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Weeding effects on soil physico-chemical properties in artificial hill plantation

Abstract

This study reports the effects of weeding on physical and chemical properties of soil from two different hill sites with rigorous plantation. Soil samples were collected from top, middle and bottom hill positions, having plot size of 0.5m × 0.5m. This study analyzed for five soil physical variables including moisture content, maximum water holding capacity, field capacity, bulk density and particle density; and seven soil chemical variables including organic matter, organic carbon, total nitrogen, pH, Carbon nitrogen ration, available potassium and available calcium. Top hill position captures significantly lower Organic matter, Organic carbon, pH, available Ca and K having with lower soil physical variables of Moisture content, Field capacity and Maximum water holding capacity in both sites irrespective of presence and absence of weed. In this study, we found that all studied soil physical and chemical variables were higher in the presence of weed in both sites except bulk density and particle density. This study concluded that weeding practice in artificial hill forest showed adverse impact on soil physical and chemical properties. Moreover, undisturbed ground vegetation will provide continuous organic matter flow after decomposition and helps to improve the soil properties. For plantation in hilly areas it is more crucial as the hill top found significantly lower physico-chemical soil properties.

Keywords: artificial forest, hilly land area, different elevation, soil moisture, organic matter and soil conservation

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Introduction

The protective role of a forest can be best achieved when understorey vegetation in forest is not weeded and burned.[1] An open forest gives only a false sense of protection, while a young forest is not as effective as a mature one. A forest does not mean only tree cover in a land, rather it is a complex of plants and animals living in, on and above soil. Although trees are the dominant vegetation in a forest, shrubs, wild flowers, grasses and vines are also important components. In addition, there are non-green plants called fungi which lives on materials derived from plants and animals, and increasing organic matter in soil by decomposing. The organic material comprises soil fauna including nematodes, earthworms, macro and micro arthropods and protozoa. These micro-organisms play a role as decomposers, N_2 fixers, algae, mycorrhizal fungi and denitrifying organisms.[2] Moreover, tree cover alone is not sufficient to protect the soil from degradation, especially in hilly areas. There are many published reports that prove erosion occurs even under mature plantations, when it is without any dense undergrowth.[3–5] Dense vegetation protects the ground from excessive evaporation, and keeps surface soil moist for longer time than a barren one and makes the soil aggregates less liable to detachment through the presence of fibrous roots of grasses and weeds, which are very effective in forming stable soil aggregates.

The common perception of plantation forest is that weeds play a role in competition for water and nutrients with target planted tree species. Continuous weeding activity is provided to avoid suppression of weeds to enhance growth of planted species. No study conducted to date addressed to what extent these undergrowths are competitive for that target planted trees regarding length of time and available different essential plant nutrition. Another observation is that immediately after cleaning of undergrowth, the soils below the undergrowth remain loosened and porous following tilling activity of earthworms, nematodes and many groups of organisms, and soils become darkened with the presence of humus materials. Absence of such features is evident side by side in the nearest regularly weeded lands or with increasing elapsed time after weeding or clearing of bushes. Apparent differences of such features in the surface soil between weeded and unweeded lands provide a challenge to investigate any measurable changes in soil physiochemical properties. With this aim, the present study was undertaken to find out the effects of weeding on soils in plantation land.

Material and methods

Study site

The study area was in Chittagong university campus situated in Hathazari Upazilla of Chittagong district between about 22° 27′ and 22° 29′ North latitudes and 91° 46′30′′ and 91° 47′ 45′′ East longitudes covering about 514.25 ha of land approximately (Figure 1). About 60% of the land area of Chittagong University Campus consists of hilly areas covered by plantation.[6] A preliminary survey was done to select representative study sites. Eventually, two hill sites were selected to conduct our study: Hilly Site A and Hilly Site B. In Site A, the plantation was established in 1998 and contained mixed plantation of Garjan (Dipterocarpus turbinatus), Akashmoni (Acacia auriculiformis), Teak (Tectona grandis), Gamar (Gmelina arborea) and Koroi (Albizia spp.); and has a hill slope about 80%. In Site B, the plantation was established in 1995 and contained plantation of Eucalyptus (Eucalyptus camaldulensis), Akashmoni (Acacia auriculiformis), Mahagony (Swietenia mahagoni), Koroi (Albizia spp.) and Chickrassi (Chikrassia tabularis); with a hill slope about 80%. A special feature of the hills of both sites is a relatively flat surface at the top.

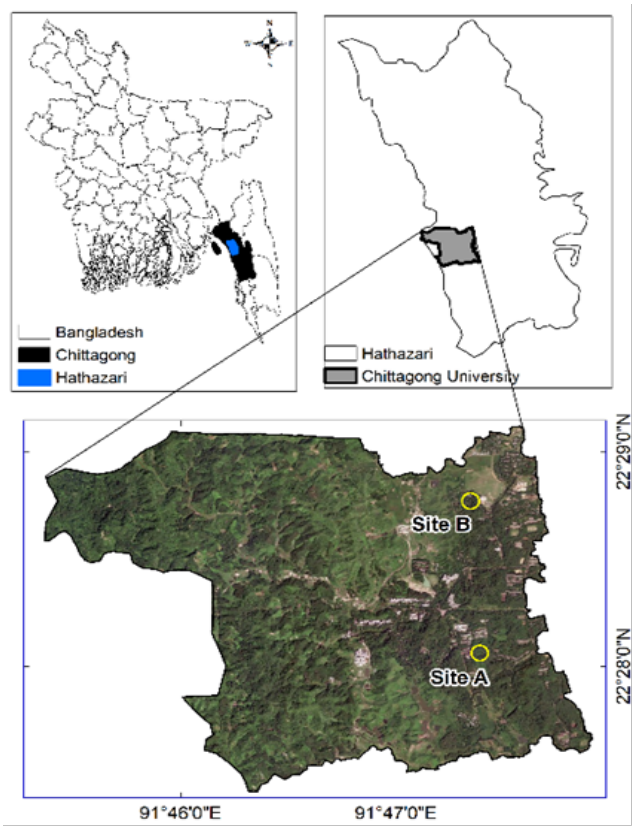

Figure 1 Map of the study area.

For each Hilly site, three different elevations were considered: Top, Middle and Bottom. At every elevation, pairs of plots were taken; weeded and unweeded, situated side by side to keep a similar slope. In both sites, the unweeded plot had been undisturbed for the last 8 years under mixed plantation of species; and the weeded plot had been subjected to weeding for the last 7 years. The weeded plot was thickly covered with different types of weeds including shrubs, herbs and grasses. Grasses were completely absent in the unweeded site. There are more growth of weeds at the top hill position for both Site A and Site B. In Site A, the unweeded site was covered with shrubs and herbs but dominated by weedy herbs in the plots. In Site B, the grass at the bottom hill position was less than at the top and middle hill positions in the weeded plot. In this plot evidence of light burning was observed on the bottom and mid hill position.

Sampling

In each site, samplings were done randomly from both weeded and unweeded plots. The samples were collected from the western aspect of the hill. Five replicated soil samples were randomly collected from each hill position having plot size of 0.5 m × 0.5 m. Soil samples were collected from each plot using a silver spoon, at depths of 0–15 cm. The collected soil of each spot was mixed together and about half a kilogram of soil taken to the laboratory in a polybag for subsequent analyses.

Soil analysis

Bulk density sample were collected from the same sample plots after collecting loose surface soil. For determination of bulk density, three soil cores were collected from the field using pre-weighed cores. Cores were driven vertically into the soil using a wooden hammer; exactly 100 cm3 soils were taken. The cores were then carefully dug out and excess soil at both ends was removed using a sharp knife. Then both the ends of the cores were wrapped with two pre weighed small pieces of cloth and rubber bands. The cores were then carried in a labelled plastic bag to the laboratory for analysis. Bulk density, Field Moisture content and Maximum water holding capacity were determined by USDA.[7] Particle density was determined taking two 10-ml cylinders, the first filled with water up to the 10 ml mark. In the second cylinder, 2 g of soil burnt in a furnace was taken and water from the first cylinder poured until water reached the 10 ml mark. The remaining water in the first cylinder indicated the volume of soil particles. The weight of soil divided by volume determined soil particle density.

Moist soil pH was determined using a TOA pH meter in triplicate at 1:2 soil water ratios. Soil organic carbon and organic matter was determined by the loss on ignition method according to Ball.[8] Total N was determined by the micro-Kjeldahl method.[9] Determination of available calcium and magnesium following formula was used by Welch et al.[10]

Statistical analysis

Replicated data were analyzed statistically for variance and two way analysis of each parameter to determine significance level for means between weeded and unweeded areas at three different elevation point of the hill (Top, Middle and Bottom) using the Software R.[11]

Results and discussion

Soil physical properties

This study found significantly lower moisture content ($p \leq 0.05$) at the top of the hills in both site A and site B. Unweeded plots in this hill position (19.45%, 12.28%; mean moisture content in site A and B respectively) showed significantly higher moisture content ($p \leq 0.05$) than weeded plots (17.03%, 9.20%; mean moisture content in site A and B respectively) in both sites. The Study also showed significantly higher moisture content ($p \leq 0.05$) in all unweeded plots for site B. Similarly, moisture content was found higher in unweeded plots in middle and bottom of the hill position in site A though they did not vary significantly, which may be due to lower run off of water at the bottom of the hill as it possessed a relatively flat surface condition. In addition, field capacity and water holding capacity varies significantly ($p \leq 0.05$) in terms of both hill position and weeding practice both in site A and B (Table 1). Their corresponding values were higher at the bottom of the hills and gradually decreased towards the top, and also higher in unweeded plots than in weeded plots. Considering both site A and B, overall mean moisture content, field capacity and water holding capacity were found higher at the hill bottom (both in weeded and unweeded plots) indicating the flow of moisture from the top of the hill to the bottom due to gravitational force. Moisture content, water holding capacity and field capacity of the soil were higher in unweeded plots on both the sites at almost all the hill positions, indicating more favorable conditions of the soil with the presence of weeds. Moisture content in weeded plots was lower because of more evaporation resulted from removal of ground vegetation. According to Haider[12] moisture content, maximum water holding capacity and field capacity were lower in completely clear felled areas compared to semi cleaned or uncleaned land. Mean soil bulk density and particle

density, on the other hand, were found higher in the weeded plots than the unweeded plots in all the hill positions in both the sites, and this decreased from the top of the hill to the bottom. However, the analysis did not show any significant variation in bulk density and particle density in terms of both hill position and weeding practice. Bulk density of soil is related to the soil compaction, presence of organic matter, faunal activities in the soil and density of roots in the soil. Lower bulk density in unweeded plots at all hill positions of the two sites indicated a decrease in soil compactness which can be attributed by higher organic matter.[13] Moreover, removal of organic matter and soil particles by runoff from the top to the bottom hill position results in a decrease in bulk density from top to bottom hill position. Similar findings were also been reported by Sing et al.,[14] showed that highest bulk density in weeded site followed by slightly weeded and the better sites.

Soil chemical properties

Mean organic matter and organic carbon were found lower at the top of the hills in both weeded and unweeded plots in both sites, followed by middle and bottom respectively, which suggests removal of organic matter from the top to the bottom of the hill. Overall, all unweeded plots showed significantly higher organic matter content ($p \leq 0.05$) than weeded plots in both site A and B (Table 2). Organic matter content in weeded plots was lower because of the washing off of organic matter by runoff water as well as leaching of humus material downward. In 2009, Haque et al.,[15] found that the amount of organic matter was lower in deforested area or naked area compared to forest covered area; and organic matter content was higher at the hill bottom compared to the other hill positions. Due to lower organic matter content and reduction of root density underneath the soil resulted in lower maximum water holding capacity and field capacity (Tables 1&2). The overall variation of soil pH between weeded and unweeded plot found significant ($p \leq 0.05$) like organic matter since presence of higher organic matter improves the soil pH. A study conducted by Azad[16] showed a similar pattern of soil pH in eroded and non eroded forest floor. Slow decomposition of litter in weeded plots may keep the pH lower than in the unweeded plots by imparting less organic matter to the soil in weeded plots. The pH values showed an increasing trend from top to bottom hill position.

Table 1 Physical properties of weeded and unweeded soils in the hilly watershed of Chittagong university campus

Site	Hill Position	Weeding Status	Moisture Content (%)	Field Capacity (%)	Maximum Water Holding Capacity (%)	Bulk Density (g cm-3)	Particle Density (g cm-3)
A	Top	Weeded	18.2 a	21.91 a	45.96 a	1.29 a	1.88 a
		Unweeded	22.98 b	25.02 b	50.25 b	1.24 a	1.82 a
	Middle	Weeded	18.43 a	21.88 a	45.39 a	1.31 a	1.83 a
		Unweeded	18.87 a	24.03 b	46.7 b	1.22 a	1.8 a
	Bottom	Weeded	20.31 a	22.82 a	46.64 a	1.29 a	1.84 a
		Unweeded	20.46 b	25.09 b	50.04 b	1.19 a	1.8 a
B	Top	Weeded	9.2 a	21.78 a	39.62 a	1.34 a	2.0 a
		Unweeded	12.27 b	24.01 b	43.34 b	1.26 a	1.96 a
	Middle	Weeded	11.68 a	21.49 a	41.07 a	1.31 a	1.94 a
		Unweeded	13.54 b	23.92 b	45.15 b	1.22 a	1.92 a
	Bottom	Weeded	13.65 a	23.79 a	44.39 a	1.29 a	1.96 a
		Unweeded	14.6 b	28.08 b	49.87 b	1.21 a	1.95 a

Different letters indicate significant difference at $p \leq 0.05$ for the means between two land uses

Table 2 Chemical properties of weeded and unweeded soils in the hilly watershed of Chittagong university campus

Site	Hill Position	Weeding Status	Organic Matter (%)	Organic Carbon (%)	Total Nitrogen (%)	C:N ratio	Soil pH	Available K (mg/100g)	Available Ca (mg/100g)
A	Top	Weeded	1.52 a	0.89 a	0.12 a	7.3 a	5.44 a	10.33 a	73.5 a
		Unweeded	1.94 b	1.13 a	0.14 a	8.25 b	5.34 a	13.33 b	85.7 b
	Middle	Weeded	1.62 a	0.94 a	0.13 a	7.52 a	5.5 a	11:00 AM	80.37 a
		Unweeded	1.84 a	1.07 a	0.15 a	7.27 a	5.28 a	12 b	90.09 b
	Bottom	Weeded	1.72 a	1:00 AM	0.14 a	7.23 a	5.4 a	12.67 a	83.93 a
		Unweeded	2.02 b	1.17 a	0.17 a	6.81 a	5.28 a	14.67 b	106 b

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Table Continued

Site	Hill Position	Weeding Status	Organic Matter (%)	Organic Carbon (%)	Total Nitrogen (%)	C:N ratio	Soil pH	Available K (mg/100g)	Available Ca (mg/100g)
B	Top	Weeded	1.57 a	1.01 a	0.12 a	7.86 a	5.16 a	22.67 a	70.07 a
		Unweeded	1.73 a	0.98 a	0.14 a	7.56 a	5.08 a	27.33 b	86.97 b
	Middle	Weeded	1.57 a	0.91 a	0.11 a	8.2 a	5.26 a	26.33 a	72.23 a
		Unweeded	1.82 a	1.06 a	0.13 a	8.03 a	5.2 a	29.33 b	92.87 b
	Bottom	Weeded	1.7 a	0.99 a	0.12 a	8.61 a	5.34 a	30 a	73.77 a
		Unweeded	1.93 a	1.12 a	0.15 a	7.47 b	5.1 a	32.33 b	116.3 b

Different letters indicate significant difference at $p \leq 0.05$ for the means between two land uses

Similarly, available potassium and calcium in all the unweeded plots were significantly higher ($p \leq 0.05$) than in the weeded plots on all the hill positions in both sites A and B. Their corresponding values were found significantly higher ($p \leq 0.05$) at the bottom of the hills followed by middle and top of the hills in all studied plots (Table 2). Soil organic matter is the reservoir of plant nutrients such as nitrogen (N), considerable phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) and trace elements are added to the soil in available forms from the decomposition of organic matter.[17] Therefore, it can be said that available potassium and calcium was found higher in bottom plots due to having higher organic matter contents. The percentage of Total nitrogen (TN) content was found higher in unweeded plots than in weeded plots and gradually increased towards the bottom of the hills in all studied plots (Table 2). However, this study did not find any significant variation of TN content both in weeded and unweeded plots and in different hill positions. In case of C/N ratio, similar characteristics were observed in all studied plots.

Haque et al.,[4] reported that most of the soil properties were lower in completely weeded compared to patch weeded plantation sites. This study also portrayed that all studied physical and chemical variables are found to be higher in unweeded plots in both sites, except bulk density and particle density. This indicates that presence of weeds play an important role in conserving soil properties. Low organic matter content in weeded soil increases bulk density and reduces porosity, thereby having a serious impact on hydraulic properties such as infiltration and percolation of water, and thus can lead to soil degradation and other adverse effects on hydrological regime.[13,18,19]

Conclusions

Weed management has significant influence on soil properties and water availability in soil. During rainfall period and dry period weed covered land showed higher soil water contents than weeded soil covers. The experimental results indicate that in tropical hill conditions where rainfall erosion is high, weed management practices can significantly alter soil surface porosity and the amount of infiltrated water. Clear weeding practice and herbicide application reduce biological activity (presence of abundant bryophytes, algae and higher worm activity) in bare soil compared to unweeded soil. Rather than applying motorized cutting, patch weeding and integrated pest management may be promising alternatives for reducing degradation of soil physical and chemical properties. Further understanding about weed control is necessary in order to reduce competition for water, especially during early stage of plantation and periods of lower rainfall and higher temperatures.

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None.

Conflicts of interest

The author declares there are no conflicts of interest.

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