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Tillage and Residue Management Effects on Soil Properties : A Review

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Abstract

Crop residues, a byproduct of crop production that can be managed to maximize various input usage efficiencies, are a widely used practice to conserve agricultural waste. The amount of crop residues generated and burned in 2017-18 was 516 MT and 116 MT, respectively. In India, rice stands first in the overall crop burning which contributes 43% compared to 21, 19 and 5% for wheat, sugarcane, and oilseed, respectively. Burning crop residue is responsible for air pollution outbreaks, radiation imbalance in people, greenhouse gas emissions, and the loss of valuable soil nutrients. Crop residue mulch improved soil quality and crop yield by increasing infiltration of water into soil profile and lessening water runoff and soil erosion. Crop residue mulch improved soil quality in terms of organic carbon and biotic activity. Crop-residue retention promotes nutrient cycling, increases nutrient availability to crops, and increases SOM content.The excessive runoff and soil erosion, low soil fertility, low groundwater availability, erratic rainfall distribution and low inputs these are major contributing factors responsible for the low yields.

Key words : Crop residues, Tillage, Bulk density, Soil organic matter, Reduced tillage and conventional tillage.

A total of 516 MT and 116 MT of crop residues were produced and burned, respectively, in the 2017-18. Every year, India produces about 141 MT of extra crop residue, of which 92 MT is burned. The overall crop residues leftovers (352 million tonnes), account for 70, 34 and 22% from cereal crops, rice, and wheat, respectively. Rice contributes 43% of the overall crop burning, compared to 21, 19 and 5% for wheat, sugarcane, and oilseed, respectively. The significant increase in agricultural residue generation can be attributable to the increase in net sown area and cropping intensity. The net sown area and cropping intensity increased from 118.75 to 140 mha and 111.07% to 139.56% in between 1970-71 to 1950-51 and 2010-11 to 1950-51, respectively. The production of food grains increased from 50 MT in 950-51 to 316.06 MT in 2022 due to an increase in cropping intensity and total cropped area, which resulted in an increase in the production of crop residue.

Low yields are a result of excessive runoff, erratic rainfall patterns, soil erosion, poor soil fertility, a lack of groundwater accessibility and insufficient inputs. The development of an effective management strategy for these soils is necessary to alleviate some of these crop production constraints. However, excessive residue removals in combination with scarce water supply may lower grain yields and degrade the soil by limiting the return of residue nutrients and carbon to the soil and by keeping the top soil unprotected and vulnerable to surface crusting, erosion, and compaction. Due to such competing motivations, we must understand better the tradeoffs involved in residue harvest, particularly about their long-term effects on soil health, water dynamics, and total agricultural profitability. Through several ways, crop residue

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retention can have a noticeable influence on water saving by Schneekloth *et al.*, (2020).

By increasing the amount of water that seeps into the soil profile and reducing water runoff and soil erosion, crop residue mulch enhances soil quality and crop output. Mulching with crop residue enhanced the biotic activity and organic carbon content of soil. Retention of agricultural residue increases nutrient cycling, raises nutrient availability to crops, and raises SOM content.In the R-M systems in the EGP, where the residues of both crops are often removed from the fields, residue retention might play a significant role. In comparison to R-W or rice-rice systems, high-yielding R-M systems extract more nutrients, especially N, P, or K. In addition, retaining the residue from a legume like mungbean can enhance the nitrogen economy of the next cereal crop by Rashid *et al.*, (2019).

Over the past two to three decades, resource-conserving technologies (RCTs) have arisen as a way of ensuring the sustainability of intensive cropping systems. RCTs increase soil fertility by improving biological activity and carbon absorption while using less energy. They help reduce cultivation expenses and create stable yields.Intensive ploughing damages soil structure quickly, oxidized soil organic matter (SOM), boosts labor and fossil fuel demand, raises production costs, and increases greenhouse gas emissions. Three fundamental concepts underlie conservation agriculture: appropriate crop rotation, continuous soil, and no or minimum tillage.The physical, chemical, and biological characteristics of the soil can be enhanced with no or limited tillage (RT) and residue retention.Additionally, drill seeders and RT can reduce labor-intensive tasks and maintain farmers' earning by Rashida *et al.*, (2019).

Reducing tillage has a good impact on several soil properties, but needless and excessive tillage activities result in the opposite phenomenon, which is detrimental to the soil. Conventional tillage techniques alter soil bulk density and moisture content, which results in changes to soil structure. Furthermore, although conservation and no-tillage techniques leave the soil unaltered, recurrent disturbance from conventional tillage results in a finer and looser-setting soil structurebyAlam *et al.*, (2014).

Methodology and Results

Three studies arereviewedin this paper on tillage and residue management effects on soil properties.The study was conductedat Eastern, Colorado,by Schneekloth *et al.* (2020)on tillage and residue management effects on irrigated maize performance and water cycling in a semiarid cropping system. Theyused four treatment combinations as shown in Table 1. According to their analysis, the three years under consideration (2016-2018) had an average maize grain output that varied between 10.5 and 13.6 Mg ha^{-1}. With no discernible effect of residue in 2016, the residue removal considerably lowers grain yields by around 1.0 and 2.0 Mg ha^{-1} in 2017 and 2018, respectively.In the three years taken into consideration, as indicated in Table 1, there was no noticeable impact of tillage on grain yield.Residue increased PSE from 34.2% in RH treatments to 53.8% in plots where residue was maintained (CT-R and NT-R) from 2016 to 2018, whereas residue retention had no effect. Precipitation storage efficiency (PSE) was rather low. During the vegetative development stage, tillage or residue had no obvious influence on evapotranspiration Removing residue often decreases overall infiltration. Both the major effects of tillage and residue had a considerable impact on penetrometer resistance measurements. Given that removing the residue enhanced penetrometer resistance independent of the tillage treatment, residue management had a more noticeable effect than tillage.

In a rice-maize-mungbean system in the Eastern Gangetic Plains, Rashid *et al*. (2014) conducted another experiment to examine the impacts of tillage and residue management on productivity, profitability, and soil parameters. As indicated in Table 2, they utilized a two-factor split-plot design in four replications, assigning tillage treatments to main plots and residue-management treatments to subplots. They found that all soil physical and chemical parameters were significantly affected by the interactions between tillage and residue management. While alternative tillage techniques, in particular PBs, ST, and ZT, reduced bulk density and improved available P, conventional tillage increased bulk density and decreased SOM, total N, and available P. Both bulk density and SOM at 0-15 cm topsoilincreased from 1.24 to 1.55 Mg m-3 and 1.32 (CT) to 1.53% (MT), respectively. Bulk density showed a declining trend with residue retention. After 3 years of Rice-maize-Mungbean (R-M-MB) cropping pattern total N, Soil exchangeable K, exchangeable S and available Zn content of soilincreased from 0.08 (CT) to 0.10% (ST and PB), 0.19 to 0.23-0.26 cmol kg^{-1}, 18.7 to 21.3 μg g^{-1} and 0.41 to 0.52 μg g^{-1}, respectively. Higher yields were found in ST, MT, and ZT compared with CT. A higher grain yield of mungbean in CT compared with alternative tillage options, which could be attributable to better soil pulverization in CT, providing favorable conditions for its growth and yield as shown in Table 2. As compared to Rice and Maize the cost of production of Mung bean was higher in CT than in all alternative tillage options.Due to enhanced decomposition rates and carbon redistribution, conventional tillage has been shown to reduce soil carbon levels in agricultural soils. Additionally, compared to no residue retention, crop residue retention under RT can considerably enhance SOM.

Research was conducted on the effects of tillage and residue management on soil characteristics and wheat and maize yields in a subhumid subtropical environment by Ghuman and Sur *et al*., (2001). They used a split-plot design with four replications with treatment combination as shown in Table 3. Theyreported that the organic carbon (OC) content was significantly increased in the MTR and MT treatments over that of CT treatment in the surface 0.02 m layer. Due to no tillage and no soil redistribution, there was likely reduced oxidation of in situ organic matter (roots, etc.) in the MT treatment, which contributed to the rise in OC. Soil organic carbon content is often higher in soils maintained with conservation tillage than with conventional tillage due to reduced soil erosion, surface runoff, and mineralization of organic matter.Bulk density in the 0-0.1, 0.075 and 0.125 m soil layer was significantly lower in the MTR, MTR, and no-till treatments than the MT-CT, MT while it was not different from the CT and conventionally tilled plots treatment, respectively. This might be the

Table 1. Mean maize grain yields (2016–2018) under different tillage and residue management combinations.

Treatment	2016 (Mg ha^{-1})		2017 (Mg ha^{-1})		2018 (Mg ha^{-1})		Average (Mg ha^{-1})	
NT/R	12.31	0.93	12.90	0.60	13.02	0.71	12.74	0.76
NT/RH	12.19	0.87	11.97	10.50	10.50	1.71	11.55	1.46
CT/R	11.73	1.54	13.58	12.55	12.55	1.38	12.62	1.59
CT/RH	11.74	1.44	12.54	10.56	10.56	1.55	11.61	1.46

(no-till + residue retention (NT-R), no-till + residue harvest (NT-RH), conventional tillage + residue retention (CT-R) and conventional tillage + residue harvest (CT-RH)) for an irrigated corn system near Akron, Colorado., Values in italics to the right of each mean represent the standard deviation of the mean. p values. Source: Schneekloth *et al*., 2020).

Table 2. Grain yield (t ha^{-1}) of maize, mungbean and rice, and rice equivalent system yield (REY) as affected by different tillage and residue management options under a rice-maize-mungbean system.

Tillage option	Residue options											
	Maize yield			Mungbean yield			Rice yield			System REY		
	CR_0	CR_{50}	CR_{100}	CR_0	CR_{50}	CR_{100}	CR_0	CR_{50}	CR_{100}	CR_0	CR_{50}	CR_{100}
2010-11												
ZT	10.4a-e	9.7c-e	10.7a-c	1.15ab	1.12ab	1.13ab	3.77c	4.06bc	4.26bc	16.8b-e	16.4de	17.5a-d
ST	10.1a-e	10.5a-e	11.2a	1.10ab	1.14ab	1.15ab	3.84c	3.90bc	4.41a-c	16.5de	17.0a-e	18.2a
MT	9.9b-e	10.0a-e	10.2a-e	1.06ab	1.18a	1.12ab	3.79c	4.43a-c	4.27bc	16.1e	17.2a-e	17.1a-e
PB	10.8a-c	11.1a	11.1ab	1.22a	1.14ab	1.14ab	4.36bc	4.29bc	4.28bc	17.9a-c	18.0ab	19.9a-c
FB	10.6a-d	11.1a	10.5a-d	1.12ab	1.02b	1.13ab	4.10bc	4.21bc	4.42a-c	17.1a-e	17.6a-d	17.49a-d
CT	9.4de	9.4de	9.3e	1.09ab	1.16ab	1.21a	4.29bc	4.55ab	16.2a	16.2e	16.6c-e	17.2a-e
2011-12												
ZT	10.4a-e	9.8c-e	10.9 ab	1.12c	1.13c	1.22a-c	3.68d	4.21a-d	4.41a-d	17.9d-g	17.6e-g	19.3ab
ST	9.7c-e	10.4e	11.3a	1.13c	1.16bc	1.21a-c	3.97b-d	4.26a-d	4.15a-d	17.3g	18.2b-g	19.7a
MT	10.0b-e	10.0b-e	10.3a-e	1.11c	1.11c	1.24a-c	3.83cd	3.92cd	3.71d	17.5fg	18.1b-g	18.7a-e
PB	10.6a-d	10.7a-c	11.3a	1.21a-c	1.18a-c	1.23a-c	4.35a-d	4.50a-c	4.83a	19.0a-d	18.9a-d	19.7a-d
FB	9.9b-e	11.1a	10.6a-d	1.19a-c	1.16bc	1.24a-c	4.27a-d	4.52a-c	4.74ab	18.0b-g	19.2a-c	19.1a-c
CT	9.4e	9.8c-e	9.6de	1.14bc	1.28ab	1.31a	4.08a-d	4.26d	4.39a-d	17.5g	18.6fg	19.0a-f
2012-13												
ZT	10.1e	10.1de	11.0a-e	1.11bc	1.15bc	1.22a-c	4.58de	4.92c-e	5.78a	18.4e	18.9de	20.8a-c
ST	10.5a-e	10.8a-e	11.0a-e	1.12bc	1.19a-c	1.27ab	4.55e	5.12b-e	5.56ab	18.8de	19.9a-e	20.8a-c
MT	10.3c-e	10.4a-e	11.1a-e	1.19a-c	1.22a-c	1.24a-c	4.61de	5.17b-d	5.27a-c	18.9de	19.6b-e	20.5a-c
PB	10.8a-e	11.7ab	11.7a-c	1.14b-c	1.19a-c	1.16a-c	5.35a-c	5.14b-d	5.80a	20.0a	20.9a-c	21.4a
FB	10.3b-e	11.8a	11.5a-c	1.09c	1.19a-c	1.22a-c	4.89c-e	5.26a-c	5.53ab	19.8ab	21.1a-c	21.1ab
CT	9.9e	10.4a-e	10.4a-e	1.17a-c	1.27ab	1.33a	5.66ab	5.63ab	4.83c-e	19.5c-e	20.3a-d	19.7b-e

(Main effects of tillage and residue management were not significant; Interaction means across columns and rows followed by the same lower-case letters are not significantly different at the 0.05 level of probability by DMRT. ZT = zero tillage, ST = strip tillage, MT = minimum tillage, PB = permanent bed, FB = fresh bed, CT = conventional tillage; CR0 = no retention of crop residues, CR50 = retention of 50% crop residues, CR100 = retention of 100% crop residues. Source: Rashid *et al.*, 2014).

reason for the reduced bulk density because crop residue mulch has been shown to increase soil quality in terms of biotic activity and organic carbon. The mean-weight diameter and geometric mean diameter of soil aggregates was significantly greater in the MTR and MTR treatment than MT and CT treatment, respectively. More water was held in the surface soil layers of minimum-till plots and the 00.05 m layer at saturation (zero suction) and 20 kPa suction than MTR and CT, respectively. In the 0.05-0.10 m layer, the CT treatment retained more water in the soil than the MTR and MT treatments. Under steady state circumstances, cumulative infiltration was greatest in the MTR treatment (0.118 m), middle in the CT (0.105 m), and lowest in the MT treatment (0.099 m). The bulk density has an inverse relationship with the steady state infiltration.Therefore, it was determined that a moisture level of 40 g kg^{-1} in

Table 3. Effect of tillage and crop residue mulch on maize grain yield (Mg ha^{-1})

Treatment	1993	1994	1995	1996	1997
MTR[a]	2.6	3.7	3.7	3.9	4.0
MT[b]	2.6	3.3	2.9	3.0	3.1
CT[c]	2.7	3.9	3.1	3.2	3.2
$LSD_{0.05}$	NS	0.3	0.5	0.4	0.3

([a]Minimum tillage residue. [b]Minimum tillage without residue. cConventional tillage without residue, Source: Ghuman and Sur, 2001).

the seed-zone was sufficient for the successful germination of wheat seed. In 1993 and 1994, respectively, the grain yield was decreased in the MTR treatment compared to the CT treatment by 2.3 and 4.5%. However, as demonstrated in Table 3, where no residue was maintained at the surface under minimal tillage (MT), grain production continuously remained lower than that in CT.The relationship between soil moisture content and nitrogen availability is important in determining how well wheat crops respond to nitrogen application.When compared to MT in 1995–1996 and to both MT and CT in 1996-1997 and 1997-1998, the WUE of wheat was considerably higher in the MTR treatment. N uptake in the MT treatment was noticeably lower than in the MTR and CT treatments.

Conclusion

The impacts of tillage and residue management on soil characteristics have been the subject of several studies; the three studies were evaluated in this work. According to this research, the preservation of residue improved water infiltration (and capture), which has been linked to more effective irrigation operations as well as decreased runoff losses and erosion. In comparison to CT, the grain yield of maize grown under R-M-MB systems may be greater in all alternative tillage options. Retaining agricultural residues can boost soil organic matter (SOM), total N, available P, and available S concentrations as well as crop yields and farmer revenue. In addition, when compared to CT, MTR emerged as a viable alternative soil management technique that might enhance and sustain greater yields of wheat and maize grown with rain.

The investigations mentioned above led to the following conclusions:

1) Long-term conservation tillage and residue management boost crop output by enhancing the physical characteristics of the soil.

2) Additionally, these techniques enhanced soil quality by boosting organic carbon, aggregate formation, infiltration rates, soil water retention, and reducing bulk density close to the soil surface.

3) The productivity and economic return may be lower, zero-tillage cropping systems are more environmentally friendly (contributing to higher soil aggregation, C accumulation, and N availability) and economically sustainable (energy savings).

4) In their various forms, areas with no tillage had the greatest overall percentages of N, P, K, and S.

References

Alam, M. K., Islam, M. M., Salahin, N.andHasanuzzaman, M. 2014. Effect of tillage practices on soil properties and crop productivity in wheat-mungbean-rice cropping system under subtropical climatic conditions. Hindawi

Publishing Corporation Scientific World Journal. 1-15. http://dx.doi.org/10.1155/2014/437283

Baumhardt, R. L., Johnson, G. L. and Schwartz, R. C. 2012. Residue and long term tillage and crop rotation effects on simulated rain infiltration and sediment transport. Soil Sci Soc Am J. 76:1370–1378. https://doi.org/10.2136/sssaj2011.0331

Bhuvaneshwari, S., Hettiarachchi, H. andMeegoda, J. 2019. Crop residue burning in India: Policy challenges and potential solutions. International Journal of Environmental Research and Public Health. doi: 10.3390/ijerph16050832

Ghuman, B. S.and Sur, H. S. 2001. Tillage and residue management effects on soil properties and yields of rainfed maize and wheat in a subhumid subtropical climate. Soil and Tillage Research 58: 1-10.

He, J. H., Li, R. G., Rasaily, Q., Wang, G., Cai, Y.,Su, X. and Liu, L. 2011. Soil Properties and Crop Yields after 11 Years of No Tillage Farming in Wheat-maize Cropping System in North China Plain. Soil and Tillage Research. doi:10.1016/j.still.2011.01.005

Melman, D. A., Kelly, C., Schneekloth, J., Calderon, F. and Fonte, S. J. 2019. Tillage and residue management drive rapid changes in soil macrofauna communities and soil properties in a semiarid cropping system of Eastern Colorado. Appl Soil Ecol. 143:98-106. https:// doi.org/10.1016/j.apsoil.2019.05.022

Potter, K. N., Torbert, H. E. and Morrison, J. 1995. Tillage and residue effects on infiltration and sediment losses on vertisols. Trans ASAE. 38(5): 1413-1419. https://doi.org/10.13031/2013.27965

Rashid, M. H., Timsina, J., Islam, N. and Islam, S. 2019. Tillage and residue-management effects on productivity, profitability, and soil properties in a rice-maize-mungbean system in the Eastern Gangetic Plains. Journal of Crop Improvement. https://doi.org/10.1080/ 15427528.2019.1661056

Sarkar, S., Samui, I., Brahmachari, K., Ray, K., Ghosh, A.and Nanda, M. K. 2019. Management practices for utera pulses in rice-fallow system under coastal saline zone of west bengal. J. Indian Soc. Coast Agric. Res. 37: 98-103.

Schneekloth, J., Calderón, F., Nielsen, D. and Fonte, S. J. 2020. Tillage and residue management effects on irrigated maize performance and water cycling in a semiarid cropping system of Eastern Colorado. Irrigation Science. 38:547–557. https://doi.org/10.1007/s00271-020-00702-2.