Article

Degradation of soil physical properties due to modernization of tillage techniques: A recent man made crisis to agro-ecology in North East India

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Abstract
Present study was undertaken to investigate the role of tillage on soil physical properties of different agro-ecosystems in Lunglei district situated in the south-central part of Mizoram state, northeastern India. Lunglei is located at 22.88°N 92.73°E. Detailed study was conducted in selected land use of the district such as home-garden or agro-forestry, forest and paddy field. Soil samples were then bagged in a polythene bag air-tight and then brought to the laboratory to analyze their soil characteristics with the standard methodologies. It was found that conventional tillage practices cause change in soil structure by modifying soil bulk density, soil moisture content and other characters. Conventional tillage is responsible for the finer and loose-setting soil structure while conservation and no-tillage methods leave the soil structure intact. Therefore, at present there is a considerable concentration and emphasis on the transform from extreme tillage to conservation and no-tillage methods for soil conservation.

Keywords agro-ecosystems; conservation tillage; crop productivity; soil health.

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1 Introduction

Tillage is one of the main agricultural activities practiced by the farmers, by different mechanical agitation such as digging, stirring, overturning etc. This technique is a fundamental agro-technical operations found in various forms, practiced from the very inception of growing plants (Noor et al., 2020). Human-powered tilling methods using hand tools include shoveling, piking, raking etc and animal-powered include ploughing, rototilling etc. With the help of tillage, soils of agricultural fields can be used to obtain ideal environment for seed germination, seedling establishment and growth of crops. Minimum tillage practices have some role to control soil erosion (Karen et al., 2019). Tillage technology has been extensively used by farmers in the production of crops since time immemorial. However, most of the farmers now-a-days may be guess the intensity of tillage practices to employ for seedbed preparation and cultivation. Tillage technology has been extensively used by farmers in the production of crops since time immemorial. Especially in some states of north east India, conventional farming has been increasing day by day, where better production is main objective (Bhuyan et al., 2013).

Tillage affects soil characteristics such physical, chemical and biological properties of soils. It has various effects on the soil both beneficial and degrading, depending on the appropriateness or otherwise of the methods used (Bhuyan and Laskar, 2020). Different soil physical effects such as infiltration rate, aggregate-stability, soil and water conservation, all are mainly responsible and have direct effect on soil sustainability and productivity (Aziz et al., 2013; Kahlon et al., 2013; Acar et al., 2017). Research results have been widely reported on the effects of tillage on soil aggregation, temperature, water infiltration and soil compaction (Daniells, 2012). Growth rates of crop plants are generally affected by diverse tillage systems (Mosaddeghi et al., 2009). Tillage mostly affects the soil aeration and also changes the rates of mineralization of organic matter decomposition. Biological activities in the soil are very important to soil productivity through the activities of termites, earthworms and the many other living creatures found in the soil. As a whole they affect water infiltration rates, soil water holding capacity by their burrowing in the soils and also promote soil compactness. Many authors have reported that root growth affected by penetration resistance in conservative systems (Moraru and Rusu, 2010; Ren et al., 2018). Conservative tillage may enhance the growth of weeds in cropland (Alamouti et al., 2015).

However, improvement in tillage study has been greatly stalled by the presence of so many variables in the soil and weather conditions which affect tillage results. However, it was found that during conventional tillage, soil structure is damaged, large energy is wasted too. On the other hand, considerable changes have taken place in tillage practices and several techniques have been introduced such as, minimum tillage, zero tillage, stubble mulch tillage. Extensive use of advanced heavy machinery destroys the soil structure and leads to erosion. Many studies reported that frequent tillage is rarely beneficial and often detrimental (Laddha and Totawat 1997; Hamza and Anderson, 2005; Mosaddeghi et al., 2009). Therefore, introduction of minimum tillage, zero tillage are new useful addition and requirement of modern agriculture. Therefore present study was undertaken to investigate the role of tillage on soil physical properties of selected Agro-ecosystems.

2 Study area and Methodology

2.1 Study site

The present study was conducted in Lunglei district situated in the south-central part of Mizoram state, northeastern India. Lunglei is located at 22.88°N 92.73°E. Average elevation of the study site is 722 metres (2368 feet). Lunglei is one of the important districts of Mizoram state. The district is surrounded by Mamit and Aizawl districts on the north, Bangladesh on the west, Lawngtlai district on the south, Saiha district on the southeast, Myanmar on the east and Champhai district on the north east. The summer season is not very hot, temperature remains between 20° to 30° Centigrade. Temperatures range between 21° to 11° Centigrade during winter season and the weather is very pleasing and cool. Mizoram witnesses heavy rainfall during the rainy season. Monsoon starts from the month of June and lasts till August. Average annual rainfall of 3000 millimeters is recorded in the state. During March and April, heavy storms occur in most parts of the state.

2.2 Soil sampling and Laboratory methods

Study was carried out in selected areas of the district. Altogether 3 different types of agro-ecosystems (Home-garden or Agro-forestry, Forest and Paddy field) present in the district were selected for soil sampling. Different level of tillage were measured in three systems such as zero in forest, 20-30% in home garden and

100% in paddy cultivated land. Soils collected from three places of each of the agro-ecosystems using steel corer, 5 cm in diameter from the respective depths (0-15 and 15-30). Soil samples were then bagged in a polythene bag air-tight and then brought to the laboratory to analyze their soil characteristics. Soils were air-dried, grinded and sieved (<150 mm) prior to the samples to understand their characteristics. Bulk density and soil moisture content is determined by Gravimetric method given by Anderson and Ingram (1993). Porosity, water holding capacity, soil particle density, soil texture was determined by Boyoucous hydrometric method given by Allen et al. (1974). Correlation analysis was completed following by the method Zar (1974).

3 Results and Discussion

Statistical analysis of the results showed that the differences in accumulated soil water depended on the variants of soil tillage and type of soil (Table 1). Soil textural types and soil structure have a huge effect on the water holding capacity of the soils.

Table 1 Details of tillage practices used in different selected agro-ecosystems.

Agro-ecosystems	Tillage%	Name of the tillage	Instruments used for tillage
Paddy AES	100	Conventional tillage	Tractor, woden plough, chisel plough etc
Home garden	20-30	Minimum tillage	Knives, daon, hoe etc
Forest	00	No tillage	....

3.1 Soil texture

Soil texture governs the order soil properties including biological characteristics (Table 2). In the present study the soil textures were loamy fine sand to fine sand in nature and it was almost similar in all the types of agro-ecosystem. In all the types of agro-ecosystem the percent of sand and clay decreases with an increased in depth and it was found similar in the entire land use pattern except in agro-forestry and paddy field. Clay content in paddy field and forest were higher in subsurface layer while home-garden was recorded lower concentration in those layer ranges from 0% to 12% in subsurface layer. The maximum percentage of silt was recorded as 80% from paddy field while the rest were in average of 5% to 70%. Lower concentrations of sand in paddy field might be due to the effect of tillage. The maximum clay percentage was recorded from forest which ranges 42% in the subsurface layer and the remaining were an average of 0% to 32% in the remaining agro-ecosystem. Even though, difference in the mean value was observed statistically, no significant difference in texture between the sites were found (Table 5).

Table 2 Soil texture of different agro-ecosystems.

Agro-ecosystems	Depth (cm)	Silt (%)	Clay (%)	Sand (%)	Texture class
Home garden	0-15	37.33	4.66	58.33	Sandy loam
	15-30	26.00	0.66	73.66	Loamy fine sand
Forest	0-15	23.33	18.66	58.00	Sandy loam
	15-30	30.33	21.66	48.00	Loam
Paddy	0-15	53.66	8.33	38.00	Silt loam
	15-30	70.00	15.33	14.66	Silt loam

3.2 Bulk density (BD), porosity, soil moisture content (SMC)

A significant difference was found among the tillage implements. The bulk density varies significantly between the various types of agro-ecosystem. The bulk density was ranges between 1.17 g cm^{-3} and 1.43 g cm^{-3}. The bulk density increases with the increase in soil depth (Table 3).

The maximum bulk density was recorded in forest ranges 1.43 g cm^{-3} and the minimum was recorded from paddy field ranges 1.17 g cm^{-3}. Those soils have higher percentages of pores seems to have minimum bulk densities than the soils which are more compact and minimum pores (Brady and Weil, 1999). Brady (1984) reported that the bulk densities of clay, clay loam, and silt loam surface soils normally ranges from 1.6 mg m^{-3} depending on their condition.

Table 3 Soil moisture content, bulk density and Porosity of the selected agro-ecosystems.

Agro-ecosystem	Depth (cm)	Soil moisture content (%)	Bulk density (gm/vol)	Porosity (%)
Home garden	0-15	15.17	1.27	34
	15-30	15.67		
Forest	0-15	11.43	1.43	20
	15-30	11.67		
Paddy	0-15	27.33	1.17	40
	15-30	24.97		

Kar et al. (1976) reported that a bulk density greater than 1.6 mg g^{-3} for loam soil adversely affected the root growth. Similarly, Bauder et al. (1981) reported that bulk density was higher in moldboard plow than chisel plow. Grant and Lafond (1993) reported that bulk density was higher in conventional tillage than in minimum tillage, but the bulk density was higher in minimum tillage than in conventional tillage in the other depths. The bulk density of a soil gives an indication of the soil’s strength and thud resistance to tillage implements or plants as they penetrate the soil.

3.3 Porosity

Tillage practices significantly affected soil porosity for both the depths. Soil porosity ranges between 20% to 40% (Table 4). The porosity decreases with increased in soil depth. The maximum ranges of porosity were recorded as 40% in paddy field and minimum was recorded as 20% in forest. The soils of paddy field and home- garden land had slightly higher values of porosity as compared to forest land. Soil porosity and pore size distribution were negatively affected by the intensity of land used. Higher soil porosity found in different field is due to minimum tillage and traditional cultivation practices in the soil (Bhuyan et al, 2004), however, decline in porosity leads to reduce pore size distribution which has an impact on productive capacity of the agricultural soil. Positive correlation with sand and significant negative correlation with clay was observed in the present study, which indicates that higher bulk density may be due to low clay and high sand content (Table 6).

Table 4 Soil physical properties (soil particle density and water holding capacity) of selected agro-ecosystems.

Agro-ecosystems	Depth (cm)	Soil particle density (mg/vol)	Water holding capacity
Home garden	0-15	1.85	42.00
	15-30	1.71	40.00
Forest	0-15	1.87	51.33
	15-30	1.80	48.66
Paddy	0-15	1.21	38.66
	15-30	2.06	39.33

Soil erosion of different levels mainly depends upon the slope and management practices. However, this erosion increases the soil bulk density (Singh and Prakash, 1985). From the present study, it is concluded that paddy field area have lower bulk density and greater porosity, and forest area have high bulk density and lower porosity. Lal et al. (1980) revealed that straw returning could increase the total porosity of soil while minimal and no tillage would decrease the soil porosity for aeration, but increase the capillary porosity; as a consequence, water capacity of soil enhances with the poor soil aeration (Wang et al., 1994; Glab and Kulig 2008). However, according to Borresen (1999) tillage and straw treatments have no significant effects on the total porosity and porosity size distribution. Allen et al. (1997) indicated that amount of big porosity can be increased by the uses of minimal tillage in the agricultural lands.

3.4 Moisture content

The soil moisture content was ranges between 6% and 28.3%. The maximum value of soil moisture content (SMC) was recorded in paddy field ranges 28.3% and minimum was recorded in forest ranges 6%. The soil moisture content increases with slightly decrease in depth of soil surface layer. Presence and percentages of soil moisture contents is greatly affected by the tillage techniques and tillage intensity. Decreasing wind effect and increasing soil roughness may preserve the soil moisture content also. Tessier et al. (1990) reported that, in general, conservation tillage significantly improved water available to crops. Similarly, Grant and Lafond (1993) and Mielke et al. (1984) reported that soil moisture was saved more under conservation tillage than under conventional tillage. Furthermore, Bauder et al. (1981) pointed out that the soil moisture content was saved less under chisel plow than under moldboard plow and disk plow on the soil surface, but in chisel plow the soil moisture content increased more than the others with increasing depth.

3.5 Soil particle density and water holding capacity (WHC)

The soil particle density was found almost similar in all the types of agro-ecosystem ranges between 1.25 g vol^{-1} to 2.27 g vol^{-1}. The maximum soil particle density was recorded in paddy field ranges 2.27 g vol^{-1} having maximum tillage and the minimum was recorded in forest ranges 1.25 g vol^{-1} where minimum tillage was applied.

Water holding capacity (WHC) was recorded ranges from 22% to 60% in all the selected types of agro-ecosystem. Water holding capacity of surface soil layer was found to be greater than the subsurface layer. Water holding capacity decreases with soil depth which might be due to high amount of organic carbon and clay in the surface than subsurface soils, which promotes formation of aggregates and retention of water. The maximum value of water holding capacity was recorded from forest ranges 60% where no tillage is being practiced and minimum was recorded in home-garden ranges 22% (15-30 cm in depth).

Table 5 ANOVA showing the effect of AES (agro-ecosystem), depth and tillage on soil properties.

Variable	BD			Porosity			WHC		
	df	F-ratio	P	df	F-ratio	P	df	F-ratio	P
AES	3	0.295	0.774	3	0.817	0.415	3	1.476	0.125
Depth	1	1.810	0.210	1	1.479	0.211	1	1.917	0.201
Tillage	3	0.395	0.757	3	1.634	0.200	3	4.257	0.012
AES x Depth	3	0.112	0.78	3	0.190	0.788	3	0.124	0.761
AES x Tillage	9	0.847	0.579	9	1.848	0.097	9	2.206	0.048
Depth x Tillage	3	0.026	0.994	3	0.155	0.925	3	0.142	0.933
AES x depth x Tillage	9	0.086	0.999	9	0.079	0.999	9	0.190	0.993

BD-Bulk density, WHC-Water Holding Capacity.

Table 6 Correlation coefficient (r) of tillage types on soil physical properties.

	Depth (cm)	Sand (%)	Clay (%)	Silt (%)	SMC (%)	pH	BD	WHC	Porosity
Conventional Tillage	0-15	0.023	-0.152	0.043	0.234	0.114	0.153*	0.198	-0.357
	15-30	0.022	0.148	-0.474	0.058	0.228	0.187	0.181*	0.278
Minimum Tillage	0-15	-0.416	0.339	-0.011	0.575**	0.510	0.139	-0.076	-0.248
	15-30	0.073	0.215	-0.218	-0.350	-0.342	-0.212	0.163	-0.276
Zero Tillage	0-15	0.038	-0.025	-0.278	0.259	0.019	-0.069	0.263	0.094
	15-30	-0.006	-0.116	0.016	-0.234	-0.178	-0.051	0.484	0.135*

n=6, p<*0.05; **0.01.

BD-Bulk Density, WHC-Water Holding Capacity.

4 Conclusion

Conventional tillage practices cause change in soil structure by modifying soil bulk density and soil moisture content. In addition, repeated disturbance by conventional tillage gives birth to a finer and loose-setting soil structure while conservation and no-tillage methods leave the soil intact. This difference results in a change of characteristics of the pores network. The number, size, and distribution of pores again control the ability of soil to store and diffuse air, water, and agricultural chemicals and thus, in turn, regulate erosion, runoff, and crop performance. Minimum tillage positively influences the soil whereas excessive and unnecessary tillage operations give rise to reverse phenomena that are damaging to soil health. Therefore, at present there is a considerable concentration and emphasis on the transform from extreme tillage to conservation and no-tillage methods for soil conservation.

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