	3.3%
	N382	**100%**		**N382**	**100%**

Table 4. Herbicides comparison on cotton – 10 years before and at present in litres.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	371	97.2%	0	42	11%
2	6	1.7%	0.35	2	0.6%
3	5	1.2%	1	15	3.9%
			1.5	97	25.4%
			2	164	43.1%
			2.5	23	6.1%
			3	11	2.8%
			3.5	28	7.2%
	N382	**100%**		**N382**	**100%**

Data analysis of reveals a significant increase in herbicide use for both paddy and cotton cultivation over the past decade. Cotton farming, however, demonstrates a more pronounced rise, likely attributed to its more intensive agricultural practices and greater economic incentives. This heightened herbicide dependence in both crops raises concerns about long-term impacts on soil and the environment. To address these concerns, sustainable agricultural practices must be integrated to ensure both productivity and environmental sustainability. These findings emphasize the need for informed agricultural policies and practices that balance productivity with environmental considerations.

Analysis of **Tables 5** and **6** data reveals significant variations in insecticide application patterns between paddy and cotton fields over the past ten years. For paddy cultivation, ten years ago, 44.8% of farmers did not use any insecticides, indicating a relatively low reliance on chemical pest control. However, the current data shows a dramatic shift, with only 0.6% of farmers refraining from using insecticides. Today, the most common application rate is 1 Liter per acre, used by 42.5% of farmers, followed by 0.75 liters, applied by 33.7% of farmers, and 0.50 liters, used by 21.5% of farmers. This significant increase in insecticide usage reflects the growing need for effective pest management strategies to maintain crop health and yield. In cotton cultivation, the change in insecticide use is even more pronounced. A decade ago, the predominant application rate was 1 Liter per acre, utilized by 64.1% of farmers. Currently, this rate has shifted to 2 liters per acre, with 56.9% of farmers adopting this amount. Additionally, 20.4% of farmers now use 1.5 liters per acre, and various other rates are also in practice, indicating a broader adoption of insecticide application. This increase highlights the intensification of pest control measures in cotton farming to combat persistent pest issues and ensure high productivity.

Table 5. Insecticide comparison on paddy – 10 years before and at present in litres.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	171	44.8%	0	2	0.6%
0.25	68	17.7%	0.25	2	0.6%
0.50	108	28.2%	0.50	82	21.5%
0.75	12	3.3%	0.75	129	33.7%
1	7	1.7%	1	163	42.5%
2	12	3.3%	1.5	2	0.6%
3	4	1.1	2	2	0.6%
	N382	**100%**		**N382**	**100%**

Table 6. Insecticide comparison on cotton – 10 years before and at present in litres.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	4	1.1%	0	2	0.6%
05	6	1.7%	0.75	2	0.6%
0.75	30	7.7%	1	8	2.2%
1	243	64.1%	1.2	2	0.6%
1.5	48	12.2%	1.5	79	20.4%
2	32	8.3%	2	217	56.9%
2.5	19	5%	2.5	42	11%
			3	30	7.7%
	N382	**100%**		**N382**	**100%**

Comparing the two crops, the data underscores that both paddy and cotton cultivation have experienced a substantial rise in insecticide usage over the past decade, with a more significant increase observed in cotton farming. The shift towards higher insecticide application rates reflects farmers' efforts to manage pest problems more effectively, but it also raises concerns about potential impacts on soil health, environmental sustainability, and the long-term viability of agricultural practices. These findings emphasize the importance of adopting balanced pest management approaches that integrate sustainable methods to mitigate negative effects while ensuring agricultural productivity. Understanding these changes can help inform future agricultural policies and practices aimed at achieving both productivity and sustainability goals.

The **Tables 7** and **8** data provided compares the application of fungicides on paddy and cotton fields over the past decade, highlighting significant changes in usage patterns. For paddy cultivation, ten years ago, 48.6% of farmers did not use any fungicides, and 34.8% used only 0.25 liters per acre. This indicates a relatively low reliance on chemical fungicides at that time. However, the current data shows a dramatic shift, with only 1.7% of farmers refraining from fungicide use. Presently, the most common application rates are 0.5 liters per acre, used by 43.6% of farmers, and 1 Liter per acre, used by 42% of farmers. This substantial increase in fungicide usage reflects the growing need for effective fungal disease management to protect crop health and yield.

Table 7. Fungicide comparison on paddy – 10 years before and at present in litres.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	186	48.6%	0	6	1.7%
0.25	133	34.8%	0.5	167	43.6%
0.50	44	11.6%	1	161	42%
1	13	3.3%	1.25	4	1.1%
2	6	1.7%	1.5	38	9.9%
			2	6	1.7%
	N382	**100%**		**N382**	**100%**

In cotton cultivation, Illustrate the change in fungicide use is even more pronounced. A decade ago, the predominant application rate was 0.50 liters per acre, utilized by 64.6% of farmers. Smaller percentages of farmers used other amounts, with only 2.2% not using any fungicides. Currently, the most common application rate has shifted to 1 Liter per acre, with 66.9% of farmers adopting this amount. Additionally, 16% of farmers now use 1.5 liters per acre, and various other rates are also in practice, indicating a broader adoption of more intensive fungicide application practices. This trend highlights the intensification of fungal disease control measures in cotton farming to maintain high productivity. Comparing the two crops, the data reveals that both paddy and cotton cultivation have experienced a significant rise in fungicide usage over the past decade. For paddy, the percentage of farmers not using fungicides has dropped from 48.6% to 1.7%, with notable increases in the application of 0.5 and 1 Liter per acre. For cotton, the shift is from a majority using 0.50 liters per acre to a predominant use of 1 litter per acre, reflecting a substantial rise in chemical interventions for fungal disease control.

Table 8. Fungicide comparison on cotton – 10 years before and at present in litres.

Before 10 Years			At Present		
liters	**Count**	**%**	**liters**	**Count**	**%**
0	9	2.2%	0	2	0.6%
0.25	9	2.2%	0.50	13	3.3%
0.50	246	64.6%	0.75	13	3.3%
0.75	38	9.9%	1	255	66.9%
1	40	10.5%	1.5	61	16%
1.5	38	9.9%	2	15	3.9%
2	2	0.6%	2.5	23	6.1%
	N382	**100%**		**N382**	**100%**

The increased use of fungicides for both paddy and cotton cultivation underscores farmers' efforts to manage fungal diseases more effectively and ensure high crop yields. However, this trend also raises concerns about the potential impacts on soil health, environmental sustainability, and the long-term viability of agricultural practices. These findings emphasize the importance of adopting balanced fungicide management approaches that integrate sustainable methods to mitigate negative effects while ensuring agricultural productivity. Understanding these changes can help inform future agricultural policies and practices aimed at achieving both productivity and sustainability goals.

The **Tables 9** and **10** data provided compares the application of Diammonium Phosphate (DAP) fertilizer on paddy and cotton fields over the past decade, highlighting significant changes in usage patterns. For paddy cultivation, ten years ago, the most common application rate was 75 kg per acre, used by 53.6% of farmers, with 41.4% applying 100 kg per acre. Presently, this trend has shifted, with 63.5% of farmers now using 100 kg per acre and 29.8% applying 125 kg per acre. This increase in DAP usage reflects efforts to enhance soil fertility and crop yields by incorporating more fertilizer into paddy farming practices. In cotton cultivation, the change in DAP application is even more pronounced. A decade ago, the predominant application rate was 100 kg per acre, utilized by 71.3% of farmers, followed by 125 kg per acre, used by 21.5%. Today, the most common rate has shifted to 150 kg per acre, with 73.5% of farmers adopting this amount, and 16% still using 125 kg per acre. Additionally, various other higher rates are being used, indicating a trend towards more intensive fertilization practices to support higher crop yields in cotton farming.

Comparing DAP application in paddy and cotton cultivation, the data reveals key differences. For paddy, the most common application rate has increased from 75 kg per acre to 100 kg per acre, with many farmers now using even higher amounts. In cotton, the predominant rate has risen substantially from 100 kg per acre to 150 kg per acre, reflecting efforts to enhance productivity. While increased DAP use aims to boost soil fertility and yields, it raises concerns about potential negative impacts on soil health and environmental sustainability. Balanced fertilization practices, integrating sustainable methods, are crucial to mitigate these risks while ensuring long-term agricultural viability. 1 These findings underscore the need for informed agricultural policies and practices that prioritize both productivity and sustainability.

Table 9. DAP comparison on paddy – 10 years before and at present in kilo grams.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	2	0.6%	0	2	0.6%
50	13	3.3%	75	2	0.6%
70	2	0.6%	100	243	63.5%
75	205	53.6%	120	2	0.6%
100	158	41.4%	125		
114	29.8%				
125	2	0.6%	150	19	5%
	N382	**100%**		**N382**	**100%**

Table 10. DAP comparison on cotton – 10 years before and at present in kilo grams.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	2	0.6%	0	2	0.6%
50	4	1.1%	100	19	5%
75	11	2.8%	125	61	16%
100	272	71.3%	150	281	73.5%
125	82	21.5%	175	13	3.3%
150	11	2.8%	200	6	1.7%
	N382	**100%**		**N382**	**100%**

The data **Tables 11** and **12** provided compares the application of urea fertilizer on paddy and cotton fields over the past decade, revealing significant changes in usage patterns. For paddy cultivation, ten years ago, the most common application rate was 100 kg per acre, used by 81.2% of farmers, with smaller percentages applying 75 kg or 125 kg. Currently, the most common rate has shifted to 125 kg per acre, adopted by 45.9% of farmers, followed by 100 kg per acre at 27.6%, and 150 kg per acre at 22.1%. This reflects an overall increase in the amount of urea being used in paddy farming, likely in efforts to enhance soil fertility and crop yields through more intensive fertilization practices. In cotton cultivation, the change in urea application is even more pronounced. A decade ago, the predominant application rate was 125 kg per acre, utilized by 49.2% of farmers, with 34.8% using 100 kg per acre. Presently, the most common rate has dramatically increased to 200 kg per acre, with 68% of farmers adopting this amount. Additionally, 25.4% of farmers now use 150 kg per acre, indicating a trend towards more intensive nutrient management to support higher crop yields. The shift to higher application rates reflects a substantial rise in fertilizer usage, highlighting the intensification of cotton farming practices.

Comparing the two crops, the data underscores key differences in urea application. For paddy, the most common application rate has increased from 100 kg per acre to 125 kg per acre, with significant numbers of farmers now using even higher amounts up to 175 kg per acre. In cotton farming, the predominant rate has risen from 125 kg per acre to 200 kg per acre, demonstrating a considerable increase in fertilizer application to enhance productivity. This trend reflects farmers' efforts to boost soil fertility and crop yields through increased fertilization, but also raises concerns about potential impacts on soil health, environmental sustainability, and long-term agricultural viability. These findings emphasize the importance of adopting balanced fertilization practices that integrate sustainable methods to mitigate negative effects while ensuring agricultural productivity. Understanding these changes can help inform future agricultural policies and practices aimed at achieving both productivity and sustainability goals.

Table 11. Urea comparison on paddy – 10 years before and at present in kilo grams.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	2	0.6%	0	2	0.6%
50	2	0.6%	100	105	27.6%
75	45	11.6%	120	2	0.6%
100	310	81.2%	125	175	45.9%
125	23	6.1%	150	85	22.1%
			175	13	3.3%
	N382	**100%**		**N382**	**100%**

Table 12. Urea comparison on cotton – 10 years before and at present in kilo grams.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	2	0.6%	0	4	1.1%
50	2	0.6%	100	2	0.6%
75	2	0.6%	125	15	3.9%
100	133	34.8%	150	97	25.4%
125	188	49.2%	175	4	1.1%
150	55	14.4%	200	260	68%
	N382	**100%**		**N382**	**100%**

The data **Tables 13** and **14** provided compares the application of potassium fertilizer on paddy and cotton fields over the past decade, highlighting significant changes in usage patterns. For paddy cultivation, ten years ago, the majority of farmers (75.1%) did not use any potassium fertilizer, with only a small percentage applying 25 kg per acre. In contrast, the current data shows a dramatic shift, with only 28.2% of farmers now refraining from potassium use, and the most common application rate being 50 kg per acre, used by 63.5% of farmers. This indicates a considerable increase in potassium usage, reflecting efforts to improve soil fertility and crop yields through enhanced nutrient management. In cotton cultivation, the change is even more pronounced. A decade ago, the vast majority of farmers (96.7%) did not use any potassium fertilizer, and only 3.3% used 25 kg per acre. Currently, this figure has dropped to 27.1%, with 63% of farmers now applying 50 kg per acre and 7.7% using 75 kg per acre. This demonstrates a significant rise in potassium usage, highlighting a shift towards more intensive fertilization practices to support higher crop yields in cotton farming.

Comparing the two crops, the data underscores key differences in potassium application. For paddy, there has been a substantial increase in potassium usage, moving from minimal application to a common rate of 50 kg per acre. In cotton farming, the shift is even more dramatic, with the majority of farmers now applying 50 kg per acre, reflecting a significant change from the previous minimal use. This trend highlights the efforts by farmers to boost soil fertility and crop productivity through increased potassium application. However, the intensified use of potassium raises concerns about potential impacts on soil health, environmental sustainability, and long-term agricultural viability. These findings emphasize the importance of adopting balanced fertilization practices that integrate sustainable methods to mitigate negative effects while ensuring agricultural productivity. Understanding these changes can help inform future agricultural policies and practices aimed at achieving both productivity and sustainability goals.

Table 13. Potassium comparison on paddy – 10 years before and at present in kilo grams.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	287	75.1%	0	108	28.2%
15	2	0.6%	25	6	1.7%
25	91	23.8%	30	2	0.6%
30	2	0.6%	40	23	6.1%
			50	243	63.5%
	N382	**100%**		**N382**	**100%**

Table 14. Potassium comparison on cotton – 10 years before and at present in kilo grams.

Before 10 Years			At Present		
Liters	**Count**	**%**	**Liters**	**Count**	**%**
0	369	96.7%	0	104	27.1%
25	13	3.3%	50	240	63.%
			60	6	1.7%
			70	2	0.6%
			75	30	7.7%
	N382	**100%**		**N382**	**100%**

3.5. Comparison of Investment, Yield, and Income of Paddy and Cotton Crops

Regarding **Table 15** paddy cultivation, most farmers (59.7%) allocated between ₹18,001 and ₹21,000 per acre. Additionally, 29.8% of farmers invested less than ₹18,000, while 10.5% invested more than ₹21,001. The most common yield range for paddy was between 20 and 21 quintals per acre, accounting for 41.4% of the cases. This was followed by yields of less than 19 quintals (36.5%) and more than 21 quintals (22.1%). The income range most frequently found for paddy was between ₹14,001 and ₹17,000 per acre, accounting for 47.5% of the cases. The next most common income range was less than ₹14,000 (30.9%), while 21.5% of the cases had an income range over ₹17,000.

An analysis of paddy cultivation revealed a positive correlation between investment and both yield and income. This suggests that increased investment in inputs generally leads to higher yields and subsequently, greater income. However, the relationship is not always linear. For instance, some farmers with high input costs experienced lower yields due to factors such as adverse weather conditions or pest outbreaks, while others with lower investments achieved higher yields due to favourable conditions or effective management practices. These findings highlight the influence of other factors beyond investment, including climatic conditions, soil quality, pest management, and irrigation, on the final outcomes.

In **Table 16** cotton cultivation, most farmers (42.5%) allocated less than ₹22,000 per acre. Following closely, 38.1% of farmers spent between ₹22,001 and ₹24,000, while 19.3% spent more than ₹24,001. The most frequent yield range for cotton was between 11 and 12 quintals per acre, accounting for 48.1% of the cases. This was followed by yields of less

Table 15. Comparison investment, yield, and income with paddy.

Investment paddy in thousands	Below ₹18,000/-	C	114
		%	29.8%
	Between ₹18,001 to 21,000	C	228
		%	59.7%
	More than ₹21,001	C	40
		%	10.5%
	Total	N C	382
		N %	100.0%
Crop yield on paddy per acre (quintals)	Below 19 quintals	C	139
		%	36.5%
	Between 20 to 21 quintals	C	158
		%	41.4%
	More than 21 quintals	C	85
		%	22.1%
	Total	N C	382
		N %	100.0%
Income on paddy per acre (in thousands)	Below ₹14,000/-	C	118
		%	30.9%
	Between ₹14,001 to 17,000	C	182
		%	47.5%
	More than ₹17,000/-	C	82
		%	21.5%
	Total	N C	382
		N %	100.0%

Note: C (Count), % (Percentage), N C (Number of Counts), N % (Number of Percentages).

than 10 quintals (39.8%) and more than 12 quintals (12.2%). The predominant revenue range for cotton cultivation was between ₹32,001 and ₹36,000 per acre, accounting for 54.1% of the cases. Income ranges below ₹32,000 accounted for 27.6% of the total, while income ranges above ₹36,001 accounted for 18.2%.

A positive correlation was observed between investment in cotton and both yield and income. This suggests that increased investment in inputs generally leads to higher yields and subsequently, greater income. However, the relationship is not always linear. For instance, some farmers with high input costs experienced lower yields due to factors such as adverse weather conditions or pest outbreaks, while others with lower investments achieved higher yields due to favourable conditions or effective management practices. This highlights the influence of other factors beyond investment, including climatic conditions, soil fertility, pest management, and irrigation, on the final outcomes.

3.6. Comparison of Paddy and Cotton

The data tables provide an overview of the output, revenue, and investment of farmers who cultivate cotton and paddy crops. Numerous patterns and connections among the variables are revealed, alongside some irregularities and outliers. The research indicates that paddy farming is associated with higher income and better investment returns, though there are instances where investment does not generate the expected income or return. Factors such as climatic conditions, irrigation practices, pest control measures, and soil composition may contribute to these variations.

For paddy cultivation, the predominant output range is 20 to 21 quintals per acre. The prevailing income range is between ₹14,001 and ₹17,000 per acre, while the prevalent investment range is between ₹18,001 and ₹21,000 per acre. A positive correlation exists between investment, yield, and income in paddy farming, although there are exceptions. Some farmers may invest more than ₹21,001 but yield less than 19 quintals, or invest less than ₹18,000 and earn more than ₹17,000. Additional factors such as climatic conditions,

Table 16. Comparison of investment, yield, and income with cotton.

Cotton investment (in thousands)	Below ₹22,000/-	C	162
		%	42.5%
	Between ₹22,001 to 24,000	C	146
		%	38.1%
	More than ₹24,001/-	C	74
		%	19.3%
	Total	N C	382
		N %	100.0%
Cotton crop yield in quintals per acre	Below 10 quintals	C	152
		%	39.8%
	Between 11 to 12 quintals	C	184
		%	48.1%
	More than 12 quintals	C	46
		%	12.2%
	Total	N C	382
		N %	100.0%
Income on cotton per acre (in thousands)	Below ₹32,000/-	C	105
		%	27.6%
	Between ₹32,001 to 36,000	C	207
		%	54.1%
	More than ₹36,001	C	70
		%	18.2%
	Total	C N	382
		N %	100.0%

Note: C (Count), % (Percentage), N C (Number of Counts), N % (Number of Percentages).

soil quality, pest management, and irrigation practices may explain these discrepancies.

In cotton cultivation, the predominant yield range is 11 to 12 quintals per acre. The prevailing income range is between ₹32,001 and ₹36,000 per acre, with the most common investment range being below ₹22,000 per acre. A positive correlation exists between investment and both yield and income for cotton, though exceptions do occur. Factors such as meteorological conditions, irrigation practices, pest control measures, and soil composition may influence these outcomes.

Comparative Analysis of Cotton and Paddy Cultivation

This analysis compares cotton and paddy cultivation, revealing key differences in profitability and risk. While cotton cultivation generally yields higher incomes, it also demands significantly higher financial investments. Furthermore, cotton farming exhibits greater variability in both production and revenue, indicating a higher level of risk and uncertainty compared to paddy cultivation. Interestingly, the data suggests a higher proportion of paddy farmers investing more than ₹21,001 per acre, potentially indicating increased demand and profitability for paddy. The data tables provide valuable insights into the investment, yield, and income dynamics of both crops in Telangana. Despite some variations, the data establish several favourable correlations among the variables. This information can empower farmers to make more informed decisions regarding crop selection and management strategies by facilitating a comparative assessment of cotton and paddy cultivation.

3.7. Knowledge and Experience in Chemical Fertilizers and Soil Health

The data reveal intriguing patterns in the relationship between farmers' agricultural experience, their knowledge of chemical fertilizers, and the impact on soil health. Among farmers with less than 10 years of experience, knowledge levels vary: 4 have "Very low" knowledge, 8 have "Low" knowledge, 6 have "Neutral" knowledge, and 5 have "High" knowledge. Similarly, farmers with 11 to 20 years of experience exhibit comparable patterns. The "High" knowledge category has a greater number of farmers across all experience levels, while the "Very low" expertise group is the smallest.

The **Table 17** analysis reveals a potential relationship between farming experience and knowledge levels. Farmers with 31 to 40 years of experience showed a distribution of 13 with "Low" knowledge, 11 with "Neutral" knowledge, and 2 with "High" knowledge. Among farmers with more than 40 years of experience, 1 had "Low" knowledge, 3 had "Neutral" knowledge, and 3 had "High" knowledge. While these observations suggest a possible link between experience and knowledge, the small sample sizes, particularly in the older group, and potential influences of other factors necessitate further statistical analysis to establish conclusive findings.

3.8. Chi-Square Test for Farmers' Experience and Knowledge of Chemical Fertilizers

A chi-square test revealed no significant association between farmers' experience and their knowledge of chemical fertilizers (χ^2 (12) = 17.174, p = 0.143). This suggests that experience level does not statistically influence farmers' knowledge.

Statistical information and degrees of freedom: χ^2 (12).

p-value: p = 0.143.

Interpretation: There is no significant association between farmers' experience and their knowledge of chemical fertilizers, indicating that experience level does not affect knowledge statistically.

4. Discussion

Soil fertility refers to the ability of soil to provide essential nutrients required for plant growth, thereby achieving optimal agricultural productivity [42]. It is crucial for agricultural output and food security, directly affecting the quantity and quality of food produced [43]. However, soil fertility is influenced by various factors such as soil pH, salinity, organic matter, texture, structure, and microbiology [44]. It is a dynamic characteristic that fluctuates over time due to both natural and anthropogenic activities [45].

Chemical fertilizers and other agricultural inputs, including herbicides, insecticides, fungicides, and pesticides, significantly impact soil fertility [46]. These substances provide essential nutrients to plants and are often administered to soil, leaves, or water systems. Chemical fertilizers enhance crop production by increasing the availability of macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur) and micronutrients (boron, chlorine, copper, iron, manganese, molybdenum, nickel, and zinc) for plant absorption [47]. Bio-fertilizers improve the physical properties of soil, such as water retention, aeration, and aggregation, by increasing soil organic matter and microbial activity [48].

However, the excessive or incorrect use of SCs can have negative effects on plant growth and soil health [49]. These fertilizers can pollute soil, cause erosion and degradation, and lead to soil acidification, salinization, nutrient imbalance, leaching, runoff, volatilization, and immobilization of nutrients [50]. They can also adversely affect the biological properties of soil, resulting in decreased biomass, biodiversity, respiration, enzyme activity, nitrogen fixation, and nutrient cycling [40]. Additionally, chemical fertilizers can cause nutritional toxicity, deficiencies, antagonisms, diseases, pests, and stress in plants [51], negatively impacting plant health.

An in-depth examination of SC and soil fertility is imperative for advancing agriculture and ensuring food security, considering that soil is a limited and irreplaceable resource vital for sustaining humanity [52]. Soil plays a crucial role in determining the potential and limitations of crop production [53] and has a significant impact on climate change mitigation and adaptation [54]. Moreover, soil is essential for providing ecosystem services such as water management, purification, nutrient cycling, biodiversity conservation, and human health protection [55]. Preserving and enhancing soil fertility can improve and expand these roles for both current and future generations [56].

This study focuses on the challenges faced by farmers in Telangana regarding agricultural activities. It emphasizes the importance of adopting sustainable methods, raising awareness about the proper use of chemical fertilizers, and receiving support from policymakers and stakeholders to promote socio-economic and agricultural progress [56]. Future research should explore the long-term impacts of different fertilization practices on soil health, crop yield, and environmental sustainability [57], while also considering the socio-economic factors influencing farmers' decisions. Implementing comprehensive soil management strategies and

Table 17. Farmers knowledge on chemical usage.

Experience in Years	Knowledge of Chemical Fertilizers and Their Impacts on Soil Health				Total
	Very Low	Low	Neutral	High	
Below 10 years	4	8	6	5	**23**
11 to 20 years	10	44	41	27	**122**
21 to 30 years	10	90	69	35	**204**
31 to 40 years	0	13	11	2	**26**
Above 40 years	0	1	3	3	**7**
Total	**24**	**156**	**130**	**72**	**382**

educating farmers on sustainable practices are crucial steps toward achieving agricultural sustainability and food security.

Farmers, institutions, governments, and stakeholders should collaborate to enhance agricultural productivity through sustainable practices [58]. Farmers need education on the optimal use of chemical fertilizers to prevent soil degradation, while institutions should facilitate research that investigates the long-term impacts of various fertilization practices on soil health and crop yield. Governments play a crucial role in forming policies that support sustainable agriculture and providing necessary resources and incentives for farmers to adopt eco-friendly practices. Stakeholders, including private organizations and NGOs, should work with agricultural communities to promote awareness and provide technical and financial support. Collaborative efforts in preserving soil fertility can lead to enhanced food security, improved crop quality, and sustainable agricultural development, benefiting current and future generations [59]. By addressing factors such as soil pH, salinity, and organic matter content, and through the balanced use of chemical and bio-fertilizers, the agricultural sector can achieve better resilience to climate change and contribute significantly to environmental sustainability.

5. Conclusions

This study examines the socioeconomic and agricultural aspects of farmers in Telangana, focusing on crop choices, factors affecting production, methods of land preparation, population characteristics, and land ownership patterns. It evaluates the profitability and revenue of farmers, their investment, yield, income, and utilization of inputs for cotton and paddy crops. The study also assesses farmers' familiarity with and understanding of chemical fertilizers, as well as their impact on agricultural output and satisfaction.

Despite owning modest parcels of land and being in their middle years, middle-class farmers regard their profitability as substantial; nonetheless, they express little satisfaction with their land holdings. Due to their lack of access to modern technologies, they depend on rented land and traditional farming practices. Farmers have transitioned from cultivating paddy to cotton due to a mix of factors including crop preferences, land conversion, and market prices. Crop selection, technological advancements, and climate change have resulted in substantial alterations to land quality and irrigation.

Most farmers experience moderate levels of investment, yield, and revenue in paddy cultivation, whereas they have low levels of investment, yield, and income in cotton cultivation. However, certain farmers diverge from this pattern due to factors such as climatic conditions, soil fertility, pest management, and water supply. While fungicide usage has somewhat increased for both crops in the past decade, the study reveals a significant surge in the use of herbicides, insecticides, DAP, and urea. Conversely, the utilization of potassium has significantly increased for cotton crops while somewhat decreasing for paddy crops.

The study also shows that there is no significant correlation between farmers' experience or knowledge of chemical fertilizers and their impact on productivity. It highlights the challenges faced by farmers in Telangana in their agricultural pursuits, particularly regarding the utilization of inputs and the impacts of chemical fertilizers. The study proposes the implementation of sustainable practices, raising awareness among policymakers about the benefits of fertilizers, and promoting socioeconomic development.

Author Contributions

Conceptualization, S.K. and R.S.B.; methodology, S.K. and R.S.B.; software, S.K. and R.S.B.; validation, S.K., R.S.B., S.T. and T.D.; formal analysis, S.K. and R.S.B.; investigation, S.K. and R.S.B.; resources, S.K. and R.S.B.; data curation, S.K., R.S.B., S.T. and T.D.; writing—original draft preparation, S.K. and R.S.B.; writing—review and editing, S.K. and R.S.B.; visualization, S.K. and R.S.B.; supervision, S.K., R.S.B., S.T. and T.D.; project administration, S.K. and R.S.B.; funding acquisition, S.K. and R.S.B. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data supporting the reported results can be found here, in the publicly archived dataset used for this study. Where privacy or ethical restrictions apply, data will be available upon reasonable request from the corresponding author.

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Conflicts of Interest

The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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