



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating: 5.20
www.agronomyjournals.com
2025; 8(3): 57-59
Received: 11-01-2025
Accepted: 17-02-2025

Atieno Ochieng
Department of Environmental
Science, University of Nairobi,
Nairobi, Kenya

Otieno Kiptoo
Department of Environmental
Science, University of Nairobi,
Nairobi, Kenya

Achieng Kiplagat
Department of Environmental
Science, University of Nairobi,
Nairobi, Kenya

Kipchoge Nyongesa
Department of Environmental
Science, University of Nairobi,
Nairobi, Kenya

Assessment of carbon sequestration potential of conservation agriculture in tropical agro-ecosystems

Atieno Ochieng, Otieno Kiptoo, Achieng Kiplagat and Kipchoge Nyongesa

DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i3a.5138>

Abstract

Conservation agriculture (CA) has been promoted across tropical Africa for two decades, yet field-level carbon sequestration evidence from East African highlands remains thin. This research quantified soil organic carbon (SOC) changes under five management systems over five years (2018-2023) at the University of Nairobi's Kabete Field Station. SOC in the 0-30 cm layer increased by 48.6% under full CA (no-till + cover crop + rotation) compared with a 9.9% decline under conventional tillage. Cumulative sequestration reached 5.15 Mg C/ha over five years. These findings indicate integrated CA packages can meaningfully rebuild soil carbon in degraded tropical croplands.

Keywords: Conservation agriculture, carbon sequestration, soil organic carbon, no-till farming, cover crops, crop rotation, tropical soils, climate change mitigation, soil health, East Africa

Introduction

When colonial-era officers first introduced the mouldboard plough to East African highlands in the 1920s, they assumed soil inversion would benefit crops just as it did in temperate Europe. A century later, the consequences are visible: eroded topsoils, depleted organic matter, and declining yields ^[1]. SOC in cultivated Kenyan soils has fallen 30-50% since conversion from native vegetation ^[2]. Conservation agriculture—minimal disturbance, permanent cover, and diversified rotations—offers a reversal pathway ^[3]. Global meta-analyses estimate CA can sequester 0.3-0.8 Mg C/ha/year in tropical systems ^[4], but rates vary with soil type and adoption completeness ^[5, 6]. This research tracked SOC under five management intensities over five years at Kabete, Kenya ^[7].

Materials and Methods

Materials

The trial was established at the University of Nairobi's Kabete Field Station (1.25°S, 36.74°E, 1820 m asl) on a humic Nitisol. Baseline properties (0-30 cm): pH 5.4, SOC 14.2 g/kg, total N 1.38 g/kg, clay content 62%. Five treatments were tested: T1—conventional tillage (disc plough + harrowing); T2—minimum tillage (single ripping); T3—no-till with herbicide-based weed control; T4—no-till + *Mucuna pruriens* cover crop; T5—full CA (no-till + cover crop + maize-bean rotation). Plot size was 10 m × 12 m ^[8].

Methods

A randomised complete block design with four replications was used. Soil samples were collected annually at three depths (0-10, 10-20, 20-30 cm). SOC was determined by Walkley-Black wet oxidation ^[9]. Bulk density was measured for stock calculations: SOC stock = concentration × bulk density × depth × 0.1. Crop yields and residue biomass were recorded each season. Repeated-measures ANOVA with Tukey's HSD ($p < 0.05$) was performed in GenStat v21. The research ran October 2018-September 2023 ^[10].

Corresponding Author:
Atieno Ochieng
Department of Environmental
Science, University of Nairobi,
Nairobi, Kenya

Results

Table 1: Soil organic carbon (g/kg) at year 5 by treatment and soil depth

Depth (cm)	Conv. till	Min. till	No-till	NT+cover	Full CA
0-10	11.4±0.8d	16.7±1.1c	18.3±1.3bc	20.8±1.4ab	23.1±1.6a
10-20	12.1±0.9c	14.8±1.0b	15.4±1.1b	16.9±1.2ab	18.4±1.3a
20-30	13.6±0.7b	14.1±0.9b	14.7±1.0ab	15.3±1.1ab	16.2±1.2a
Mean 0-30	12.4±0.8d	15.2±1.0c	16.1±1.1bc	17.7±1.2b	19.2±1.4a

Different letters within rows indicate significant differences at $p < 0.05$. Baseline SOC was 14.2 g/kg across all depths. Mean $\pm$ SD ($n = 4$).

After five years, SOC ranged from 12.4 g/kg under conventional tillage to 19.2 g/kg under full CA (Table 1). The greatest differences appeared in the 0-10 cm layer. Conventional tillage

was the only treatment where SOC fell below the 14.2 g/kg baseline.

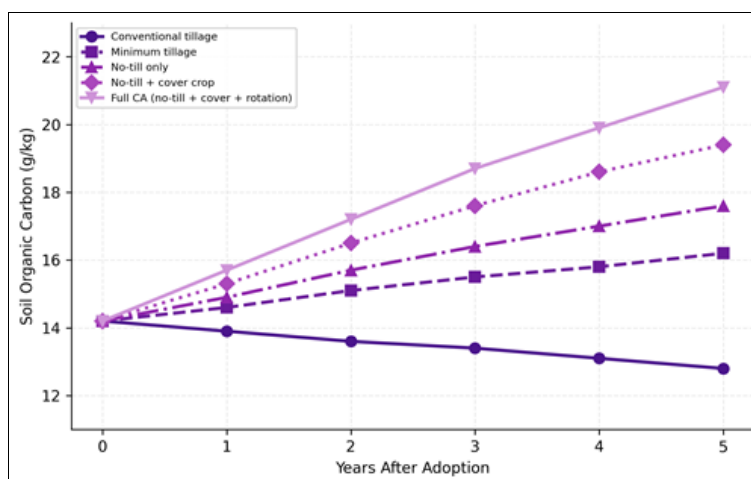


Fig 1: Soil organic carbon concentration (g/kg, 0-30 cm mean) over five years under different management systems

Table 2: Cumulative carbon sequestration (Mg C/ha) and annual rates by treatment over five years

Treatment	Cumulative (Mg C/ha)	Annual rate (Mg C/ha/yr)	Residue input (Mg/ha/yr)	Maize yield (t/ha)
Conventional	-1.47±0.21d	-0.29±0.04d	3.8±0.4c	3.92±0.31c
Minimum till	1.83±0.24c	0.37±0.05c	4.6±0.5bc	4.38±0.34b
No-till	2.67±0.31b	0.53±0.06b	5.1±0.5b	4.51±0.37b
NT + cover	3.94±0.38a	0.79±0.08a	7.3±0.7a	4.74±0.39ab
Full CA	5.15±0.43a	1.03±0.09a	8.1±0.8a	5.12±0.41a

Different letters within columns indicate significant differences at $p < 0.05$. Mean $\pm$ SD ($n = 4$). Negative values indicate net carbon loss.

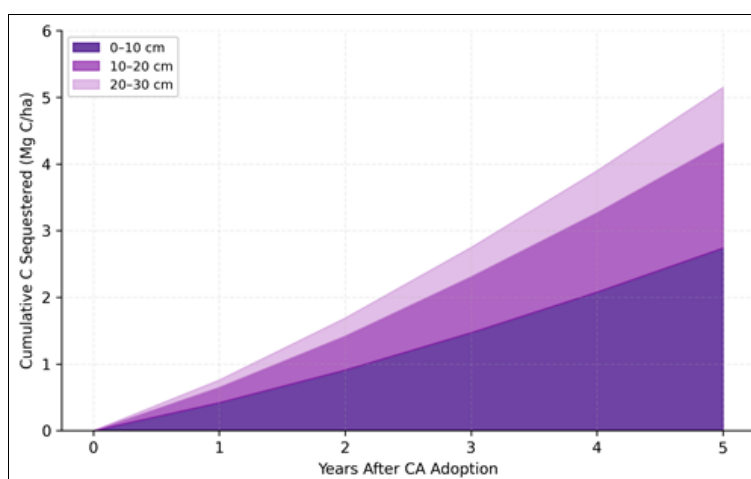


Fig 2: Cumulative carbon sequestration (Mg C/ha) under full CA by soil depth layer over five years

Full CA sequestered 5.15 Mg C/ha at 1.03 Mg C/ha/year (Table 2). The 0-10 cm layer accounted for 53.2% of total sequestration (Figure 2). Maize yields under full CA were 30.6% higher than conventional tillage, indicating carbon gains didn't come at a productivity cost.

Discussion

The annual sequestration rate of 1.03 Mg C/ha/year under full CA exceeds the 0.3-0.8 Mg C/ha/year tropical range [4], likely because Kabete's humic Nitisol has high clay content (62%) and strong organo-mineral stabilisation [11]. The steep SOC gradient

between surface and deeper layers reflects surface-concentrated residue inputs typical of no-till systems^[5]. Conventional tillage's continued SOC decline highlights the carbon cost of soil inversion where warm temperatures accelerate decomposition^[12]. The +30.6% yield advantage agrees with sub-Saharan trials showing 15-35% gains once CA stabilises after 2-3 years^[6]. Cover crop biomass was the main driver separating partial from full CA^[13].

Conclusion

Full CA sequestered 5.15 Mg C/ha over five years on a Kenyan Nitisol, while conventional tillage lost 1.47 Mg C/ha. Partial adoption delivered roughly half the carbon benefit. For tropical smallholders seeking productivity and climate mitigation, these results argue for the complete CA package. Carbon gains were concentrated in the top 10 cm, making surface soil protection through permanent cover especially important^[14].

References

1. Nyberg G, Bargues Tobella A, Kinyangi J, Ilstedt U. Soil property changes over a 120-year chronosequence from forest to agriculture in western Kenya. *Geoderma*. 2012;179:41-47.
2. Bationo A, Hartemink A, Lungu O, Naimi M, Okoth P, Smaling E. African soils: their productivity and profitability of fertilizer use. In: Background paper for Africa Fertilizer Summit. Nairobi: IFDC; 2006.
3. Kassam A, Friedrich T, Derpsch R. Global spread of conservation agriculture. *Int J Environ Stud*. 2019;76(1):29-51.
4. Powlson DS, Stirling CM, Jat ML, Gerard BG, Palm CA, Sanchez PA. Limited potential of no-till agriculture for climate change mitigation. *Nat Clim Chang*. 2014;4(8):678-683.
5. Corbeels M, Marchao RL, Neto MS, Ferreira EG, Madari BE, Scopel E. Evidence of limited carbon sequestration in soils under no-tillage systems in the cerrado of Brazil. *Sci Rep*. 2016;6:21450.
6. Thierfelder C, Wall PC. Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe. *Soil Tillage Res*. 2009;105(2):217-227.
7. Hobbs PR, Sayre K, Gupta R. The role of conservation agriculture in sustainable agriculture. *Philos Trans R Soc B*. 2008;363(1491):543-555.
8. Lal R. Soil carbon sequestration impacts on global climate change and food security. *Science*. 2004;304(5677):1623-1627.
9. Nelson DW, Sommers LE. Total carbon, organic carbon, and organic matter. In: Sparks DL, editor. *Methods of soil analysis*. Part 3. Madison: SSSA; 1996. p. 961-1010.
10. Payne RW, Murray DA, Harding SA. *An introduction to the GenStat command language*. 18th ed. Hemel Hempstead: VSN International; 2017.
11. Six J, Conant RT, Paul EA, Paustian K. Stabilization mechanisms of soil organic matter: implications for C-saturation of soils. *Plant Soil*. 2002;241(2):155-176.
12. Davidson EA, Janssens IA. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature*. 2006;440(7081):165-173.
13. Blanco-Canqui H, Shaver TM, Lindquist JL, Shapiro CA, Elmore RW. Cover crops and ecosystem services: insights from studies in temperate soils. *Agron J*. 2015;107(6):2449-2474.
14. Govaerts B, Verhulst N, Castellanos-Navarrete A, Sayre

KD, Dixon J, Dendooven L. Conservation agriculture and soil carbon sequestration. *Crit Rev Plant Sci*. 2009;28(3):97-122.