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Unveiling the Detrimental Effects of Concentrated Soil Management: Experience of Monoculture Cultivation in Telangana, India

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ABSTRACT

The relentless pursuit of increased agricultural productivity has driven the widespread adoption of synthetic chemicals in soil management. Although these chemicals undeniably enhance crop yields, their long-term environmental impacts raise significant concerns. This study examines the implications of synthetic chemical use in agriculture, emphasizing the urgent need for sustainable practices that balance productivity with environmental preservation and move beyond monoculture systems. By evaluating actual farming practices and analyzing non-regulatory policies, we highlight the challenges that our planet faces. Our investigation revealed several compelling findings: 98.2% of farmers now rely entirely on synthetic chemicals, and 87.6% have abandoned traditional tools in favor of mechanical alternatives. Furthermore, a staggering 84.8% of farmers adopted monocropping practices, particularly cotton cultivation, over the past eight years. Senior farmers, drawing on their extensive experience, expressed reservations about the effectiveness of livestock manure under current conditions. A significant 73.56% of respondents believed that livestock contributions may not produce the expected outcomes. As we explored this issue further, we recognized the urgent need to address additional contributing factors. Protecting human health and the environment requires a fundamental shift in current assumptions and practices. Therefore, we propose strategies that balance agricultural productivity and ecological sustainability, fostering a more harmonious coexistence between humans and nature.

Keywords:
Environmental sustainability, monoculture, livestock integration, soil health, synthetic chemicals.

1. Introduction

The Green Revolution, driven by an overwhelming desire to increase agricultural productivity, relied heavily on the use of synthetic fertilizers and pesticides (Patel, 2013). Although this approach was initially successful in boosting crop yields, it has now reached a turning point (Horlings and Marsden, 2011). The relentless pursuit of maximizing agricultural output has led to the degradation of healthy soil, a critical and often overlooked natural resource that underpins food production, biodiversity, and environmental stability (Srivastava et al., 2016).

Soil, being finite and slow to regenerate, requires centuries to recover once depleted. Human activities, including intensive farming, deforestation, and pollution, have disrupted soil ecosystems, resulting in erosion, nutrient loss, and reduced organic matter content (Sanchez et al., 2015). While these activities fulfill immediate human needs, they jeopardize long-term agricultural sustainability and ecological balance. As the dominant species on Earth, humans rely on soil for sustenance, shelter, and economic prosperity (Van De Vliert, 2013). To mitigate these consequences, adopting regenerative practices such as crop diversification, reduced tillage, and organic farming is essential for conserving soil health and securing a sustainable future.

Soil is a finite and essential resource that supports life, and it requires centuries to regenerate once depleted, underscoring the need for effective conservation. This non-renewable resource plays a critical role in food production (Lal et al., 2017). Soil fertility depends on a complex ecosystem composed of microorganisms, organic matter, and minerals (Huang et al., 2005). The intensive use of synthetic chemicals disrupts this delicate balance, leading to soil degradation, erosion, and ultimately, reduced productivity (Tripathi et al., 2020).

The negative consequences of monoculture-based soil cultivation extend beyond farms, significantly affecting environmental and ecological stability. One major concern is contaminated runoff, which carries excess agricultural inputs, such as fertilizers and pesticides, into nearby water bodies, causing pollution that harms aquatic life and poses risks to human health (Sankhla et al., 2016). Furthermore, in monoculture systems, the continuous use of soil amendments and chemical treatments can disrupt the natural soil microbiome, thereby reducing overall soil fertility and resilience. This intensive management approach often requires higher application rates of agrochemicals, exacerbating soil degradation and creating a cycle of dependence on external inputs (Riyaz et al., 2022).

In addition, the selection pressure generated by continuous chemical exposure accelerates the emergence of resistant pests and pathogens, ultimately driving farmers toward increasingly unsustainable cultivation practices (Mandal et al., 2020). By distinguishing between agricultural input management focused on chemical applications and soil cultivation management associated with monoculture cropping strategies, this study highlights the systemic impacts of intensive soil management on long-term soil health and sustainability.

Synthetic chemicals, such as fertilizers and pesticides, have revolutionized agriculture (Sharma & Singhvi, 2017). They enhance crop yields, enabling us to meet the demands of a growing global population (Horrigan et al., 2002a). However, their widespread use has raised serious concerns regarding soil health, water contamination and biodiversity loss (Lal, 2015). Although monoculture practices are often promoted for their high productivity, their long-term effects may undermine the foundation of sustainable agriculture (Smith et al., 2016).

The depletion of soil health, loss of biodiversity, and increasing dependence on external inputs highlight the risks associated with intensive soil management practices. To ensure a resilient agricultural system, it is crucial to strike a balance between high-yield cultivation and environmental preservation (Gomiero, 2016). Responsible soil management extends beyond maximizing productivity; it requires strategies that enhance soil fertility, support ecological stability and mitigate negative environmental impacts (Cataldo et al., 2021). Therefore, sustainable soil cultivation practices are essential, as long-term agricultural success depends on maintaining soil integrity while meeting production demands.

Although policies exist to regulate chemical use, their enforcement remains inconsistent (Gunningham & Sinclair, 2019). Regulations often remain confined to policy documents or news headlines, while practical implementation continues to lag behind, leaving substantial room for improvement in the field. Authorities must prioritize environmental protection and ensure that policies are translated into effective actions.

This study examined the motivations behind farmers' adoption of specific agricultural methods, with a particular focus on soil cultivation management in monoculture. Through case studies and focus group analyses, we identified gaps in policy implementation and proposed actionable strategies to improve sustainable soil management practices (Grimshaw et al., 2012; Foley et al., 2011). Recognizing the urgent need to safeguard soil health, this study highlights the importance of responsible soil management for long-term agricultural sustainability in the region. Furthermore, we analyzed the effectiveness of existing environmental regulations and policies in promoting sustainable practices, critically assessing their impacts rather than making broad generalizations.

This study employed case studies and focus group discussions to collect firsthand data on farmers' lived experiences, understanding soil health, and perspectives on environmental regulations. By systematically evaluating these insights, this study aims to bridge knowledge gaps and inform strategies for improving soil cultivation practices, ultimately contributing to more resilient agricultural systems. This study provides valuable insights into the challenges and opportunities associated with transitioning to more sustainable agricultural practices. Ultimately, our goal is to identify strategies that ensure long-term food security by fostering a more balanced relationship between agricultural production and environmental health.

This study explored the actual agricultural practices of farmers, focusing on their implementation and perspectives. Specifically, this study aimed to investigate the influence of synthetic chemicals on soil productivity, while also examining farmers' decision-making processes regarding high-input agricultural practices. In addition, the economic viability of chemical-intensive agriculture was evaluated. The widespread use of synthetic chemicals has raised significant concerns about soil health and ecosystem sustainability (Horrigan et al., 2002b). By examining farmers' practices, this study identified areas for improvement and explored potential sustainable alternatives. As stewards of the land, farmers face the challenge of maximizing crop yields while safeguarding the environment (Mlambo & Mnisi, 2019). Therefore, this study seeks to identify strategies that achieve a balance between agricultural productivity and environmental preservation in the region. Despite the existence of environmental regulations, their practical enforcement remains inconsistent. By understanding farmers' perspectives, this study proposes policy recommendations to support the more effective implementation of regulations that protect both soil health and economic prosperity (Liu et al., 2018). Overall, this study contributes to ongoing efforts to promote responsible soil management and foster a more harmonious coexistence between agriculture and nature in the future.

2. Materials and Methods

This study was conducted in the Kommaram Bheem district of Asifabad, Telangana, India. The study focused on farmers enrolled in the Rythu Bandhu Scheme, a state initiative that provides financial assistance of ₹7,500 per season during India's two main cropping seasons, Kharif and Rabi. Kharif crops, such as rice and maize, are cultivated during the monsoon season, being sown in June and harvested in October, whereas Rabi crops, including wheat and mustard, are grown during the winter season, being sown in October and harvested in April under cooler climatic conditions. This study surveyed 382 farmers representing various landholding categories and cultivation practices. Data were collected from different communities, namely the General Category, Other Backward Classes, Scheduled Castes, and Scheduled Tribes.

To comprehensively examine farmers' perspectives and experiences, a mixed-methods approach was employed that combined quantitative and qualitative research techniques. Primary data were collected using a structured questionnaire designed to capture information on farming practices, soil management strategies, challenges faced, and awareness of environmental policies. In addition, structured interviews were conducted to gain deeper insights into the farmers' experiences with monoculture cultivation, decision-making processes, and soil health-related challenges.

In-depth case studies were conducted to analyze specific instances of monoculture farming, allowing for a detailed examination of the associated challenges and management strategies. Furthermore, focus group discussions were held with representative farmer groups to explore collective perspectives, discuss gaps in policy implementation, and identify common concerns regarding soil degradation and sustainability of monoculture practices. The data collected were analyzed using IBM SPSS software. Descriptive statistics, including frequency distributions and percentages, were used to summarize key trends in farming practices, soil management, and farmers' awareness of policy frameworks. Thematic analysis was applied to the qualitative data obtained from the case studies and focus group discussions to identify recurring patterns and emerging themes related to soil degradation and the effectiveness of policies. To enhance the validity and reliability of the findings, the results from the surveys, case studies, and group discussions were cross-verified, ensuring a comprehensive understanding of soil cultivation management practices and their environmental implications.

3. Results.

Table 1 presents various social communities, including the General Category (GC), Backward Classes (BC), Scheduled Tribes (ST), and Scheduled Castes (SC). Among the 382 respondents, 26.16% belonged to the GC and SC groups, and 29.84% belonged to the BC and ST communities. Although the study area is legally classified as a Scheduled Tribal Agency Area (STAA), most farmers and farm holdings belong to the Backward Classes, followed by the Scheduled Tribes (ST).

The primary occupation in the study area is agriculture, with 87.6% of the population directly or indirectly dependent on the agricultural sector for their livelihoods. Specifically, 65.97% of individuals rely directly on agriculture, and 12.4% depend on it indirectly. Furthermore, within the farming community, 65.97% and 12.4% possess small- to medium-sized landholdings (less than 2 and 4 acres of wet and dry land, respectively).

Among these farmers, 12.4% also work as agricultural laborers on other farmers' lands, while some within the 65.97% group engage in sharecropping and leased farming arrangements, accounting for 13.9% and 4.19%, respectively. Notably, most farmers had more than 30 years of farming experience, even among those aged around 50 years. Although they previously cultivated a diverse range of crops, monoculture cultivation currently predominates, albeit with some degree of flexibility.

Table 1. Social Status, Dependence, and Landholding

Aspect	Category	(%)	N	Notes/Observations
Social Status	General Category (GC)	26.16	100	Equal representation with SC
	Backward Classes (BC)	29.84	114	Largest group in study area
	Scheduled Tribes (ST)	29.84	114	Area legally classified as STAA
	Scheduled Castes (SC)	26.16	100	Equal representation with GC
Landholding & Occupation	Direct dependence on agriculture	65.97	252	Majority directly engaged in farming
	Indirect dependence on agriculture	12.40	47	Linked through allied activities
	Other occupations	21.63	83	Non-agricultural livelihoods
	Small to medium land holdings (<2 acres wet / <4 acres dry)	65.97	252	Typical holding size
	Agricultural labourers	12.40	47	Work on others' lands
	Shared croppers	13.90	53	Engage in crop-sharing
	Leased croppers	4.19	16	Lease land for cultivation

3.1. *Case Study: The farmers expressed the practice of agriculture from the process of Transition from Diverse Cropping to Monoculture*

Rajaiah, a seasoned 58-year-old farmer with 32 years of experience, resides in Buruguda village within the K.B. Asifabad district. *"His observations shed light on the shift from traditional diversified cropping practices to monoculture in agriculture. Previously, our farmers adhered to a diverse crop rotation pattern based on seasonal variation. Narsaiah, a 40-year-old farmer from Ada village, recalled that during the Kharif season (June to October), they cultivated paddy in wetlands and white sesame, flaxseeds, soybeans, corn, and pulses in drylands. In the Rabi season (October to March), sunflowers, chickpeas, wheat, and vegetables were grown in wetlands, whereas red gram, black sesame, sorghum, and sunflowers thrived in drylands. Some farmers also opted for whole-season crops like cotton and chili (CS-I)."*

Venkatasham, a marginal farmer from Cherakunta village, owns 10 acres of dryland and has 15 years' experience. *"He exclusively cultivated cotton, initially relying on livestock manure and minimal synthetic fertilizers – approximately 150 kg of DAP and 100 kg of urea per acre – yielding 7 to 8 quintals per acre. However, the landscape has been transformed. Currently, they utilize approximately 250 kg of DAP, 175 kg of urea, and 100 kg of potassium per acre. The market offers a variety of chemical fertilizers that attract farmers to use them. Insecticides, fungicides, pesticides, and herbicides are now commonplace in cotton farming, resulting in increased yields – around 11 to 14 quintals per acre – despite the absence of livestock (CS-II)."*

Narayana, another farmer from the same village, also practices monocropping. *"He acknowledges the economic benefits of this intensive approach but raises concerns about health and soil degradation due to chemical pesticide application. Without these chemicals, productivity seems unattainable, making them an indispensable part of modern agricultural production (CS-III)."*

3.2. Impact of Monocropping and Synthetic Chemicals on Soil Quality

Over the years, the adoption of monocrops and widespread use of synthetic chemicals have significantly transformed agricultural practices (Crews et al., 2018). Farmers now prioritize economic gains and cultivation and harvesting efficiency. Assessing land quality over the past decade has revealed a complex picture.

Fifteen years ago, the soil quality was high, but production and irrigation remained relatively low. However, the present scenario tells a different story that is more complex. Soil quality has degraded, and irrigation and production have increased substantially. This shift can be attributed to the excessive application of synthetic fertilizers and intensive irrigation, which are hallmarks of Highly Intensive Agriculture (HIA) practices. Interestingly, some study areas exhibit crop diversity, although it does not always translate into profitable production. Despite adequate irrigation and chemical fertilizer use, the overall impact on soil health is concerning. The relentless pursuit of higher yields has compromised soil organic matter, ultimately affecting the production capacity. As we grapple with these challenges, it is crucial to strike a balance between economic incentives and sustainable soil management.

3.3. Livestock Decline and Its Impact on Soil Health and Agricultural Practices

Table 2 shows that a decade ago, every family in the study area maintained livestock, typically consisting of at least two bulls and one cow or a buffalo. However, the current landscape has changed significantly. Only 12.4% of farmers possess the minimum required number of livestock. This decline poses a serious threat to agriculture, particularly in terms of soil fertility, as livestock play a crucial role in enhancing natural soil health. When livestock interact with the soil, decomposition processes occur, fostering the development of beneficial microorganisms. These microorganisms contribute to nutrient cycling and the release of essential elements, including carbon dioxide (CO_2), which supports plant growth.

Traditionally, farmers have heavily relied on manual labor and traditional equipment for tilling the soil. However, owing to reduced livestock numbers and time constraints, an increasing number of farmers have shifted to mechanical soil preparation methods. Currently, 87.6% of farmers utilize mechanical aids for tilling, whereas only 8.54% continue to employ traditional methods. However, this transition has led to several adverse consequences. Soil compaction has intensified, unwanted weed growth has proliferated, water retention capacity has diminished, and carbon dioxide (CO_2) levels in the soil have declined. In response to rampant weed growth, farmers have turned to herbicides as effective weed-removal agents. Despite their efficiency in saving time and labor costs, herbicides have a significant drawback: they harm essential microorganisms and macro-organisms in the soil, which are vital for maintaining soil fertility.

Table 2. Livestock Status and Soil Preparation Methods

Aspect	Category	(%)	N	Notes/Observations
Livestock Ownership	Families maintaining minimum livestock (≥2 bulls + 1 cow/buffalo)	12.40	47	Sharp decline compared to a decade ago when every family-maintained livestock
	Families without minimum livestock	87.60	335	Decline threatens soil fertility due to reduced natural manure and microbial activity
Soil Preparation Methods	Mechanical aids for tilling	87.60	335	Widely adopted due to reduced livestock and time constraints
	Traditional manual methods	8.54	33	Declining use of traditional equipment and labour

3.4. *A Focus Group Study: Farmers from three mandals in K.B. Asifabad district expressed diverse perspectives on Livestock Management and Chemical Utilization in Agriculture*

In this focus group study, the researcher explored the varying opinions of farmers regarding the interplay between livestock management and chemical fertilizers. While some view these practices as complementary, others express concerns regarding their impact on soil health and human well-being.

3.4.1. *Kowtala Mandal: Livestock Manure vs. Synthetic Fertilizers*

Farmers from Kowtala Mandal reminisce about a time when they relied heavily on livestock manure for crop production. *"During this period, they observed healthier food production, even though the yields remained average. However, the decline in livestock numbers has led to a noticeable decrease in soil fertility and in human health. Interestingly, some farmers now advocate for a combination of livestock and synthetic fertilizers, recognizing that this hybrid approach can enhance productivity (FGS-I)."*

3.4.2. *Bejjur Mandal: Sole Dependence on Chemical Fertilizers*

A different perspective emerges in Bejjur Mandal. Here, farmers expressed deep concerns about relying solely on chemical fertilizers for crop production. *"Managing livestock in the present context has become challenging, and livestock-rearing practices are increasingly critical. Despite these challenges, the current approach benefits farmers economically and provides them with more leisure time than traditional farming. Farmers argue that effective management of chemical utilization can mitigate any adverse effects on the environment and human health (FGS-II)."*

3.4.3. *Kaghaznagar Mandal: Balancing Perspectives*

Farmers in the Kaghaznagar Mandal have a variety of notions. Some advocate for an extensive form of agriculture to achieve high yield. *"They emphasized the need for ultra-synthetic fertilizers to boost production. However, a smaller segment of farmers believes that current agricultural practices do not harm soil health or human well-being. According to them, individual practices and concerns play pivotal roles. Expanding chemical utilization in the soil, they argue, can lead to increased production and greater benefits for the farming community (FGS-III)."*

The contrasting views expressed by the farmers underscore the complexity of managing livestock and utilizing synthetic fertilizers in agriculture. As we seek sustainable solutions, understanding these perspectives is crucial for informed decision-making and promoting soil health while ensuring human welfare. Further research and dialogue are essential to strike a balance that benefits both farmers and the environment in the long run.

3.5. Perspectives and Practices: Chemical Fertilizers vs. Sustainable Agriculture

Table 3 shows the current agricultural landscape, where chemical fertilizers dominate, with 90.5% of farmers preferring their use. Only a small fraction (9.61%) relied on natural manure in conjunction with chemical fertilizers. Remarkably, an even smaller percentage (0.26%) practiced entirely chemical-free farming. Farmers' perspectives on sustainable agricultural practices (SAP) reveal interesting insights. While 34.29% believe that SAP enhances crop and soil fertility, no one actively follows these practices; it remains an assumption. Furthermore, 88.22% of farmers consistently apply chemical fertilizers, bypassing manual labor or biofertilizers for weed removal. In contrast, 11.52% opted for manual weed removal without herbicides. Interviews with senior farmers shed light on the impact of livestock on the crop production. A significant majority (73.56%) doubted that livestock manure alone could yield the expected production levels. Conversely, 26.70% acknowledged its potential but recognized that it fell short of the efficacy of chemical fertilizers.

Table 3. Sustainable Agriculture Perspectives, and Farmers' Views on Livestock Manure

Aspect	Category	(%)	N	Notes/Observations
Fertilizer Use	Chemical fertilizers (dominant use)	90.50	346	Majority prefer chemical fertilizers
	Natural manure + chemical fertilizers	9.61	37	Small fraction combining both
	Entirely chemical-free farming	0.26	1	Rare practice
Sustainable Agriculture Practices (SAP)	Believe SAP enhances crop & soil fertility	34.29	131	Perception only; no active adoption
	Active adoption of SAP	0	0	Not practiced
Weed Removal Methods	Chemical fertilizers/herbicides (bypassing manual labour/bio-fertilizers)	88.22	337	Dominant practice
	Manual weed removal (without herbicides)	11.52	44	Minority practice

Farmers' Views on Livestock Manure	Doubt manure alone yields expected production	73.56	281	Majority skeptical
	Acknowledge manure's potential but less effective than chemical fertilizers	26.70	102	Minority supportive but cautious

3.6. Transition from Diversified Cropping to Monoculture: Implications for Soil Health and Environmental Well-being

Over the past decade, the agricultural landscape in the study region has shifted significantly from wetlands to drylands. This transformation primarily caters to the cultivation of commercial crops, notably cotton and chilies. Cotton crops are popular among farmers. In the past, wetland farmers predominantly cultivated paddy as their major crop, whereas dryland farming involved a diverse range of crops, such as sesame, soybeans, flaxseeds, sorghum, and pulses. However, the present scenario reflects a major shift, with cotton emerging as the primary crop in the dryland areas. Cotton is a year-round crop, with cultivation beginning in June and extending until March, and production primarily occurring from November to February.

Farmers have adapted their practices to maximize production efficiency and minimize labor. This transition involves moving from multi-cropping to monoculture, traditional methods to mechanization, and a shift from biofertilizers to chemical fertilizers. In the past, farmers relied mainly on diammonium phosphate (DAP) and urea for crop harvesting, occasionally using insecticides for cotton, red gram, and chili crops. However, recent trends indicate a move toward Highly Intensive Agriculture (HIA) practices. An overwhelming 98.2% of farmers now rely on DAP, urea, and potassium for all crops. Additionally, various types of insecticides, fungicides, and herbicides are employed across crops, including paddy, cotton, and chili. However, this intensified approach poses risks to human health and the environment, warranting careful consideration of sustainable alternatives.

4. Discussion

The significant shift in agricultural practices towards monoculture, chemical fertilizers, and mechanization in this region has undoubtedly brought economic benefits. However, we must acknowledge the potential risks that these practices pose to soil health and the environment (Tahat et al., 2020). To ensure long-term sustainability, research proposes a multifaceted approach that prioritizes both economic viability and environmental protection.

One crucial step in achieving this is to promote crop diversity. Encouraging farmers to move beyond cotton and chili through crop rotation and intercropping can significantly enhance soil fertility (Wang et al., 2014). This not only reduces pest pressure but also fosters a more sustainable agricultural ecosystem (Liu et al., 2022). Furthermore, educating farmers about the importance of organic manure and biofertilizers is essential (Selim, 2020). A balanced approach that combines the use of chemical fertilizers with natural inputs can optimize yields while safeguarding soil health (Uikey & Patil, 2024).

Similarly, advocating for Integrated Pest Management (IPM) practices offers a promising solution (Lamichhane et al., 2018). By implementing strategies such as utilizing beneficial insects, trap crops, and cultural practices, we can effectively manage pests without jeopardizing soil organisms (Boeraeve & Hatt, 2024), which is a significant advantage over relying solely on herbicides and insecticides.

Reviving livestock integration presents another opportunity (Katherasala & Bheenaveni 2024). Encouraging livestock rearing not only provides economic benefits but also contributes to soil health (Kibblewhite et al., 2007). Organic materials play a crucial role in both production and ecological sustainability by replenishing organic matter, improving soil structure, and enhancing nutrient cycling (Sarkar, 2023).

To effectively disseminate knowledge of these sustainable practices, collaboration with agricultural universities and extension agencies is vital (Davis et al., 2008; Kibblewhite et al., 2007). Farmer training programs and field demonstrations can significantly promote the adoption of these methods among the agricultural community (Kansanga et al., 2021).

Finally, establishing a system for the regular monitoring and assessment of soil health, water quality, and crop productivity allows for data-driven decision-making (Liang & Shah, 2023). Implementing adaptive management strategies based on empirical data ensures continuous improvement and addresses unforeseen challenges (Bouwen & Taillieu, 2004). Fostering sustainable agriculture requires a comprehensive approach that balances economic goals and environmental stewardship (Velten et al., 2015). By implementing the recommendations outlined above, farmers can be empowered, the negative impacts of intensive practices can be mitigated, and the long-term well-being of both agricultural livelihoods and the surrounding ecosystem can be ensured.

4. Conclusion

By embracing these multifaceted solutions, promoting crop diversity, balancing inputs, adopting IPM, reviving livestock integration, and establishing robust monitoring, we can pave the way for a future of sustainable agriculture. This approach will not only empower farmers with knowledge and practices that ensure long-term soil health and environmental protection but also guarantee the continued economic viability of the region's agricultural sector. Achieving a sustainable future requires a collaborative effort that prioritizes both economic prosperity and environmental well-being.

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