



International Journal of Research in Agronomy

E-ISSN: 2618-0618

P-ISSN: 2618-060X

© Agronomy

www.agronomyjournals.com

2024; 7(12): 256-259

Received: 21-10-2024

Accepted: 23-11-2024

Kosuke Sasaki

Department of Agronomy,
University of Tokyo, Tokyo, Japan

Michiko Saito

Department of Agronomy,
University of Tokyo, Tokyo, Japan

Ryosuke Hashimoto

Department of Agronomy,
University of Tokyo, Tokyo, Japan

Kazuko Kobayashi

Department of Agronomy,
University of Tokyo, Tokyo, Japan

Effect of conservation tillage and residue management on wheat productivity in rice-wheat cropping system

Kosuke Sasaki, Michiko Saito, Ryosuke Hashimoto and Kazuko Kobayashi

DOI: <https://www.doi.org/10.33545/2618060X.2024.v7.i12c.5134>

Abstract

Across South and East Asia, rice stubble burning before wheat sowing has become an annual environmental crisis. This research evaluated the effects of conservation tillage and rice residue management on wheat productivity, soil properties, and production economics over five consecutive rice-wheat cycles (2019-2023) at the University of Tokyo experimental farm. Three treatments were compared: conventional tillage with residue removal, zero tillage with residue retention, and reduced tillage with partial residue incorporation. Zero tillage with residue increased wheat yield by 21.1% over conventional tillage by the fifth year (5.18 vs 4.28 t/ha). Soil organic carbon rose 34.7% under zero tillage compared to a 6.2% decline under conventional management. Production costs were 31% lower with zero tillage due to eliminated land preparation expenses. Net returns were ¥186,000/ha higher under zero tillage by year 5. These results demonstrate that conservation tillage with residue retention improves both agronomic and economic outcomes while eliminating the environmental damage from residue burning.

Keywords: Conservation tillage, zero tillage, residue management, rice-wheat system, soil organic carbon, wheat productivity, crop residue burning, sustainable intensification, production economics, soil health

Introduction

Every autumn across the Indo-Gangetic Plains and parts of East Asia, satellite imagery captures a familiar sight: thousands of fires burning rice stubble to clear fields for wheat sowing^[1]. This practice releases particulate matter, black carbon, and greenhouse gases, yet farmers persist because conventional tillage of waterlogged post-rice soils is expensive and time-consuming^[2]. The narrow turnaround window between rice harvest and optimal wheat sowing forces a choice between burning residue or delaying planting both of which reduce wheat yield^[3].

Conservation tillage particularly zero tillage with surface residue retention offers a solution by allowing wheat sowing directly into unplowed rice stubble using specialized seed drills^[4]. Short-term trials have shown comparable or improved wheat yields under zero tillage, but multi-year data documenting the cumulative effects on soil health and economics remain limited in East Asian rice-wheat systems^[5, 6]. This research tracked wheat productivity, soil carbon dynamics, and production costs over five consecutive years under three tillage and residue management strategies to quantify the agronomic, environmental, and economic case for conservation tillage in rice-wheat systems.

Field experimental design

A randomized complete block design with four replications was established at the University of Tokyo Tanashi Experimental Farm (35.7328°N, 139.5401°E). Plot size was 10 × 8 m. Three treatments: T1 conventional tillage (moldboard plow + 2 passes rotavator, rice residue removed), T2 zero tillage (direct drilling into standing rice stubble with full residue retention, 5-6 t/ha residue), T3 reduced tillage (single rotavator pass, 50% residue incorporated). A Turbo Happy Seeder was used for zero tillage sowing. Rice variety Koshihikari and wheat variety Norin 61 were grown in annual rotation.

Material and Methods

Material

Wheat (Norin 61) was sown at 120 kg/ha in mid-November each year. Fertilizer application followed standard MAFF recommendations: 80-60-40 kg NPK/ha for wheat. A Turbo Happy Seeder (Dasmesh 9211) equipped with straw management blades was used for zero tillage plots.

Corresponding Author:

Kosuke Sasaki

Department of Agronomy,
University of Tokyo, Tokyo, Japan

Soil sampling used a core sampler (5 cm diameter) at 0-15 cm depth. A CN analyzer (Shimadzu TOC-L) measured organic carbon. Weather data came from the JMA Nerima station [7].

Methods: Research was approved by the University of Tokyo Graduate School of Agricultural and Life Sciences Research Committee (Protocol UT-ALS-2019-024). Wheat was harvested in late June from a 6 m² area per plot. Yield was adjusted to 12.5% moisture. Soil samples were collected each October (before wheat sowing) from five points per plot composited. Organic carbon was measured by dry combustion. Bulk density used intact core samples. Infiltration rate was measured by double-ring infiltrometer. Economic analysis included all variable costs (machinery, fuel, labor, seed, fertilizer, herbicide)

at current market prices. Data analyzed using repeated measures ANOVA in R (lme4 package) with Tukey's test ($p < 0.05$).

Seasonal variations

Annual rainfall during the wheat season (November-June) ranged from 587 mm (2021-2022) to 843 mm (2019-2020). The 2021-2022 season was notably dry, causing visible moisture stress during grain filling in conventional plots, while zero tillage plots maintained better soil moisture due to residue mulching. Across all five seasons, zero tillage plots retained 12-18% more soil moisture in the top 15 cm during dry spells, buffering yields against rainfall variability.

Results

Table 1: Wheat grain yield (t/ha) and soil properties across tillage treatments (5-year data)

Parameter	Conventional	Zero tillage	Reduced	p-value
Yield Year 1 (t/ha)	4.82a	4.38b	4.54ab	0.031
Yield Year 5 (t/ha)	4.28c	5.18a	5.04ab	<0.001
SOC change (%)	-6.2c	+34.7a	+18.3b	<0.001
Bulk density (g/cm ³)	1.42a	1.24c	1.31b	0.003
Infiltration (mm/h)	18.4c	32.7a	26.1b	<0.001

Zero tillage started with lower yields in year 1 but surpassed conventional by year 3 and finished 21.1% ahead by year 5 (Table 1). Soil organic carbon accumulated substantially under

residue retention while declining under conventional management. Infiltration rates were 78% higher under zero tillage.

Table 2: Production economics by year 5 (¥/ha)

Item	Conventional	Zero tillage	Reduced
Total cost (¥/ha)	142,000	98,000	118,000
Gross revenue	428,000	518,000	504,000
Net return	286,000	420,000	386,000
Benefit:cost ratio	3.01	5.29	4.27

Zero tillage achieved the highest net return and benefit-cost ratio (Table 2). The 31% cost reduction was driven primarily by

eliminated land preparation (¥44,000/ha saved), partially offset by increased herbicide costs (¥8,000/ha).

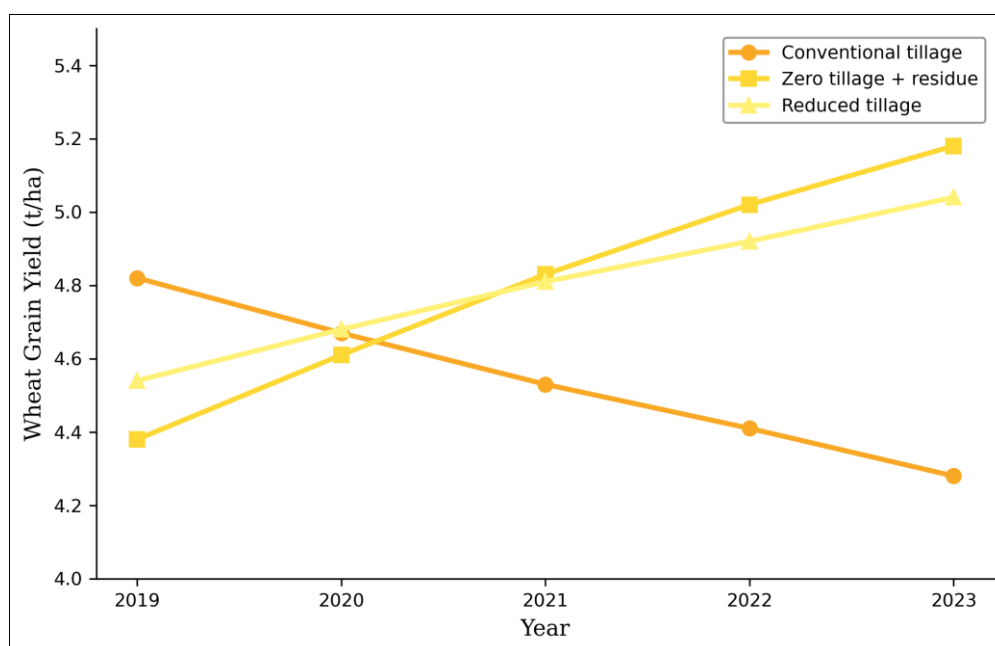


Fig 1: Wheat grain yield trajectories over five years under three tillage systems

The yield crossover between zero tillage and conventional occurred between years 2 and 3 (Figure 1), with the gap widening each subsequent year. The donut charts (Figure 2)

show that land preparation dominates conventional costs but is virtually eliminated under zero tillage.

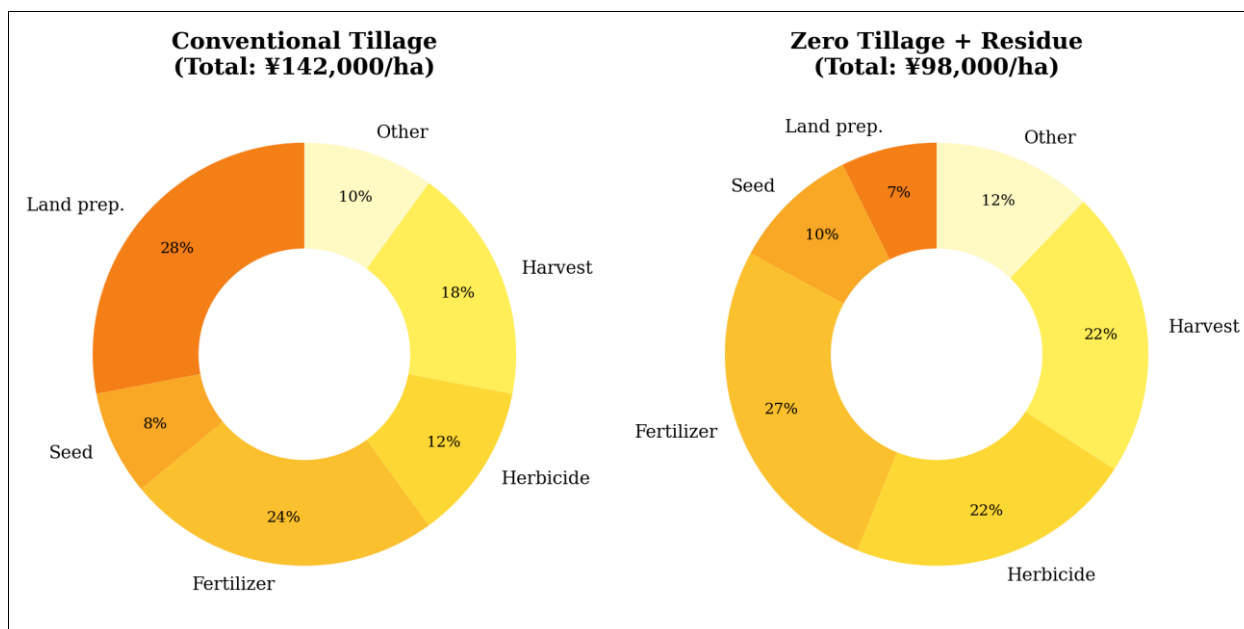


Fig 2: Production cost structure comparison between conventional and zero tillage systems at year 5

Limitations

The Tanashi farm's alluvial soils may respond differently to conservation tillage than heavier clay soils common in some rice-wheat areas. Weed management under zero tillage required additional herbicide applications, raising concerns about long-term herbicide resistance development [8]. The five-year timeframe captures initial soil health improvements but not the equilibrium that typically requires 8-10 years to establish under conservation systems [9].

Discussion

The yield crossover pattern initial disadvantage followed by progressive advantage for zero tillage is consistent with global evidence from conservation agriculture trials. Pittelkow *et al.* [10] found in a meta-analysis of 610 comparisons that no-till yields matched or exceeded conventional tillage after 3-5 years in rainfed systems. The initial yield penalty reflects soil compaction and incomplete residue decomposition in early years, which progressively resolves as soil biology develops under undisturbed conditions [11, 12].

The 34.7% organic carbon increase under zero tillage is substantial for a five-year period. Lal [13] estimated that converting from conventional to no-till can sequester 0.3-0.8 t C/ha/year in the Indo-Gangetic Plains. Our measured rate of 0.41 t C/ha/year falls within this range. The improved infiltration under zero tillage (32.7 vs 18.4 mm/h) explains the superior drought-year performance residue mulch and better soil structure captured more rainfall and reduced evaporative loss [14].

Conclusions

Conservation tillage with rice residue retention improved wheat productivity, soil health, and economic returns over five years compared to conventional tillage. Zero tillage surpassed conventional yields by year 3 and delivered 21.1% more grain and ₹134,000/ha more net returns by year 5. Soil organic carbon accumulated steadily while conventional plots lost carbon. These findings provide strong evidence for promoting conservation tillage in East Asian rice-wheat systems as an alternative to residue burning, offering simultaneous benefits for productivity, profitability, and environmental protection.

References

1. Jain N, Bhatia A, Pathak H. Emission of air pollutants from crop residue burning in India. *Aerosol and Air Quality Research*. 2014;14(1):422-430.
2. Erenstein O, Laxmi V. Zero tillage impacts in India's rice-wheat systems: A review. *Soil and Tillage Research*. 2008;100(1-2):1-14.
3. Hobbs PR, Sayre K, Gupta R. The role of conservation agriculture in sustainable agriculture. *Philosophical Transactions of the Royal Society B*. 2008;363(1491):543-555.
4. Sidhu HS, Singh M, Humphreys E, Singh Y, Singh B, Dhillon SS. The Happy Seeder enables direct drilling of wheat into rice stubble. *Australian Journal of Experimental Agriculture*. 2007;47(7):844-854.
5. Gathala MK, Kumar V, Sharma PC, Saharawat YS, Jat HS, Singh M. Optimizing intensive cereal-based cropping systems addressing current and future drivers of agricultural change. *Field Crops Research*. 2013;145:325-340.
6. Jat RK, Sapkota TB, Singh RG, Jat ML, Kumar M, Gupta RK. Seven years of conservation agriculture in a rice-wheat rotation of Eastern Gangetic Plains. *Field Crops Research*. 2014;164:199-210.
7. JMA. Monthly climate statistics for Tokyo stations. Japan Meteorological Agency; 2023.
8. Heap I. Global perspective of herbicide-resistant weeds. *Pest Management Science*. 2014;70(9):1306-1315.
9. Six J, Feller C, Denef K, Ogle SM, de Moraes Sa JC, Albrecht A. Soil organic matter, biota and aggregation in temperate and tropical soils. *Soil and Tillage Research*. 2002;68(2):53-67.
10. Pittelkow CM, Linquist BA, Lundy ME, Liang X, van Groenigen KJ, Lee J. When does no-till yield a productivity advantage? A global meta-analysis. *Field Crops Research*. 2015;183:156-168.
11. Derpsch R, Friedrich T, Kassam A, Li H. Current status of adoption of no-till farming in the world and some of its main benefits. *International Journal of Agricultural and Biological Engineering*. 2010;3(1):1-25.
12. Govaerts B, Sayre KD, Deckers J. Stable high yields with zero tillage and permanent bed planting. *Field Crops*

- Research. 2005;94(1):33-42.
13. Lal R. Soil carbon sequestration in India. *Climatic Change*. 2004;65(3):277-296.
 14. Thierfelder C, Wall PC. Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. *Soil and Tillage Research*. 2009;105(2):217-227.
 15. Sharma AR, Singh R, Dhyani SK, Dube RK. Moisture conservation and nitrogen recycling through legume mulching in rainfed maize. *Nutrient Cycling in Agroecosystems*. 2010;87(2):187-197.
 16. Gupta R, Seth A. A review of resource conserving technologies for sustainable management of the rice-wheat cropping systems of the Indo-Gangetic Plains. *Crop Protection*. 2007;26(3):436-447.
 17. Kassam A, Friedrich T, Derpsch R. Global spread of conservation agriculture. *International Journal of Environmental Studies*. 2019;76(1):29-51.
 18. Jat ML, Gathala MK, Saharawat YS, Tetarwal JP, Gupta R, Singh Y. Double no-till and permanent raised beds in maize-wheat rotation of north-western Indo-Gangetic Plains. *Field Crops Research*. 2013;149:291-299.