

## Supplementary Material

### Improvement of Active Organic Carbon Distribution and Soil Quality with The Combination of Deep Tillage and No-Tillage Straw Returning Mode

#### Supplementary Tables

**Table S1.** Soil weight of different soil layers treated by varying straw return modes and N application rates per unit area (t/ha).

Treatments	0–10cm	10–20cm	20–30cm	30–40cm
NPT–N0	1194.03±39.38Bbc	1503.53±88.36Aab	1563.70±39.80Aab	1455.63±49.69Ac
NPT–N192	1284.20±37.70Cb	1358.33±64.41BCbc	1472.47±93.41ABbc	1552.40±49.95Aab
NPT–N240	1166.65±70.65Cc	1321.40±91.95BCc	1392.20±119.00ABc	1551.37±55.17Aab
RT–N0	1138.53±41.73Bc	1502.17±114.10Aab	1580.10±33.62Aab	1527.73±50.74Aabc
RT–N192	1158.40±62.01Bc	1536.20±94.92Ba	1530.60±39.16Bab	1474.33±39.05Abc
RT–N240	1175.33±98.19Bc	1562.43±43.30Ba	1606.77±33.71Ba	1508.23±38.53Aabc
Before the experiment	1496.77±25.80Ba	1511.50±18.74Ba	1563.55±30.72Aab	1580.12±22.33Aa

**Note:** The values are showed as means ± standard deviation (n=3). Different lowercase letters in a column mean significant difference at 5% level among different treatments, and different uppercase letters in a row mean significant difference at 5% level among different soil layers.

**Table S2.** Differences between SOC storage in various soil layers (0–40 cm) of different treatment and before the experiment.

Storage	Treatments	0–10cm	10–20cm	20–30cm	30–40cm	Total (0–40cm)
SOC (t/ha)	NPT–N0	13.76±2.13ABc	16.46±2.71Aa	14.42±2.10ABbc	12.30±0.79Bbc	56.94±6.35b
	NPT–N192	14.69±1.16Abc	16.53±2.49Aa	15.47±2.33Aab	13.94±1.11Aa	60.63±6.23ab
	NPT–N240	13.88±1.16Bc	16.35±1.56Aa	16.80±0.58Aa	13.72±1.33Bab	60.74±4.21ab
	RT–N0	20.80±0.34Aa	16.74±0.61Ba	12.41±0.13Cc	13.06±0.49Cab	63.02±1.20ab
	RT–N192	22.40±1.19Aa	16.67±0.98Ba	13.00±0.54Cc	12.65±0.54Cab	64.72±0.64a
	RT–N240	21.08±0.67Aa	15.84±2.67Aa	12.19±0.89Cc	11.78±0.23Cc	60.89±2.67ab
	Before the experiment	16.40±0.46Ab	16.01±0.63Aa	13.02±0.47Bc	12.54±0.24Bab	57.98±1.22ab

Note: The values are showed as means ± standard deviation (n=3). Different lowercase

letters in a column mean significant difference at 5% level among different treatments, and different uppercase letters in a row mean significant difference at 5% level among different soil layers.

**Table S3.** SOC and its active fractions (MBC, DOC, LOC) content in different soil layers under various return methods and N fertilizer rates.

Soil depth (cm)	Treatments	MBC (mg/kg)	DOC (mg/kg)	LOC (g/kg)	SOC (g/kg)
0–10	NPT–N0	57.67±6.55Bc	27.24±6.08Ac	1.61±0.42Ac	8.57±1.33ABb
	NPT–N192	108.10±13.61Bb	42.01±12.49Ac	1.73±0.31Ac	9.14±0.72Ab
	NPT–N240	77.35±6.76Cc	36.90±11.16Ac	2.89±0.25Aab	8.64±0.72Bb
	RT–N0	175.68±13.95Aa	67.59±7.14Ab	2.32±0.38Ab	12.95±0.21Aa
	RT–N192	189.78±9.81Aa	82.94±12.19Aab	3.01±0.28Aa	13.94±0.74Aa
	RT–N240	164.30±11.83Aa	89.74±0.62Aa	2.55±0.28Aab	13.12±0.41Aa
10–20	NPT–N0	103.35±3.56Ac	28.40±6.48Ab	1.46±0.10Aa	10.24±1.69Aa
	NPT–N192	200.36±16.05Aa	45.30±9.04Aa	1.35±0.12ABa	10.29±1.55Aa
	NPT–N240	184.84±5.58Aa	46.63±8.26Aa	1.17±0.34Ba	10.17±0.97Aa
	RT–N0	137.63±5.38Bb	54.27±2.59Ba	1.40±0.12Ba	10.42±0.38Ba
	RT–N192	148.06±2.21Bb	55.41±12.65Ba	1.56±0.25Ba	10.37±0.61Ba
	RT–N240	149.65±10.45Ab	58.25±3.06Ba	1.77±0.84ABa	9.86±1.66Ba
20–30	NPT–N0	65.42±3.88Bd	23.07±1.65ABbc	0.83±0.21Bd	8.97±1.31ABbc
	NPT–N192	209.33±8.36Aa	36.58±12.09ABab	1.23±0.13Bbc	9.63±1.45Aab
	NPT–N240	124.53±2.59Bb	47.44±10.83Aa	1.20±0.11Bbcd	10.45±0.36Aa
	RT–N0	73.30±5.71Cd	24.47±6.56Cbc	2.07±0.42Aa	7.72±0.08Cc
	RT–N192	104.13±3.38Cc	17.77±3.56Cc	1.58±0.09Bb	8.09±0.34Cbc
	RT–N240	95.94±5.16Bc	16.46±1.86Cc	0.97±0.09BCcd	7.59±0.55Cc
30–40	NPT–N0	50.74±10.55Bc	17.17±0.71Bab	0.82±0.12Bab	7.66±0.49Bc
	NPT–N192	97.23±6.82Ba	18.83±2.09Ba	1.20±0.27Ba	8.68±0.69Aa
	NPT–N240	84.11±12.58Cab	17.09±3.31Bab	1.08±0.50Bab	8.54±0.83Bab
	RT–N0	72.75±11.80Cab	17.88±1.84Ca	1.23±0.18Ba	8.13±0.31Cab
	RT–N192	82.21±14.32Cab	16.88±0.82Cab	1.09±0.35Bab	7.87±0.34Cab
	RT–N240	57.27±10.70Cbc	14.05±0.62Cb	0.57±0.34Cb	7.33±0.14Cc

Note: The values are showed as means  $\pm$  standard deviation (n=3). Different lowercase letters in a column mean significant difference at 5% level among different treatments, and different uppercase letters in a row mean significant difference at 5% level among different soil layers.

**Table S4.** Stratification ratios of SOC and its active fractions (MBC, DOC, LOC) in different soil layers under various return methods and N fertilizer rates (SR1, SR2, SR3).

Stratification ratios	Treatments	MBC	DOC	LOC	SOC
SR1	NPT-N0	0.56 $\pm$ 0.06c	0.98 $\pm$ 0.24b	1.12 $\pm$ 0.34b	0.84 $\pm$ 0.04b
	NPT-N192	0.55 $\pm$ 0.11c	0.92 $\pm$ 0.13b	1.30 $\pm$ 0.33b	0.90 $\pm$ 0.06b
	NPT-N240	0.42 $\pm$ 0.04c	0.79 $\pm$ 0.21b	2.55 $\pm$ 0.48a	0.85 $\pm$ 0.04b
	RT-N0	1.28 $\pm$ 0.14a	1.24 $\pm$ 0.11ab	1.65 $\pm$ 0.20b	1.24 $\pm$ 0.03a
	RT-N192	1.28 $\pm$ 0.08a	1.56 $\pm$ 0.45a	1.96 $\pm$ 0.32ab	1.35 $\pm$ 0.14a
	RT-N240	1.10 $\pm$ 0.02b	1.54 $\pm$ 0.08a	1.68 $\pm$ 0.80b	1.36 $\pm$ 0.27a
SR2	NPT-N0	0.88 $\pm$ 0.09c	1.18 $\pm$ 0.27c	1.96 $\pm$ 0.36bc	0.96 $\pm$ 0.15b
	NPT-N192	0.52 $\pm$ 0.04d	1.16 $\pm$ 0.18c	1.42 $\pm$ 0.30d	0.96 $\pm$ 0.10b
	NPT-N240	0.62 $\pm$ 0.07cd	0.85 $\pm$ 0.48c	2.40 $\pm$ 0.07ab	0.83 $\pm$ 0.06b
	RT-N0	2.41 $\pm$ 0.36a	2.92 $\pm$ 0.91b	1.14 $\pm$ 0.17d	1.68 $\pm$ 0.05a
	RT-N192	1.82 $\pm$ 0.11b	4.87 $\pm$ 1.66a	1.91 $\pm$ 0.25c	1.72 $\pm$ 0.11a
	RT-N240	1.72 $\pm$ 0.22b	5.50 $\pm$ 0.61a	2.63 $\pm$ 0.29a	1.74 $\pm$ 0.18a
SR3	NPT-N0	1.16 $\pm$ 0.20b	1.59 $\pm$ 0.38d	2.02 $\pm$ 0.73b	1.12 $\pm$ 0.13c
	NPT-N192	1.11 $\pm$ 0.06b	2.28 $\pm$ 0.82d	1.55 $\pm$ 0.64b	1.06 $\pm$ 0.12c
	NPT-N240	0.94 $\pm$ 0.23b	2.25 $\pm$ 0.87d	2.95 $\pm$ 0.92b	1.01 $\pm$ 0.01c
	RT-N0	2.45 $\pm$ 0.31a	3.79 $\pm$ 0.36c	1.90 $\pm$ 0.34b	1.59 $\pm$ 0.04b
	RT-N192	2.34 $\pm$ 0.32a	4.93 $\pm$ 0.80b	2.98 $\pm$ 1.11b	1.77 $\pm$ 0.13a
	RT-N240	2.95 $\pm$ 0.62a	6.40 $\pm$ 0.32a	5.38 $\pm$ 2.45a	1.79 $\pm$ 0.03a

Note: The values are showed as means  $\pm$  standard deviation (n=3). Different lowercase letters in a column mean significant difference at 5% level among different treatments.

**Table S5.** Carbon pool management index in different soil layers under various return methods and N fertilizer rates (AI, CPI, CPMI).

Index	Treatments	0–10cm	10–20cm	20–30cm	30–40cm
AI	NPT-N0	1.14 $\pm$ 0.49Ab	1.09 $\pm$ 0.11Aab	0.29 $\pm$ 0.13Bc	0.68 $\pm$ 0.09ABab
	NPT-N192	1.08 $\pm$ 0.24Ab	0.98 $\pm$ 0.11Aab	0.40 $\pm$ 0.03Bc	0.89 $\pm$ 0.16Aab
	NPT-N240	2.32 $\pm$ 0.31Aa	0.84 $\pm$ 0.24Bb	0.36 $\pm$ 0.05Bc	0.83 $\pm$ 0.44Bab

	RT-N0	1.00b	1.00ab	1.00c	1.00a
	RT-N192	1.28±0.25Ab	1.14±0.15Aab	0.67±0.08Bb	0.91±0.31ABab
	RT-N240	1.11±0.12Ab	1.38±0.53Aa	0.40±0.05Ba	0.48±0.30Bb
CPI	NPT-N0	0.66±0.10Bb	0.98±0.16Aa	1.16±0.17Aabc	0.94±0.06Abc
	NPT-N192	0.71±0.06Cb	0.99±0.15Ba	1.25±0.19Aab	1.07±0.08Aba
	NPT-N240	0.67±0.06Cb	0.98±0.09Ba	1.35±0.05Aa	1.05±0.10Bab
	RT-N0	1.00a	1.00a	1.00c	1.00abc
	RT-N192	1.08±0.06Aa	1.00±0.06Aba	1.05±0.04ABbc	0.97±0.04Babc
	RT-N240	1.01±0.03Aa	0.95±0.16Aa	0.98±0.07Ac	0.90±0.02Ac
CPMI	NPT-N0	72.30±23.55Bd	105.57±5.27Aa	32.66±9.58Cd	63.77±10.03Bab
	NPT-N192	76.25±16.57ABd	96.26±8.54Aa	50.02±5.19Bc	96.01±24.17Aab
	NPT-N240	154.17±18.46Aa	82.50±26.74Ba	48.19±5.27Bc	87.33±46.54Bab
	RT-N0	100.00cd	100.00a	100.00a	100.00a
	RT-N192	136.50±18.53Aab	113.80±20.41ABa	69.78±5.90Cb	88.09±32.68BCab
	RT-N240	112.08±14.75ABbc	135.64±74.53Aa	39.44±3.92Bcd	43.47±28.06Bb

Note: The values are showed as means ± standard deviation (n=3). Different lowercase letters represent different treatments at the 5% level, and different uppercase letters in a row mean significant difference at 5% level among different soil layers, with RT-N0 treated soil as the reference soil.

**Table S6.** Soil active organic carbon storages in various soil layers under different return methods and N application rates.

Storages	Treatments	0–10cm	10–20cm	20–30cm	30–40cm	Total (0–40cm)
MBC (kg/ha)	NPT-N0	92.66±10.52BCe	166.05±5.72Ad	105.11±6.23Bd	81.53±16.95Cd	445.35±34.53d
	NPT-N192	173.69±21.88Bc	321.93±25.78Aa	336.34±13.43Aa	156.22±10.95Ba	988.17±20.48a
	NPT-N240	124.29±10.86Ad	297.00±8.97Ab	200.09±4.17Bb	135.14±20.21Aab	756.52±18.69c
	RT-N0	282.28±22.41Aab	221.14±8.64Bc	117.78±9.17Cd	116.89±18.96Cbc	738.09±37.81c
	RT-N192	304.93±15.77Aa	237.90±3.55Bc	167.32±5.42Cc	132.10±23.01Dab	842.24±34.84b
	RT-N240	263.99±19.01Ab	240.45±16.79Ac	154.16±8.29Bc	92.01±17.19Ccd	750.61±25.92c
DOC (kg/ha)	NPT-N0	43.77±9.78Ac	45.63±10.41Ab	37.08±2.65ABbc	27.58±1.14Bab	154.06±16.37d
	NPT-N192	67.51±20.07Ac	72.79±14.53Aa	58.77±19.43ABab	30.25±3.36Ba	229.32±51.1c
	NPT-N240	59.29±17.93Ac	74.92±13.28Aa	76.23±17.41Aa	27.45±5.31Bab	237.89±10.71bc
	RT-N0	108.60±11.48Ab	87.20±4.16Ba	39.32±10.55Cbc	28.73±2.96Cab	263.84±6.39abc

	RT-N192	133.26±19.59Ab	89.02±20.32Ba	28.55±5.71Cc	27.12±1.32Cab	277.95±18.76ab
	RT-N240	144.19±1.00Aa	93.59±4.91Ba	26.45±2.99Cc	22.57±1.00Cb	286.80±5.91a
LOC (t/ha)	NPT-N0	2.59±0.67Ac	2.35±0.15Aa	1.33±0.33Bd	1.32±0.19Cab	7.59±0.61d
	NPT-N192	2.79±0.49Ac	2.17±0.20ABa	1.98±0.21Bbc	1.92±0.44Ba	8.86±0.40cd
	NPT-N240	4.64±0.40Aab	1.88±0.55Ba	1.93±0.18Bbcd	1.74±0.80Bab	10.19±1.88abc
	RT-N0	3.72±0.61Ab	2.25±0.19Ba	3.32±0.67Aa	1.98±0.28Ba	11.27±1.33ab
	RT-N192	4.83±0.44Aa	2.50±0.41Ba	2.54±0.15Bb	1.75±0.56Bab	11.63±0.15a
	RT-N240	4.09±0.45Aab	2.84±1.35ABa	1.56±0.14BCcd	0.92±0.54Cb	9.40±1.13bcd

Note: The values are showed as means ± standard deviation (n=3). Different lowercase letters in a column mean significant difference at 5% level among different treatments, and different upppercase letters in a row mean significant difference at 5% level among different soil layers.

**Table S7.** The effect of straw return methods and nitrogen fertilizer dosages on maize yield for three consecutive years (2018–2020).

Treatments	Annual yield of maize (t/ha)		
	2018	2019	2020
NPT-N0	5.36±0.65b	5.78±0.82c	5.76±1.24c
NPT-N192	10.28±0.45a	12.43±0.32ab	10.94±0.57a
NPT-N240	9.72±0.54a	12.54±0.30ab	10.75±1.16a
RT-N0	4.97±1.37b	4.20±0.61d	4.23±0.65c
RT-N192	9.05±0.36a	11.29±0.30b	8.90±1.14b
RT-N240	10.10±0.78a	12.98±1.27a	11.32±0.60a

Note: The values are showed as means ± standard deviation (n=3). Different lowercase letters in a column mean significant difference at 5% level among different treatments.