

Sowing a Sustainable Future: Zero Tillage Potato Cultivation in Begusarai

1. Introduction:

Begusarai district in Bihar, located along the northern banks of the Ganga, is one of the state's key agricultural regions where a large proportion of households depend on farming for their livelihoods. The district cultivates a diverse range of crops, including paddy, wheat, maize, pulses, and oilseeds, alongside an expanding horticulture sector. Among these, potato has emerged as the fourth most important food crop in Bihar after rice, wheat, and maize, offering high yields within a short growing period and serving as an important source of income and nutrition for small and marginal farmers. Despite its potential to enhance food security and improve household earnings, potato cultivation in Bihar has not fully realized its promise. Productivity remains low at around 17.78 t/ha, considerably below leading potato-producing states such as West Bengal, where yields average 24.70 t/ha (Shankar et al., 2014).

Fig 1: Area production and productivity of potato in major districts of Bihar (2009-10). Source Directorate of Horticulture, Govt. Of Bihar.

District	Area (ha)	Pro-duction (t)	Yield (t/ha)	District	Area (ha)	Pro-duction (t)	Yield (t/ha)
Patna	16050	409400	25.50	West Champaran	12200	201300	16.50
Nalanda	27000	653320	24.19	Muzaffarpur	12000	210980	17.58
Rohtas	10700	195100	18.23	Vaishali	13500	255040	18.89
Gaya	11500	190240	16.54	Madhubani	10600	168040	15.85
Saran	13500	249970	18.51	Samastipur	12300	250910	20.39
Siwan	10300	113460	11.01	Others	149240	2430310	16.28
Gopalganj	12200	210470	17.25	Total	322840	5741290	17.78
East Champaran	11750	202750	17.25				

Source: Shankar et al., 2014

Multiple structural challenges constrain potato production in regions like Begusarai. Rising input costs, particularly for land preparation through tractor tilling and hired labour, have increased the financial burden on resource-poor farmers. Continuous cultivation on the same plots has resulted in soil fatigue, declining soil organic matter, and increased vulnerability to pests and diseases, making conventional farming practices increasingly unsustainable. Water scarcity, shrinking arable land, and the effects of climate variability further heighten production risks. The reliance on chemical fertilizers and pesticides has also contributed to soil degradation and higher production costs, limiting profitability for smallholders.

These intertwined agronomic, economic, and environmental constraints have created a situation where traditional potato cultivation yields low returns despite high labour and input investments. For many small and marginal farmers, this has led to stagnating incomes and reduced resilience, making potato cultivation a risky enterprise. Conservation agriculture approaches such as Zero Tillage potato cultivation under rice straw mulch have therefore gained increasing attention for their potential to address these challenges. According to a study published by GIZ (2023), the use of rice straw mulch in Zero Tillage systems acts as a natural protective layer that conserves soil moisture, reduces weed pressure, and maintains favourable soil temperatures, while simultaneously curbing stubble burning, a major contributor to air pollution in northern India. The approach also lowers labour requirements

and input costs, particularly for land preparation and irrigation, and supports improved soil health and biodiversity. By aligning with principles of climate-smart and resource-conserving agriculture, Zero Tillage offers a promising pathway for enhancing sustainability and profitability in smallholder potato production systems.

2. Study Objectives:

The primary objective of this pilot study is to assess the introduction and adoption of Zero Tillage potato cultivation under rice straw mulch (PZTM) among small and marginal farmers in Matihani block of Begusarai, Bihar, and to examine its potential to address key constraints in traditional potato production. Specifically, the study aims to:

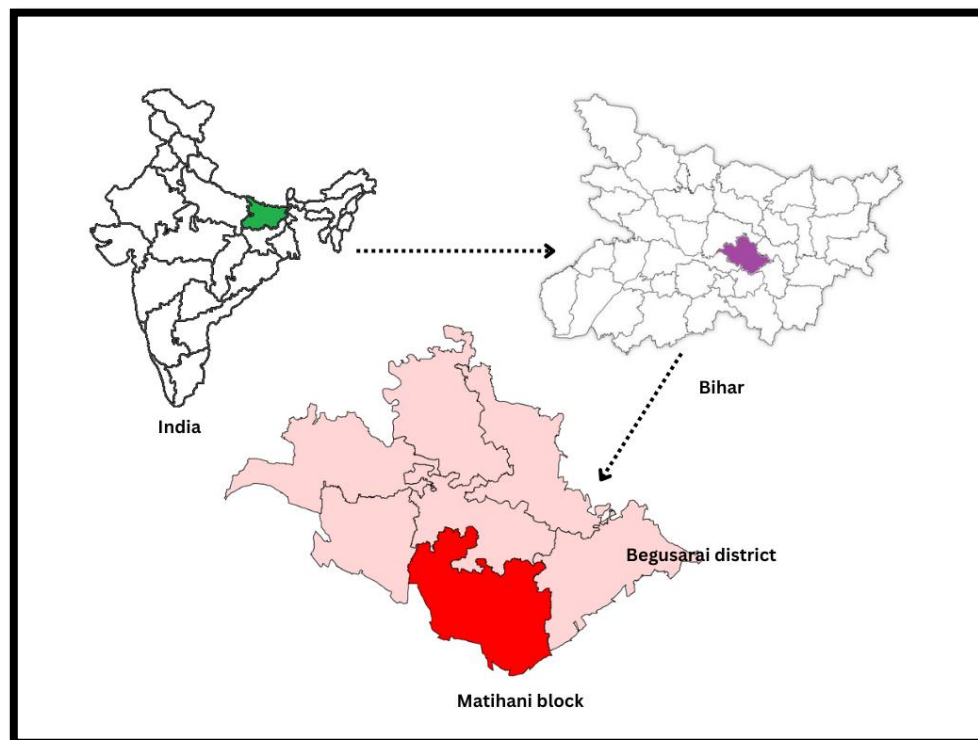
1. Evaluate the agronomic and economic performance of Zero Tillage potato cultivation in comparison to conventional practices, with particular focus on production costs, labour requirements, and crop yield outcomes.
2. Analyze the contribution of PZTM to livelihood resilience, including its effects on farm profitability, input dependency, and income stability among resource-poor households.
3. Examine soil- and resource-conservation benefits associated with the use of rice straw mulch, including moisture retention and reduced residue burning.
4. Assess farmer knowledge, adoption behaviour, and capacity-building outcomes resulting from demonstration-based learning and community engagement activities.
5. Explore the potential of PZTM as a climate-smart agricultural practice suitable for regions experiencing declining soil fertility, water scarcity, and increasing production risks.

3. Materials and Methods:

3.1. Implementation Agency and Study Site Selection:

This pilot intervention was implemented by Sarva Seva Samity Sanstha (4S India), a grassroots organization working in Begusarai district through livelihood enhancement and community development programs. Matihani block was purposively selected as the study site due to the organization's engagement in the region, established institutional relationships with Self-Help Groups (SHGs), and detailed understanding of local agricultural constraints such as high tillage costs, residue burning, and declining soil fertility. This existing presence facilitated effective community mobilization, trust-building, and smooth execution of the intervention.

Fig 2: Geographical location of the study area



3.2. Research Design:

This study adopts a quantitative research design involving 100 participating farmers, wherein the before-and-after performance of Zero Tillage potato cultivation under rice straw mulch (PZTM) was compared with their previous conventional cultivation practices. Key agronomic and economic indicators including input use, labour requirements, cost of cultivation, yield, and net returns were measured for the same farmers across two conditions (pre-intervention and post-intervention), allowing for a direct assessment of changes attributable to the introduction of Zero Tillage.

3.3. Farmer Selection and Sampling:

A systematic farmer selection process was adopted to ensure relevance and feasibility of Zero Tillage potato cultivation. The following criteria were applied:

- ownership or access to at least one kattha (0.03 acre) of cultivable land
- active engagement in farming activities
- willingness to experiment with new cultivation practices
- membership in a functioning SHG to promote peer learning
- demonstrated interest and enthusiasm toward sustainable agriculture

Based on these criteria, 100 small and marginal farmers across four Gram Panchayats were selected. Each participant allocated one kattha (0.03) of land for demonstration and adoption of the Zero Tillage Potato Cultivation under rice straw mulch (PZTM) approach.

3.4. Capacity Building and Technical Support:

To ensure proper adoption and skill development, the implementation strategy included:

- structured training programs introducing the concept, process, and benefits of PZTM
- instructional videos in the local language for simplified learning
- hands-on field demonstrations conducted by agricultural specialists
- one-on-one mentoring and regular follow-up visits by field facilitators
- peer learning platforms within SHGs for experience sharing and problem-solving

3.5. Demonstration Plots:

100 demonstration plots were established as practical learning hubs across the four Gram Panchayats. These served as community-level observation sites where neighboring farmers could witness the cultivation process and outcomes. Plot selection was based on:

- land suitability
- accessibility for community visits
- farmer motivation and engagement

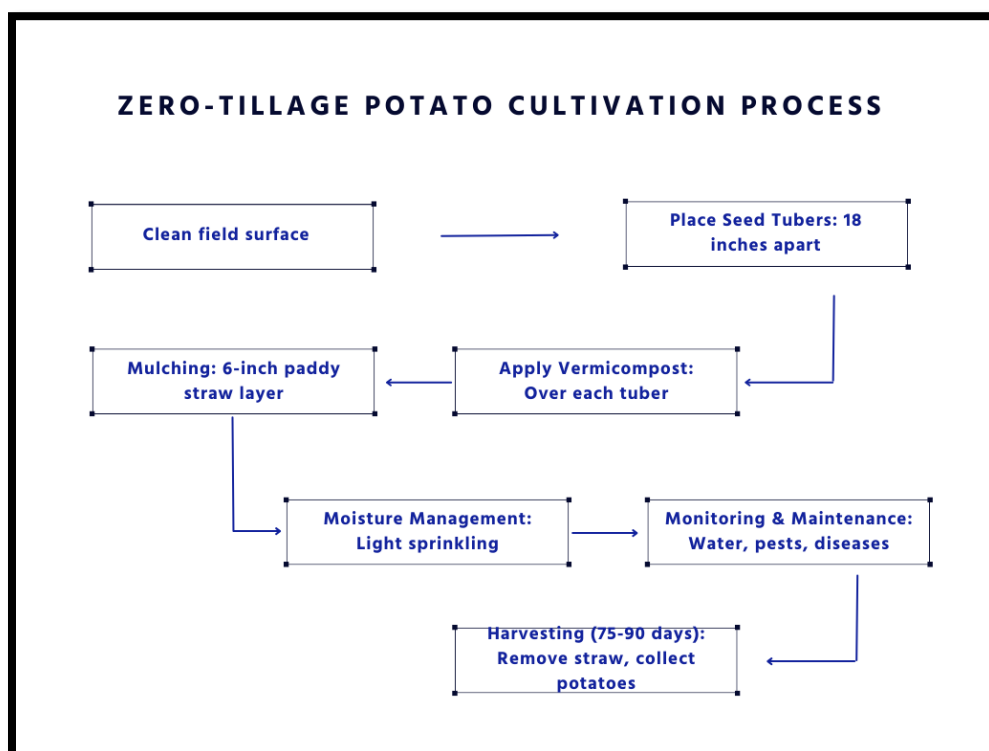
Regular field visits, community walkthroughs, and interaction sessions were organized to showcase progress, address challenges, and encourage wider dissemination.

3.6. Input Support:

To minimize financial risk and support successful implementation, participating farmers received:

- 30 kilograms of the locally adapted “Saresa” potato variety
- vermicompost and organic fertilizers
- guidance on sourcing and applying rice straw mulch

Fig 3: Process flow of Potato Zero Tillage under rice straw mulch (PZTM) cultivation.



3.7. Data Collection and Analysis:

Primary quantitative data were collected from 100 participating farmers through structured interviews and field-based measurements during the 2024–25 potato season. Information on input use (seed quantity, fertilizer and organic inputs, labour days, mulch volume), production practices, cost of cultivation, yield, and sales returns was recorded using a standardized data collection format administered by trained field facilitators. Plot-level yield data were obtained through harvesting and weight measurement directly from the demonstration plots. To assess the effect of the intervention, a before–after comparison was conducted for all 100 farmers, using their previous season’s conventional potato cultivation as the baseline.

Quantitative data were analyzed using descriptive statistics, including calculation of mean values, percentage changes, and cost–benefit estimates. Comparative analysis was used to evaluate differences in input costs, labour requirements, yield performance, and profitability between Zero Tillage and conventional cultivation. Results were summarized in tables and graphs for clarity and interpretation. Qualitative insights from field observations and farmer interactions were used only to support interpretation of quantitative findings, particularly relating to adoption behaviour and perceived benefits.

Secondary information from published research papers, government agricultural statistics, and technical reports was reviewed to contextualize the findings.

3.8. Ethical Considerations:

All participants were informed about the purpose of the study, and verbal consent was obtained prior to participation. Anonymity and confidentiality were strictly maintained, and no personally identifiable information has been disclosed in the re-ported of findings.

3.9. Limitations of the Study:

This study, based on a sample of 100 farmers, provides valuable early evidence on the potential of Zero Tillage Potato cultivation. However, as it focuses on a single block and one cropping season, the findings are specific to the local agro-climatic and seasonal context. Broader studies across multiple locations and cropping seasons would be necessary to capture long-term trends in yield performance, soil health, and profitability.

4. Results:

The findings from the pilot study are presented below based on data collected from 100 participating farmers who adopted Zero Tillage Potato Cultivation under rice straw mulch (PZTM) during the 2024–25 season. The results compare the farmers’ previous year’s conventional potato cultivation practices with their outcomes under Zero Tillage. The analysis focuses on farmer characteristics, cost differentials, irrigation requirements, yield performance, profitability, and changes in input and labour use.

4.1. Farmer Profile:

All 100 participants were small and marginal farmers belonging to four Gram Panchayats of the Matihani block—Maniyappa, Matihani-1, Safapur, and Sonapur. Each farmer cultivated one kattha of land (0.03 acre) under both conditions: conventional farming (baseline) and Zero Tillage (intervention), allowing for a uniform and reliable comparison. All participants were women farmers who were active members of Self-Help Groups (SHGs) and regularly engaged in agricultural activities. Most households depended primarily on agriculture for their livelihoods, with potato being an important seasonal cash crop. Landholdings were generally fragmented and small, ranging from 0.06 to 7.5 acres per family. Prior to the

intervention, the predominant constraints highlighted by farmers included high tillage costs, labour shortages, the need for multiple irrigation cycles, and recurring expenditure on chemical fertilizers.

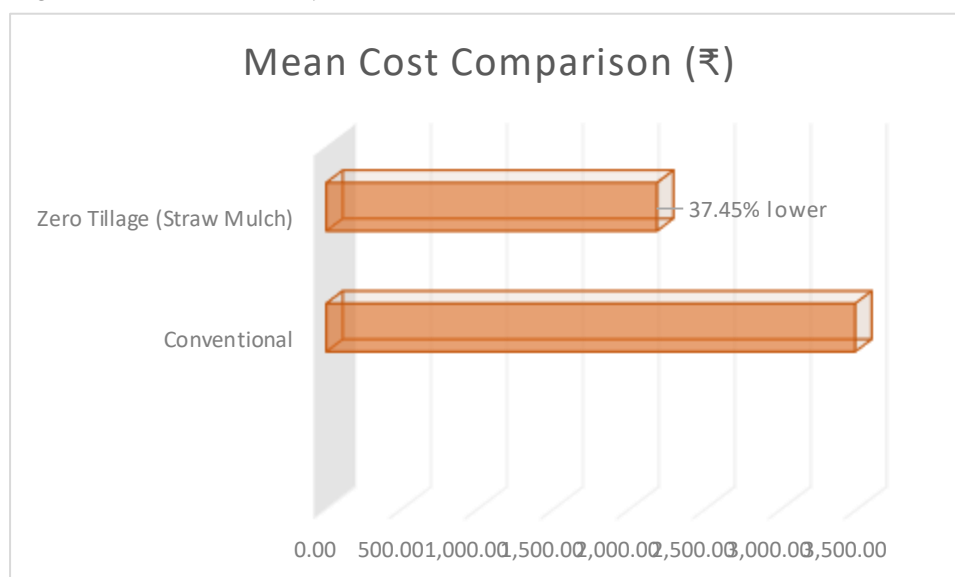
4.2. Cost of Cultivation:

The cost of cultivation for 100 farmers was analysed for both the conventional method and the Zero Tillage method. The analysis includes mean cost, minimum–maximum range, and standard deviation to understand the central tendency and variability of costs under each method.

Table 1: Cultivation Cost (₹/0.03Acre)

Cost Indicator	Conventional Method	Zero Tillage Method
Minimum Cost	3,165	1,750
Maximum Cost	3,901	2,840
Mean Cost	3,483.94	2,179.00
Standard Deviation (SD)	184.43	186.07
Cost Reduction (₹)	–	1,304.94
Percentage Reduction (%)	–	37.45% lower

Figure 4: Mean Cost Comparison

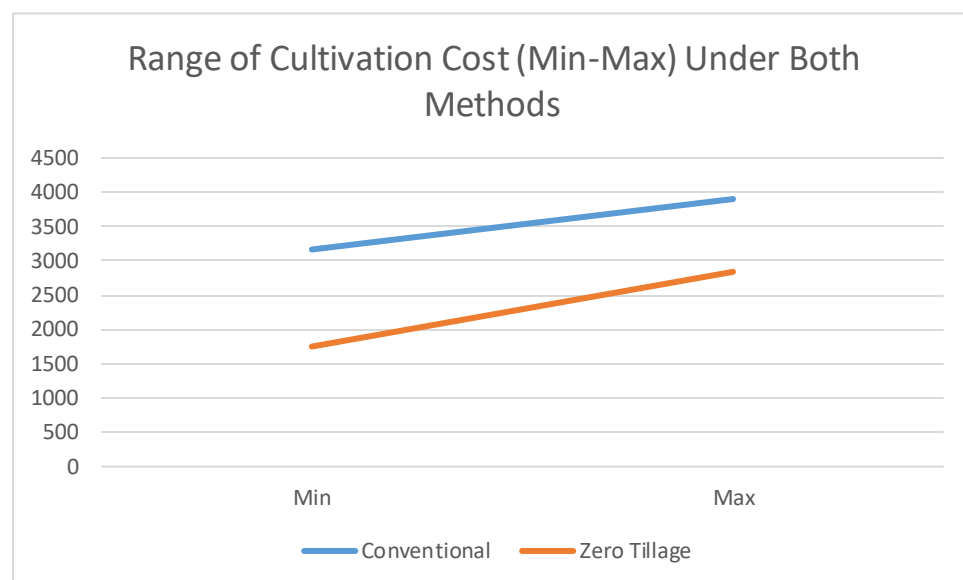


The total cost of cultivation was computed using detailed farmer-level data on all major input components required for potato production under each method. For the conventional method, the cost estimation included: (i) seed cost calculated at ₹25 per kg for 35 kg of seed; (ii) chemical fertilizers such as urea (5 kg @ ₹125), DAP (2.5 kg @ ₹125), potash sulphur (250 g @ ₹33), boron (2.5 g @ ₹25), Thimat pesticide (250 g @ ₹50), and Andi insecticide (5 kg @ ₹200); (iii) flood irrigation charges @ ₹60 per hour for three to four rounds of irrigation; (iv) ploughing cost @ ₹30 per hour for land preparation; and (v) labour cost for sowing, fertilizer application, weeding, and other intercultural operations.

For the Zero Tillage method, the cost calculation incorporated: (i) seed requirement of 30 kg, with seed support provided entirely by Sarva Seva Samity Sanstha (4S India); (ii) straw for mulching @ ₹2 per kg to cover the seed bed and conserve soil moisture; (iii) sprinkler-based irrigation (two rounds); (iv) vermicompost application @ ₹7 per kg in place of chemical fertilizers; and (v) reduced labour cost due to elimination of ploughing and furrow preparation.

The analysis of total cultivation cost revealed a substantial economic advantage for farmers adopting the Zero Tillage method. The average cost under the conventional method was ₹3,483.94 per acre, ranging between ₹3,165 and ₹3,901, whereas Zero Tillage reduced the average cost to ₹2,179 with a lower range of ₹1,750 to ₹2,840. This reflects a significant cost reduction of ₹1,304.94 per acre, equivalent to a 37.45% decrease in total expenditure. Although the standard deviation values were similar for both methods (184.43 for conventional and 186.07 for Zero Tillage), indicating comparable variability among farmers, the entire cost distribution for Zero Tillage remained consistently lower; its highest cost (₹2,840) was still below the lowest recorded cost in the conventional system (₹3,165). This demonstrates that Zero Tillage not only reduces average cost but also provides a more predictable and financially less risky cultivation practice. The major components driving cost savings include the elimination of ploughing operations, reduced seed requirement with additional seed support from 4S India, fewer irrigation rounds due to sprinkler use, lower labour requirement, and substitution of chemical fertilizers with vermicompost and straw mulch.

Figure 5: Minimum and maximum cultivation costs observed among 100 farmers under conventional and Zero Tillage methods.



4.3. Irrigation Requirement:

A clear difference was observed in the irrigation requirement between the two cultivation methods. Under the conventional method, farmers typically applied 3-4 rounds of flood irrigation, depending on soil type and water availability. This method demanded higher volumes of water, greater pumping time, and higher operational expenditure. In contrast, farmers adopting the Zero Tillage method required only 2 rounds of sprinkler irrigation, supported by the moisture-retaining effect of rice straw mulch.

The reduction in irrigation rounds directly translated into lower water use and reduced energy or pump rental costs. While conventional cultivation incurred an irrigation charge of approximately ₹60 per hour (average cost incurred around ₹160) due to repeated flood irrigation cycles, Zero Tillage (average around ₹75) required substantially fewer irrigation events and less operational time, resulting in meaningful cost savings. The combination of mulching, moisture conservation, and the efficient sprinkler system allowed Zero Tillage plots to maintain adequate soil moisture with less frequent watering.

4.4. Yield Performance:

To assess the productivity effects of the intervention, yield data were collected from 100 farmers who cultivated identical plot sizes under both methods. The comparison focuses on average production, minimum–maximum yield range, standard deviation, and the seed input required to achieve the observed output.

Table 2. Yield Comparison Between Conventional and Zero Tillage Methods (kg/0.03 acre)

Yield Indicator	Conventional Method	Zero Tillage Method
Seed Quantity Used	35 kg	30 kg
Minimum Yield (kg)	360	340
Maximum Yield (kg)	420	440
Mean Yield (kg)	387.61	389.10
Standard Deviation	12.09	26.56

The findings show that average yield under Zero Tillage (389.10 kg/0.03 acre) was almost identical to the conventional method (387.61 kg/0.03 acre). Interestingly, this yield parity was achieved despite using a lower seed quantity—Zero Tillage plots used 30 kg of seed, while the conventional method used 35 kg, representing a 14% reduction in seed requirement. Achieving similar production with fewer seeds indicates improved input-use efficiency and better plant establishment under the Zero Tillage system, supported by mulching and soil moisture conservation.

Zero Tillage exhibited a wider yield range (340–440 kg) and higher variability (SD = 26.56) compared to the conventional system (360–420 kg; SD = 12.09). This increased variability is partly explained by the late execution of the Zero Tillage initiative, which restricted the available Rabi season for farmers. Many farmers were compelled to harvest earlier than the optimal maturity stage, resulting in inconsistent yield outcomes. Despite these constraints, the overall mean yield under Zero Tillage remained stable and comparable to the conventional method.

Figure 6: Zero Tillage achieved comparable yield with 14% less seed, demonstrating higher seed-use efficiency.

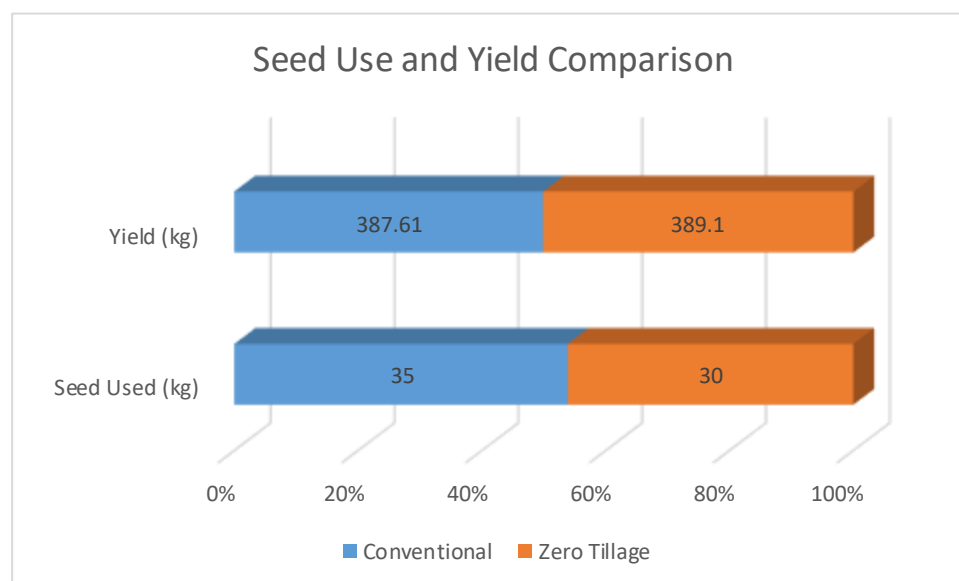
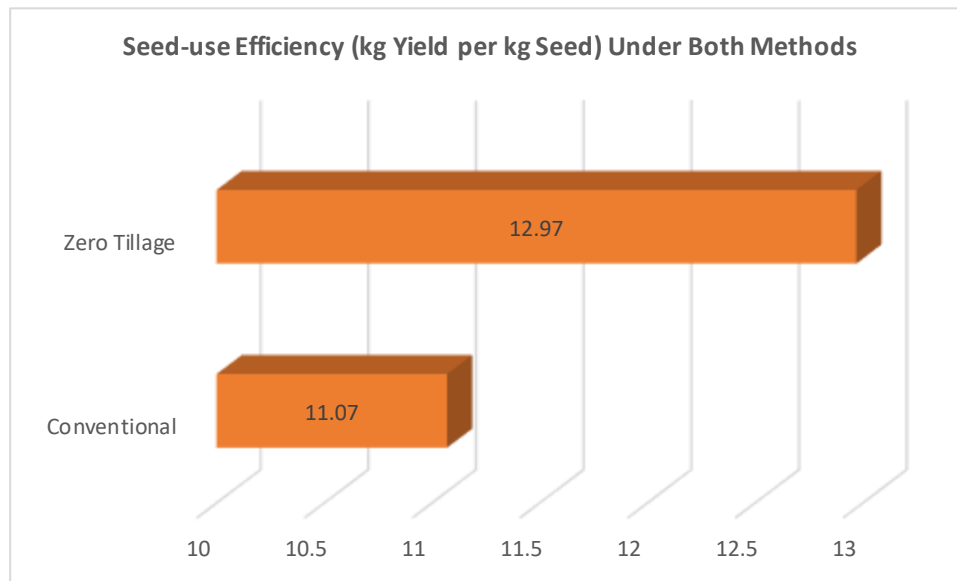


Figure 6: Zero Tillage achieved comparable yield with 14% less seed, demonstrating higher seed-use efficiency.

Figure 7: Zero Tillage produced more yield per kilogram of seed, indicating higher seed-use efficiency.



4.5. Profitability:

Profitability assessment was conducted to understand the economic returns associated with the two cultivation practices. This section compares the income earned and net profit achieved by farmers under the conventional method and the Zero Tillage method. The analysis is based on average production and cost data reported by 100 participating farmers and highlights how reduced input requirements and improved cost efficiency under Zero Tillage translate into higher overall profitability.

Table 3: Profitability Comparison per 0.03 acre

Indicator	Conventional Method	Zero Tillage Method
Average Yield (kg)	387.61	389.10
Selling Price (₹/kg)	15	30
Average Income (₹)	5,814.15	11,673.00
Minimum Income (₹)	5,400	10,500
Maximum Income (₹)	6,300	13,200
Cost of Cultivation (₹)	3,483.94	2,179.00
Average Net Profit (₹)	2,330.21	9,494.00
Profit Difference (₹)		+7,163.79
Percentage Increase in Profit (%)		307% higher

The profitability assessment clearly demonstrates that Zero Tillage significantly enhances farmers' economic returns. Under the conventional method, the average income per kattha (0.03 acre) was ₹5,814.15, while Zero Tillage nearly doubled this amount, yielding ₹11,673 on average. Even the income range shows a substantial improvement: the lowest Zero Tillage income (₹10,500) exceeded the highest income recorded under the conventional method (₹6,300).

This improvement is driven by two key factors:

- (i) lower cultivation cost (₹2,179 under Zero Tillage vs ₹3,483.94 under conventional), and

(ii) better price realization and market preference for potatoes grown under Zero Tillage.

Consequently, the average net profit increased from ₹2,330.21 in the conventional method to ₹9,494 under Zero Tillage, representing a 307% rise in profitability. This demonstrates that Zero Tillage is economically superior, offering higher revenue, lower input cost, and substantially better margins even with a lower seed requirement (30 kg vs. 35 kg).

Figure 8: The minimum income under Zero Tillage was higher than the maximum income under the conventional method, indicating a complete upward shift in income distribution.

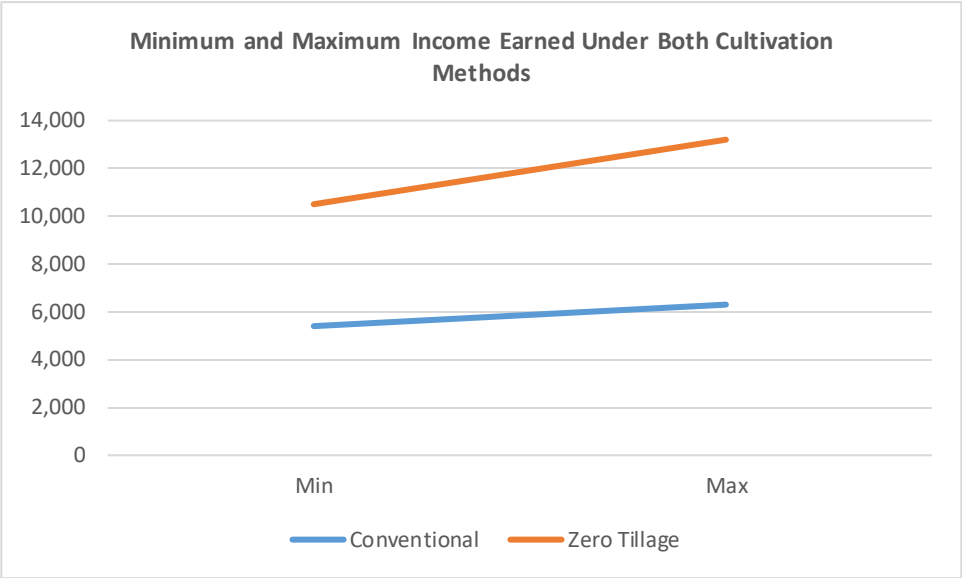
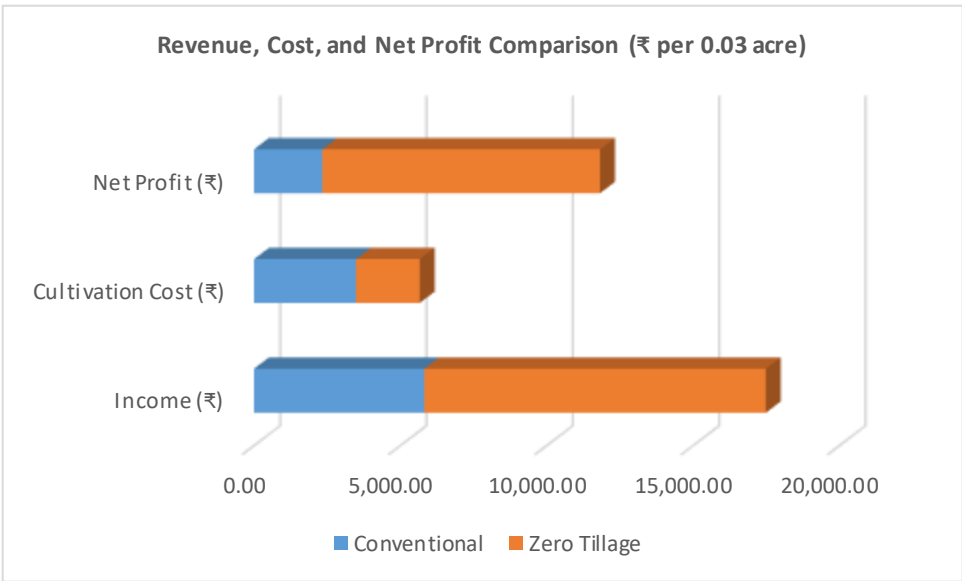


Figure 9: Comparative breakdown of total income, cultivation cost, and net profit under conventional and Zero Tillage methods.



5. Discussions:

The findings from this pilot study clearly demonstrate that Zero Tillage potato cultivation under rice straw mulch (PZTM) provides multiple agronomic, economic, and environmental benefits over the conventional tillage-based system practiced in Matihani block. The comparison of cultivation parameters at every stage—land preparation, seed management, irrigation, fertilizer use, pest control, and cost—reveals that Zero Tillage offers a more resource-efficient and farmer-friendly approach, particularly for small and marginal farmers cultivating 1 kattha (0.03 acre).

A major advantage of the Zero Tillage method lies in land preparation. Unlike conventional farming which requires ploughing, harrowing, and levelling, Zero Tillage eliminates soil disturbance entirely. Direct sowing on existing soil reduces land preparation costs from ₹100–₹120 to about ₹30 per kattha (0.03 acre), confirming the cost-saving estimates in the comparison table. This reduction in tillage operations also minimizes labour dependency, diesel expenditure, and soil degradation—consistent with conservation agriculture principles. The study also highlights improvements in seed-use efficiency. Farmers using the conventional method applied 35 kg of seed per kattha (0.03 acre), whereas Zero Tillage required only 30 kg—a 14% reduction—yet achieved nearly identical average yields (389.10 kg vs. 387.61 kg per 0.03 acre). This efficiency gain is attributed to improved seed placement practices: Zero Tillage avoids furrow making and places seeds directly on the soil surface, covering them with vermicompost or straw mulch. This enhances moisture conservation, reduces temperature fluctuations, and promotes better germination, which aligns with established findings on mulch-based systems.

The water requirement also differed significantly between the two systems. Conventional potato cultivation relies on 3–4 rounds of flood irrigation, a method that is both water-intensive and inefficient. Zero Tillage required only two rounds of sprinkler irrigation, corresponding to a water saving of approximately ₹100 per 0.03 acre (₹50 × 2). Mulching played a crucial role in retaining soil moisture, reducing evaporation loss, and ensuring more uniform water distribution. These observations confirm global literature indicating that Zero Tillage with residue retention improves water-use efficiency and strengthens resilience to moisture stress—an important factor in climates such as Bihar's.

A sharp contrast was observed in fertilizer and pest management practices. Conventional methods relied heavily on chemical fertilizers (Urea, DAP, Potash, Boron) and chemical pesticides such as Thimat and Andi. In contrast, Zero Tillage plots used vermicompost, bio-fertilizers, and Neemastra—resulting in estimated savings of ₹1,000–₹1,200 per kattha (0.03 acre). The thick straw mulch reduced weed emergence, eliminating the need for herbicides or manual weeding. This substantially lowered labour burden, especially for women farmers who typically handle weeding and fertilizer application. The shift toward organic inputs promotes soil microbial activity, improves soil structure, and enhances long-term fertility—benefits also reflected in the comparison table, which notes better soil health and biodiversity under Zero Tillage.

Despite the lower input use, yield performance remained stable. Zero Tillage yielded 340–440 kg per 0.03 acre (mean: 389.10 kg), compared to 360–420 kg (mean: 387.61 kg) under conventional practices. The larger variability under Zero Tillage (SD: 26.56) versus conventional farming (SD: 12.09) is attributed to the delayed implementation of the intervention. Many farmers were unable to utilize the full cropping window, resulting in early harvesting before optimum maturity. Under timely implementation, the variability is expected to decrease, and yields may increase further, as supported by research on conservation agriculture in the eastern Indo-Gangetic plains.

The most substantial impact of Zero Tillage appears in its economic performance. Average cultivation cost dropped from ₹3,483.94 (conventional) to ₹2,179 (Zero Tillage), a reduction of 37.45%. Even the maximum Zero Tillage cost (₹2,840) was lower than the minimum cost

under conventional farming (₹3,165), indicating far lower financial risk. Coupled with higher market price realization for cleaner, blemish-free potatoes, Zero Tillage generated an average income of ₹11,673 compared to ₹5,814 under the conventional method. Consequently, net profit increased from ₹2,330.21 to ₹9,494, representing a 307% increase in profitability. The entire income distribution shifted upward: the lowest Zero Tillage income (₹10,500) exceeded the highest income under conventional farming (₹6,300). This complete upward shift suggests that Zero Tillage not only improves average profitability but also reduces the likelihood of low-income outcomes.

Beyond economic returns, farmers expressed positive feedback regarding reduced labour intensity, lower physical drudgery, and simpler field management. The weed-suppressing effect of straw mulch and the elimination of heavy land preparation reduced dependence on hired labour—a significant advantage in areas facing labour shortages and rising wage rates. Zero Tillage also supports environmental sustainability by utilizing rice straw that would otherwise be burned, thereby reducing air pollution and contributing to climate-smart agriculture goals.

While the overall results strongly support the agronomic and economic viability of Zero Tillage potato cultivation, the pilot's limitations should be acknowledged. The intervention began late in the season, affecting crop duration and yield consistency. Additionally, the study was conducted over a single season in one block; long-term, multi-season evaluation is required to assess cumulative soil health gains and broader adoption potential.

Despite these limitations, the pilot provides compelling evidence that Zero Tillage potato cultivation under rice straw mulch is a cost-effective, resource-efficient, environmentally sustainable, and scalable practice. With adequate training, timely implementation, and institutional support, the method can significantly enhance profitability, reduce input dependency, improve soil health, and strengthen livelihood resilience among small and marginal farmers across Bihar.

6. Conclusion

The findings of this study clearly establish that Zero Tillage potato cultivation under rice straw mulch offers a highly efficient, low-cost, and sustainable alternative to the conventional tillage-based system practiced by small and marginal farmers in Matihani block. By eliminating ploughing, reducing seed requirement, minimizing irrigation rounds, and relying largely on organic inputs, Zero Tillage significantly lowers the cost of cultivation while maintaining comparable yields. The method not only reduces financial risk but also improves seed-use efficiency, labour productivity, and water-use efficiency—benefits that are particularly important for resource-poor farming households.

Economically, the impact is substantial. Cultivation costs declined by nearly 37%, while net profit increased more than threefold, with even the lowest Zero Tillage income surpassing the highest income under conventional practices. This demonstrates a complete upward shift in the income distribution, making Zero Tillage a more reliable and profitable option. Furthermore, the use of rice straw as mulch enhances soil moisture retention, suppresses weed growth without the need for herbicides, and contributes to long-term soil health—strengthening the ecological foundation for sustainable production.

Although the pilot faced timing constraints that affected yield uniformity, the results show that with timely implementation and continued farmer training, Zero Tillage potato farming has the potential to deliver even higher productivity. The method aligns closely with principles of climate-smart agriculture, reduces labour drudgery, and lowers dependency on chemical inputs, thereby promoting both economic and environmental resilience.

Overall, this study concludes that Zero Tillage potato cultivation is a scalable, climate-resilient, economically viable, and farmer-friendly practice that can significantly enhance livelihoods when adopted at larger scale. Strengthening extension support, ensuring input

access, and promoting community-level awareness can help accelerate widespread adoption and long-term sustainability of this transformative cultivation method.

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