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Effect of Cropping Intensity on Soil Physical Properties: A Study on Bulk Density, Particle Density and Porosity at Kalaroa Upazila in Satkhira District

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Abstract: Intensive land use and frequent tillage practices are common in high cropping intensity regions like Bangladesh. Although the role of fertilizers on yield has been widely studied, effect of tillage intensity on physical health of soil remains under explored, particularly in multiple cropping areas. Our investigation is to explore the effect of cropping intensities on key physical properties of soil: bulk density, particle density, and porosity, in Kalaroa Upazila, Satkhira district. Soil samples from four distinct cropping intensities (200%, 250%, 300%, and 350%) were collected during the Rabi season from surface layers (0–15 cm) of "Ishurdi" soil series. Standard laboratory analyses including the core method for bulk density, pycnometer method for particle density and porosity estimation from density values were conducted. Tillage frequency ranged from 9 to 14 operations per year across the plots. Results indicated that increasing intensity generally led to reduced bulk density and porosity, while particle density exhibited minor variations. The lowest bulk density (1.247 g/cm³) and porosity (41.12%) were recorded in the most intensively cultivated plot (350% intensity, 14 tillages/year), suggesting potential degradation of soil structure due to over-cultivation. In contrast, moderate tillage (250% intensity) maintained the highest porosity (51.46%), indicating better soil aeration and structure. This study underscores that excessive intensity can adversely affect soil physical properties, diminish its capacity to support sustaiSnable crop production.

Keywords: Cropping Intensity, Bulk Density, Particle Density, Porosity, Soil Health

I. INTRODUCTION

The growing global population, combined with shifts in dietary patterns and an escalating demand for biofuels, necessitates a substantial rise in global crop production to avert a resurgence of widespread malnutrition and hunger (Keyzer et al., 2005). Discussions surrounding how to meet this demand have largely focused on the resources required—such as water, nutrients, energy, and genetic material—and whether yield intensification alone will suffice or expansion of cropland is also needed (Rost et al., 2009). In densely cultivated regions like India, Bangladesh, and others worldwide, it is common to harvest up to four crops annually. In such systems, the frequency of tillage operations often reflects the cropping intensity, as tillage is integral to most forms of cultivation. According to the FAO (2010), global crop land comprising arable and permanent crop areas—totals approximately 15.3 million km², encompassing land used at least once within a five-year span but excluding areas with longer fallow cycles. The reported harvested area, at around 11.8 million km² per year, yields a global cropping intensity of roughly 0.77 crops annually. Notably, this figure underestimates the true extent of fallow land, as many fields are cultivated more than once a year. The widespread adoption of chemical fertilizers has led to a neglect of the soil's physical characteristics by both farmers and researchers, particularly in Bangladesh, where the focus has remained largely on soil chemistry and fertility. Yet, neither improved crop varieties nor increased fertilizer inputs can sustainably enhance yields without adequate management of soil physical conditions. While chemical fertilizers account for nearly half of the world's crop production (Pradhan, 1992), their exclusive use cannot maintain long-term soil productivity. Likewise, relying solely on organic amendments is insufficient to meet the demands of high-yield farming systems (Rose et al., 2001).

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Tillage, as a fundamental agronomic practice, plays a crucial role in improving soil conditions for plant growth. It assists in weed control, pest and disease management, seedbed preparation, organic matter incorporation, and the optimization of soil structure and aeration. These effects collectively influence water retention, nutrient availability, root penetration, and overall crop productivity (Dexter, 1999). Soil physical characteristics, such as water-holding capacity, porosity, and compaction, directly impact root development and thus determine agricultural output (Benjamin et al., 2003). Soil functions—both chemical and physical—are governed by key physical attributes including texture, micro-aggregate formation, bulk and particle density, porosity, permeability, and hydraulic conductivity. Effective management of these parameters is only possible through a deeper understanding of soil physics. This study posits that intensive cultivation practices may adversely affect the soil's physical, chemical, and biological attributes, potentially compromising long-term soil health and agricultural sustainability. Accordingly, this research focuses on evaluating the impact of prevailing tillage intensity on select soil physical properties—namely bulk density, particle density, and porosity in a highly cropped area of Kalaroa Upazila in Satkhira District, Bangladesh.

II. MATERIALS AND METHODS

Soil samples of "Ishurdi" series were collected from 4 locations during "Rabi" season. Village: Jhampaghat Union: Halatola, Thana: Kalaroa , District: Satkhira. The physiography of four selected plots is of Ganges tidal floodplain. The relief is nearly level with less than 2% slope. The soils are not generally flooded during rainy season or by tidal flow (SRDI, 2006). A total of four soil samples were collected from four distinct plots using the grid sampling method for subsequent laboratory analysis. Samples were obtained from the surface layer, specifically at a depth of 0–15 cm. Upon collection, each sample was placed in a plastic bag and appropriately labeled with the corresponding profile number and depth information. Once transported to the laboratory, the samples were air-dried by spreading them individually on clean sheets of paper. Following air-drying, larger soil aggregates were gently disaggregated using a wooden mallet. A representative portion of each sample was then sieved through a 2.0 mm mesh to obtain fine earth fractions. The sieved soil samples were stored in plastic bags and labeled accurately for analysis. The four selected plots were assigned codes C1, C2, C3, and C4, corresponding to cropping intensities of 200%, 250%, 300%, and 350%, respectively.

A. *Cropping Intensity And Tillage Intensity Of The Study Plots*

Cropping intensities of four different study plots were calculated by the following formula as suggested by Singh (2004).

Cropping Intensity= *(Total cropped area/ Net cultivated area)x100*

The cropping patterns of selected plots are presented in table1.

Table 1. cropping intensity, cropping pattern, tillage intensity and texture of the field plots.

Intensity Code	Present land use	Cropping Pattern	% Cropping Intensity (CI)	Tillage intensity (No. of tillage year $^{-1}$)	Texture
C1	Dal, Paddy	Paddy-Dal-Arum-Pumkin	200	9	Clay loam
C2	Jute, vegatables, arum	Arum-Vegetable- Jute	250	11	Clay
C3	Rice, Jute, vegetables	Jute-Vegetable-Vegetable	300	12	Clay loam
C4	Paddy, vegatables, Jute	4 crops (Arum- Spices-Vegetable- Vegetable)	350	14	Clay loam

III. SOIL PHYSICAL PROPERTIES

A. *Particle Size Analysis*

Soil particle size distribution was determined using the Bouyoucos hydrometer technique, originally outlined by Bouyoucos (1936). In this procedure, 50 grams of air-dried soil, previously sieved through a 2 mm mesh, were combined with 100 mL of distilled water and 10 mL of a dispersing agent—commonly a 40 g/L sodium hexametaphosphate solution—in a beaker. The suspension was left to stand overnight to facilitate thorough dispersion of soil particles. Subsequently, the mixture was agitated using a mechanical stirrer for five minutes to disintegrate any remaining aggregates. The well-dispersed soil suspension was then transferred into a 1000 mL graduated cylinder and brought up to volume with distilled water.

After vigorous mixing, hydrometer readings were recorded at 40 seconds and again after 2 hours to assess the concentration of silt plus clay, and clay particles, respectively. A control solution containing only the dispersant was used to adjust for background readings, and temperature corrections were applied to account for any deviation from the standard hydrometer calibration temperature of 20°C. Final percentages of sand, silt, and clay were calculated from the corrected hydrometer readings, thereby enabling the classification of soil textural classes.

B. Soil Bulk Density

Bulk density was assessed by collecting undisturbed soil samples of known volume and calculating the ratio of oven-dried mass to the field volume of the respective sample. To facilitate this measurement, intact soil cores were extracted using a manually operated core sampler. Special care was taken during collection to prevent any artificial compaction, ensuring that the soil surface level within the core matched the surrounding ground elevation. The soil samples were carefully trimmed to conform precisely to the volume of the sampling cylinder and subsequently oven-dried at 105°C to obtain a constant mass for accurate determination (Blake and Hartge, 1986).

C. Soil Particle Density

The determination of soil particle density was conducted using the pycnometer method, in accordance with the protocol described by Blake and Hartge (1986). Approximately 10 grams of air-dried, finely pulverized soil sieved to pass through a 2 mm mesh was accurately weighed and transferred into a clean, dry pycnometer. The mass of the empty pycnometer and that containing the dry soil was recorded with precision. Subsequently, distilled water was introduced to the bottle until it was half-filled, and the mixture was stirred gently to eliminate entrapped air and ensure thorough wetting of the soil particles. The pycnometer was then topped off with distilled water, sealed with its stopper, and the exterior was carefully wiped dry before recording its total mass. To establish a reference, the pycnometer was also completely filled with distilled water and weighed separately. The displaced volume of the soil was deduced from the mass differences, enabling calculation of the particle density by dividing the oven-dry weight of the soil by the volume it occupied. All measurements were performed under controlled temperature conditions, typically maintained at around 25°C, to ensure reliability and consistency in the results.

D. Total Porosity of Soil

Total soil porosity was calculated using the measured particle and bulk density values, applying the formula proposed by Strickling (1956).

Porosity = (1-Bulk Density/Particle Density)x100

E. Statistical Analysis

The statistical evaluation of the experimental data was conducted using the software program MSTAT-C. This tool facilitated the analysis of variance and other relevant statistical computations. Its application ensured accurate interpretation and validation of the observed results.

IV. RESULTS AND DISCUSSION

Soil samples were collected following point sampling in such a manner to represent the field condition. Soil samples were examined to assess the effects of varying tillage intensities on selected physical and physico-chemical properties of soil, with particular emphasis on soil organic matter content—an essential indicator of soil health. The properties that determined were bulk density, porosity and particle density etc. Results are tabulated in Table 1. In this chapter of the manuscript, codes C_1, C_2, C_3, and C_4 were used instead of cropping intensity values of 200%, 250%, 300% and 350% respectively.

A. Particle Density

Data cropped from soil sample analyses showed significant differences on particle density due to cropping intensity and it varies within the range of 2.62 to 2.70 g cm^{-3}. It also showed that cropping intensity C_3 is superior in increasing particle density to other cropping intensities (Fig. 1). Statistical analysis showed that particles density values varied insignificantly (at 1% level) in different cropping intensity (Table 2).

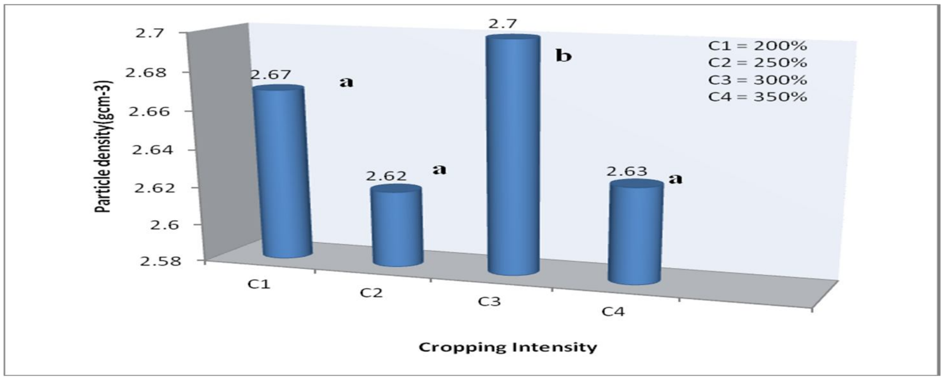

Fig 1. Changes of particle density under different cropping intensity.

B. *Bulk Density*

The results indicated that cropping intensity exerted a statistically significant influence on soil bulk density. The maximum bulk density, measured at 1.40 g cm^{-3}, was observed under cropping intensities C1 and C3, whereas the minimum value was recorded under cropping intensity C4 (Fig 2).

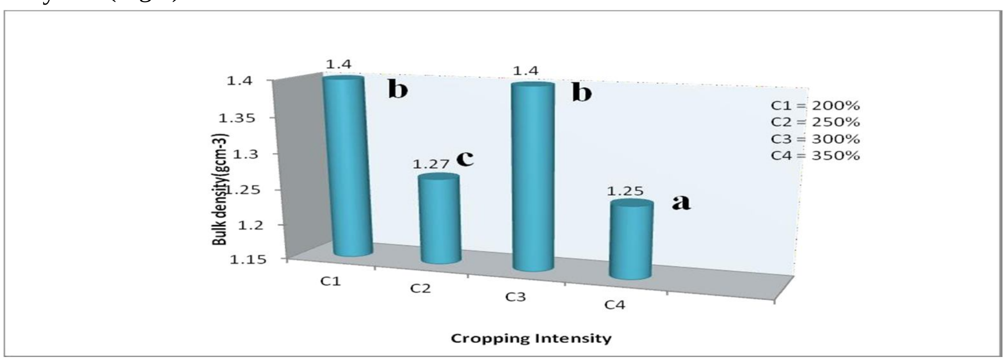

Fig 2 Changes of bulk density under different cropping intensity.

Low intensity cultivation may provide time for structural regeneration. However, uncultivated fallow land (low cropping intensity) exhibits higher bulk density but intensive cultivation decrease bulk density. Similar observation was also reported by (Xu and Mermoud, 2001). The variations in the bulk density values were statistically significant at 1% level for different cropping intensity (Table 2).

C. *Porosity*

Soil porosity results showed that changes in the values were statistically significant at 1% level with different cropping intensities (Table 2) and the highest soil porosity (51.46%) was found in cropping intensity C2, whereas lowest porosity (41.12%) was measured for intensively cultivated field (Fig. 3). Result revealed that mostly intensive cultivated field had a negative influence on soil porosity. Brady (1990) stated that continuous cropping significantly reduced the total pore space and soil organic matter content

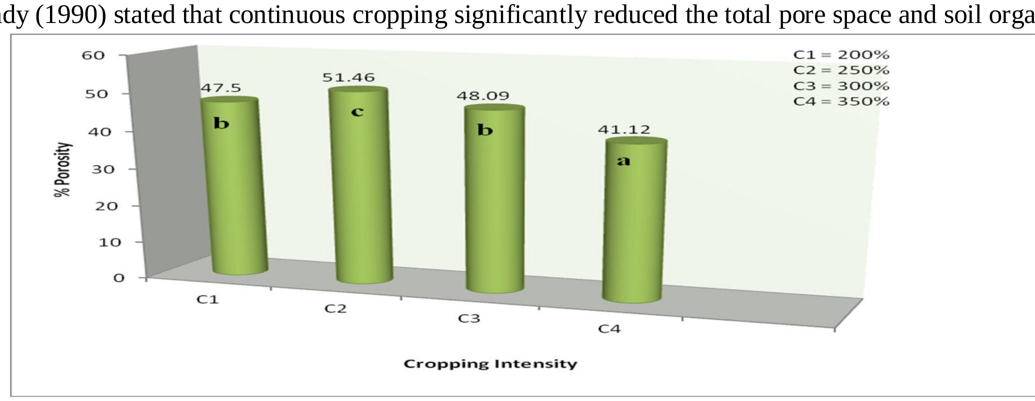

Fig. 3. Changes of porosity under different cropping intensity.

Table 2. Effect of cropping intensity on soil properties

Intensity Code	Bulk Densdity(g/cm^3)	Particle Density (g/cm^3)	Porosity (%)
C_1	1.400^a ±0.01	2.667^b ±0.01	47.503^b ±0.08
C_2	1.270^a ±0.01	2.617^a ±0.01	51.463^c ±0.18
C_3	1.403^b ±0.00	2.703^b ±0.01	48.087^b ±0.39
C_4	1.247^a ±0.01	2.627^a ±0.01	41.117^a ±0.20
CV	0.75%	0.53%	0.70%
*Significant level	0.01	0.01	0.01

V. CONCLUSION

Field experiments were conducted on 4 different plots in Kalaroa Upozilla. The study was carried out to observe the changes in soil physical properties with the change in cropping intensity. The findings of the study are summarized below. Particles density values varied insignificantly in different cropping intensity. Highest intensity showed the lowest bulk density. Porosity became decreased with increasing intensity of cultivation. The determined soil physical parameters, bulk density, particle density and soil porosity, were unfavorably changed with increasing cropping intensity which may cause ultimately deterioration of soil health.

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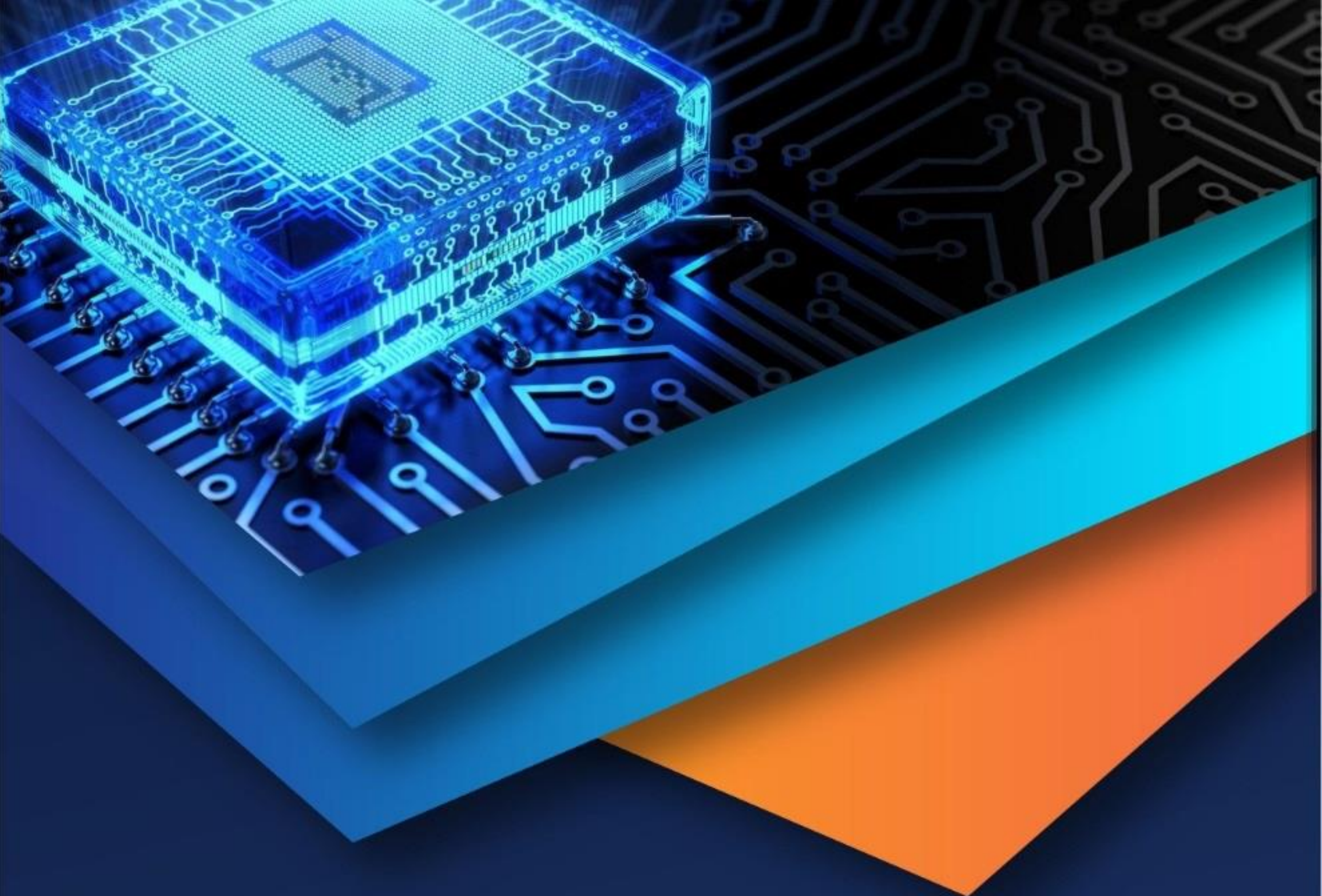

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