

EFFECTS OF DEFORESTATION ON THE PROPERTIES OF SOIL OF *SAL* FORESTS IN BANGLADESH

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Abstract

This study examined the effect of deforestation on the soil properties (physico-chemical and bacterial) of the *Sal* (*Shorea robusta* Roxb. Ex Gaertn.) forests in Bangladesh. Physico-chemical properties and the bacterial colony counts of soil were studied by comparing a natural *Sal* forest site with deforested and planted with Menjium site, deforested and planted with Mahogoni site, as well as deforested but not planted but covered with profuse growth of *Axonopus compressus* grass species site. Moisture content was significantly lower in the deforested and planted with Menjium site and deforested and planted with Mahogoni site than the natural forest site and the deforested but not planted site. Total organic carbon, total nitrogen and available nitrogen contents were significantly lower in the natural forest site. Significantly higher number of bacterial colony and higher organic carbon and moisture contents were found in the deforested but not planted site indicating that both organic carbon and moisture content were important for microbial growth. The present study clearly showed that deforestation significantly altered the soil physico-chemical and bacterial communities of the *Sal* forests. It was also revealed that plantation with different exotic plants were found to be different in influencing soil properties.

Introduction

Effects of deforestation on the properties of soil are manifold. Changes in the soil physico-chemical properties due to deforestation are associated with a number of changes in the soil hydrological regime, microclimate, and energy balance of the forest ecosystems.⁽¹⁾ Alteration in the soil microbial communities as a result of deforestation is likely to influence ecosystem properties since they play the key role in organic matter decomposition and nutrient mineralization in the terrestrial ecosystems.⁽²⁾ Therefore, it is important to understand the effects of deforestation on the properties of soil particularly in the tropics like Bangladesh where the rate of deforestation is alarming due to population pressure and rapid urbanization.

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The *Sal* forests dominated by *Sal* (*Shorea robusta* Roxb. Ex Gaertn.) in the central plains and north-western regions of Bangladesh is mostly a deciduous forests.⁽³⁾ Having a total area of 1,20,000 hectares in the country the *Sal* forests support livelihood of a significant number of people living surrounding the area.⁽⁴⁾ However, with an alarming average annual deforestation rate of 3.3% in the country, the *Sal* forests along with other forest areas have been disappearing fast.⁽⁵⁾ Clear cutting, encroachment, and indiscriminant plantation are some of the key causes of deforestation in the *Sal* forests in Bangladesh. Although some data are available on the effects of deforestation on the soil properties of the tropical *Sal* forests in Indian part, there is a dearth of data on it in the *Sal* forests areas of Bangladesh.^(1,6) Therefore, the aim of the present study was to find out the effect of deforestation on soil properties through a comparative analysis of soil physico-chemical and bacteriological characteristics of a natural forests and deforested sites under *Sal* forests area.

Materials and Methods

Site description: The *Sal* forests in Bangladesh are mostly deciduous in type and distributed mostly in the central plains of Madhupur tract under Gazipur, Mymensingh and Tangail districts and the north-western district of Dinajpur of Bangladesh.^(3,4) The *Sal* forests in the Madhupur tract is moist deciduous while that in the Dinajpur district is dry deciduous in type. The *Sal* forest of the Madhupur tract was selected for this study. *Sal* forests consist of both highlands called 'Chalas' covered by forest plants predominantly *Sal* and depressions called 'Baidis' are cultivated with rice. The annual rainfall of the area is *ca.* 1800 mm, 90% of which occurs in the period of May through October.⁽⁷⁾ The temperature of the area is moderate ranging from 30.3 to 20.9°C.⁽⁸⁾

Deforestation in the Madhupur *Sal* forest was done mostly for cultivation of pineapple and banana about 40 to 50 years ago. In 1989, with a view to afforestation, the Government of Bangladesh handed over forest areas to Eucalyptus (*Eucalyptus* sp.), Menjium (*Acacia menjium*), and Mahogoni (*Swietenia mahagoni*) plantations under a program entitled "Thana Afforestation and Nursery Development Project" funded by the Asian Development Bank. In this study, three deforested sites in addition to a natural *Sal* forest site, were selected that included deforested and planted with Menjium site, deforested and planted with Mahogoni site and deforested but not planted with tree species site. The last one was found to be covered with profuse growth of grass species mostly *Axonopus compressus*.

All of the four study sites were selected within approximately two kilometers from each other in the *Sal* forest under Gazipur district with a view to minimizing variation in soil properties due to geographical distance and climate (Fig.1). The

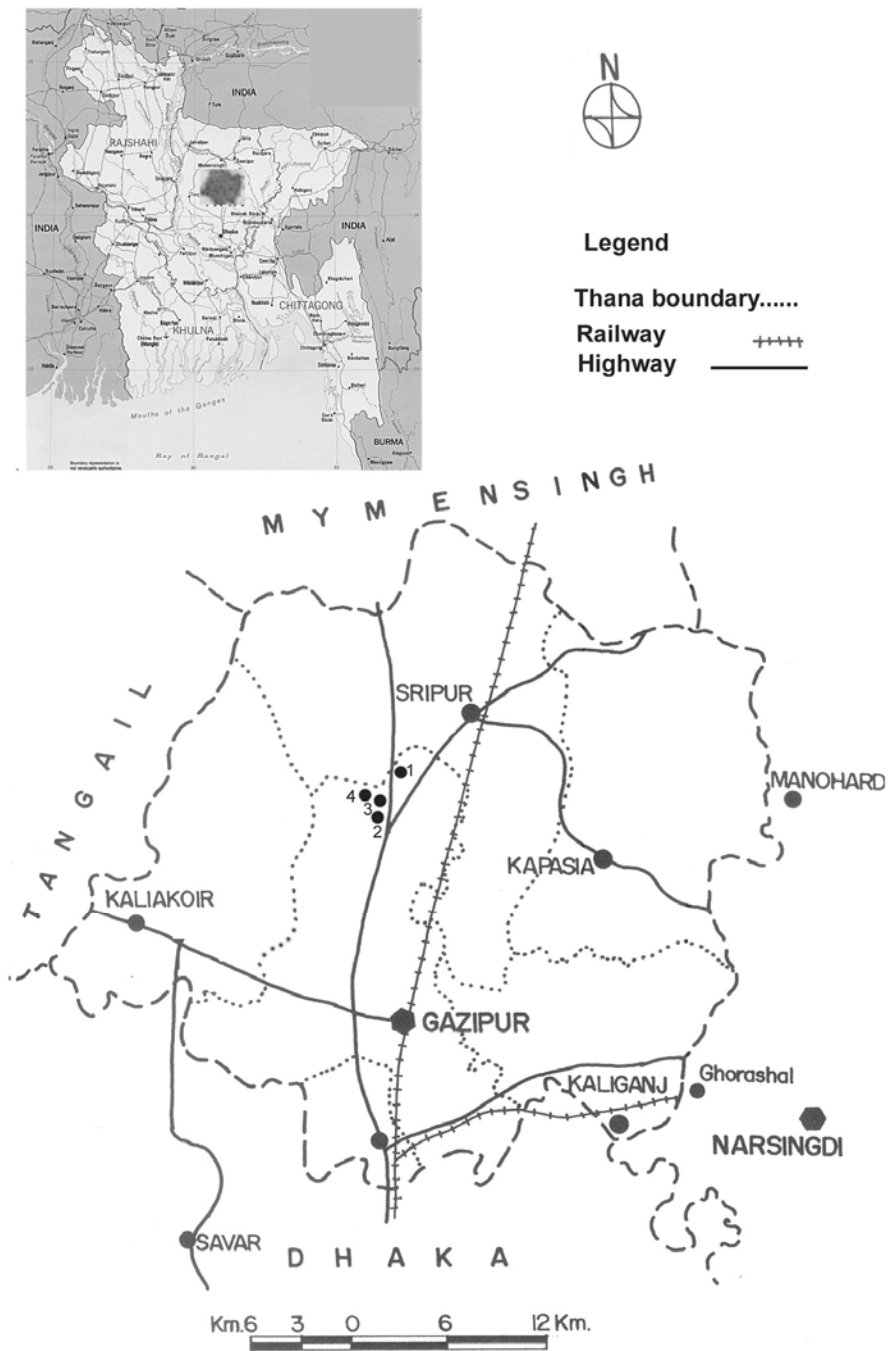


Fig. 1. Map showing the study sites selected from the *Sal* forests area under Gazipur district, Bangladesh. The numbers 1, 2, 3 and 4 stand for the sites of natural *Sal* forest, deforested and planted with Menjium, deforested but not planted, and deforested and planted with Mahogoni, respectively.

natural *Sal* forest site was selected at north to the Bhawal National Park in the eastern side of the Dhaka-Mymensingh road. The deforested and planted with Menjium site was about 2 km south of the natural forest site in the west site of the Dhaka-Mymensingh road in the Salna area. The deforested but not planted with tree site was about 500 m north to the deforested and planted with Menjium site in the North Salna. The deforested and planted with Mahogoni site was also in north Salna which was about 500 m north-west to the deforested but not planted site.

Vegetation analysis and soil sampling: Vegetation analysis and soil sampling were done in September, 2008. A 100 m long transect was placed in each of the four study sites, namely natural forest site, deforested and planted with Menjium site, deforested and planted with Mahogoni site and deforested but not planted site. Then, a quadrat of 64 m² (8 × 8 m) was placed at a distance of 50 m from each other along the transect so that a total of three quadrats were placed in each site. Although a single type of quadrat (64 m²) was placed in the natural forest site, another type of quadrat of 0.25 m² (0.5 × 0.5 m) in size was placed in the centre of the 64 m² quadrat in the other three deforested sites since plants growing naturally in these sites were herbaceous in habit. Then, vegetation analysis was done in 64 m² quadrat in the natural forest site and in 0.25 m² quadrates in the three deforested sites. In the deforested sites, planted tree species were also counted in the 64 m² quadrat. Soil sample was taken from the centre of each of the quadrats. Plants were identified by visual observation and by comparing with herbarium specimens of the Salar Khan Herbarium, Department of Botany, University of Dhaka.

Soil samples were collected from 0 - 10 cm depth and kept in a plastic bag. Immediately after collection, soil samples were brought to the laboratory and separated into two sub-samples; one for bacteriological analysis that was kept in a refrigerator at 4°C and the other for the analysis of physico-chemical properties. The collected soils were sieved through a 2-mm-mesh screen to remove plant roots, rocks, and macrofauna. After sieving, soil samples were analyzed to characterize their physico-chemical properties.

Analysis of soil physico-chemical properties: The pH of soil was measured in a soil water suspension (1 : 2, soil : water). Soil moisture content was determined by weight loss after drying 10 g fresh soil at 60°C for 24 h. Total N was determined by Kjeldahl method following extraction from 2 g soil with conc. H₂SO₄.⁽⁹⁾ Available N content was also determined by Kjeldahl method following extraction from 10 g dry soil using 1N KCl solution. Organic carbon content of the soil was determined by Wakley and Black method using 1 g soil.⁽⁹⁾ Organic matter was determined by multiplying the value of organic carbon by 1.724 (Van Bemmelen factor).

Bacteriological analysis: Nutrient agar medium was used for the enumeration of bacteria present in soil samples. The pH was adjusted before the addition of agar and

sterilization. Serial dilution plate technique was used for the isolation of bacteria.⁽¹⁰⁾ One gram soil sample was diluted (1 : 100) with 100 ml distilled water in a sterile conical flask and shaken well. This suspension was then used to prepare serial dilutions. One ml of this suspension was transferred to 9 ml of sterile water for tenfold (1 : 10) dilution and further diluted up to 10⁵ times dilutions.

Plating in duplicate plates was made for each diluted sample. One ml of each of the diluted sample was taken in a sterilized Petri dish by pipette. Then molten agar medium was poured and mixed thoroughly by rotating the Petri dish, first in one direction and then in the opposite direction. After setting the medium, the plates were inverted and incubated at 37°C for 48 h in an incubator (Memmert GmbH + Co Kg 8540 Schwabach).

After 48 h of incubation, the plates having well discrete colonies were selected for counting. The selected plates were placed on a colony counter (Digital colony counter, DC-8OSK 1000086, Kayagaki, Japan). Colonies were counted and categorized into three groups based on different sizes such as large, intermediate and small colony.

Results and Discussion

Vegetation structure: In the natural *Sal* forest site, the average number of species in a quadrat (64/m²) was 9.6 (Table 1). The species richness excluding the planted species, in deforested and planted with Menjium site, deforested and planted with Mahogoni site and deforested but not planted site in a quadrat (0.25/m²) were 2.0, 2.33, and 1.67, respectively. Plant density in the natural forest site in a quadrat (64 m²) was 126.67. Among the deforested sites mean plant density, excluding planted trees, in a quadrat (0.25 m²) was the highest in the deforested but not planted site (134.33) followed by deforested and planted with Menjium site (53) and deforested and planted with Mahogoni site (25.67). The average number of planted trees in the deforested sites was 22 per 64 m². In the natural forest site, the highest coverage in a quadrat (64 m²) was for *S. robusta* (31.35%) followed by *Curcuma zeoderia* (23.50%). *A. compressus* showed the highest coverage in a quadrat (0.25 m²) in all of the three deforested sites; 88.79% in deforested and planted with Menjium site, 84.42% in the deforested and planted with Mahogoni site and 97.91% in the deforested but not planted site. The average undergrowth vegetation height in the natural sites was 97.78 cm. Among the deforested sites, average plant height of the vegetation excluding planted tree species was 1.33, 1.67 and 2.33 cm, respectively in deforested and planted with Menjium site, deforested and planted with Mahogoni site and deforested but not planted site.

Soil physico-chemical properties: As shown in Table 2, moisture content was significantly ($p < 0.005$) higher in the natural forest site (24.89%) and deforested but not planted site (24.70%) than the deforested and planted with Menjium site (9.92%)

Table 1. Vegetation structure of the four sites selected from Sal forests under Gazipur district, Bangladesh.

Properties	Natural	Deforested and planted with Menjium	Deforested and planted with Mahogoni	Deforested but not planted
Coverage	Shorea robusta (31.35%) Curcuma zeoderia (23.50%)	Axonopus compressus (88.79%) Evolvulus nummularius (11.21%) (Excluding Menjium)	A. compressus (84.42%) (Excluding Mahogoni)	A. compressus (97.91%)
Species richness	9.67/64 m ²	2.0/0.25 m ² (Excluding Menjium)	2.33/0.25 m ² (Excluding Mahogoni)	1.67/0.25 m ²
Plant density	126.67/64 m ²	53.0/0.25 m ²	25.67/0.25 m ²	134.33/0.25 m ²
Plant height (cm)	97.78 (Understory vegetation)	1.33 (Excluding Menjium)	1.67 (Excluding Mahogoni)	2.33

Table 2. Physico-chemical properties of soils of the four sites selected from Sal forests under Gazipur district, Bangladesh.

Properties	Natural	Deforested and planted with Menjium	Deforested and planted with Mahogoni	Deforested but not planted	p
Moisture (%)	24.89 ^a	9.92 ^b	10.41 ^b	24.70 ^a	0.0051
pH	4.77 ^b	4.73 ^c	5.36 ^a	5.36 ^a	<0.0001
Organic carbon (%)	0.72 ^b	1.66 ^a	0.92 ^{ab}	1.64 ^a	0.0085
Organic matter (%)	1.24 ^b	2.86 ^a	1.59 ^{ab}	2.83 ^a	0.0085
Total N (%)	0.29 ^c	0.55 ^a	0.412 ^b	0.40 ^{bc}	0.0003
Available N (µg/g soil)	4.20 ^b	7.14 ^{ab}	12.60 ^a	11.34 ^{ab}	0.0309

Different letters indicate significant difference (Multiple comparison using Tukey-Kramer HSD).

and deforested and planted with Mahogoni site (10.41%). Soil pH was significantly ($p < 0.0001$) higher in the deforested and planted with Mahogoni and deforested but not planted site (5.36) than deforested and planted with Mahogoni site (4.73) and the natural forest site (4.77). Percentage of organic carbon was significantly ($p < 0.0085$) higher in the deforested and planted with Menjium site (1.66) and deforested but not planted site (1.64) than the natural forest site (0.72) while deforested and planted with Mahogoni site (0.92) was intermediate. The four sites showed a trend of soil organic matter contents (%) which was similar to that of the organic carbon contents (%). Total N content was significantly ($p < 0.0003$) higher in the deforested and planted with Menjium site (0.554%) and deforested and planted with Mahogoni site (0.412%) than the other sites. Natural forest site soil also showed a significantly ($p < 0.03$) lower amount of available N content (4.20 $\mu\text{g/g}$ soil) than the deforested and planted with Mahogoni site (12.6 $\mu\text{g/g}$ soil).

Soil bacterial community: Number of the total bacterial colony was significantly ($p < 0.0001$) higher in the deforested but not planted site (5.72×10^6 cfu/g soil) than the other three sites (Table 3). Similar to the total number of bacterial colony, number of bacterial colonies of various size such as large, intermediate and small were significantly higher in the deforested but not planted site than the other sites.

Table 3. Number of bacterial colony forming unit (cfu/g soil) in the four sites selected from *Sal* forests.

Type of bacterial colony	Natural	Deforested and planted with Menjium	Deforested and planted with Mahogoni	Deforested but not planted	P
Large	8.97×10^{4b}	1.10×10^{5b}	2.33×10^{4b}	5.17×10^{5a}	0.0003
Intermediate	1.83×10^{5b}	1.85×10^{5b}	2.18×10^{5b}	8.33×10^{5a}	0.0039
Small	4.00×10^{5b}	3.32×10^{5b}	3.27×10^{5b}	4.73×10^{6a}	<0.0001
Total	6.85×10^{5b}	5.77×10^{5b}	5.67×10^{5b}	5.72×10^{6a}	<0.0001

Different letters indicate significant difference (multiple comparison using Tukey-Kramer HSD).

Plant cover decreases the evaporation rate by lowering light intensity and air movement that ultimately causes increased moisture content in soil.⁽¹¹⁾ Significantly higher moisture content in the natural forest site and the deforested but not planted site as observed in the present study might be associated with the increased plant coverage in these two sites compared to deforested and planted with Menjium site and deforested and planted with Mahogoni site. The natural forest site had stratified vegetation where *S. robusta* was the dominant tree species under which there were a number of shrub and herb species. The deforested but not planted site was densely covered with the profuse growth of *A. compressus*. Compared to the deforested and planted with Menjium site and deforested and planted with Mahogoni site density and average height of the herbaceous plants were higher in the deforested but not

planted site indicating profuse growth of the herbaceous plants in this site. The results of the present study also indicated that Menjium and Mahogoni plants might also be responsible for the loss of water in soil, and it requires further study.

Although pH showed a significant difference among the four sites, soils of all of the sites studied were acidic in nature. This result was in the general agreement that *Sal* forest occurs mainly in acidic soil.⁽¹²⁾ The difference in the soil pH of the sites studied might be related with the changes in vegetation or other disturbances in this area.

In the present study, the organic carbon content in the natural forest site soil was found 0.72% which was almost similar to the result obtained previously by others who reported it to be 0.73%.⁽¹³⁾ However, the results showed that deforestation significantly influenced the soil organic carbon content in the *Sal* forests. Increased organic carbon in the deforested but not planted site might be associated with the plant productivity because organic carbon (i.e. organic matter) in soil usually comes from plant sources. Deforested but not planted site showed the highest plant density (about 134 individual in a quadrat of 0.25 m²) compared to other two deforested sites and was densely covered with *A. compressus* grass species (97.91% of all species). Other study also reported that grassland was the most productive in terms of soil organic matter production among different ecosystems.⁽¹⁴⁾ Significantly lower amount of organic carbon (i.e. organic matter), total N content and available N content in the natural forest site suggested that the natural forest was found to be less fertile and less productive compared to the deforested sites. These results agree with the general agreement that stable and mature forest sites are least fertile among other vegetation sites.⁽²⁾

Carbon content is an important determinant of the microbial growth in soil. The increased organic carbon in the deforested but not planted site might be responsible for the increased bacterial abundance in this site. Other study also showed that microbial biomass is positively related to soil organic matter contents in most ecosystems.^(15, 16) However, in addition to carbon availability in soil, moisture content is also an important factor for microbial growth.⁽¹⁷⁾ Therefore, in spite of increased organic carbon due to lower moisture content in soil, soil bacterial biomass was significantly lower in the deforested and planted with Menjium site than deforested but not planted site where both organic carbon and moisture contents were significantly higher. These results thus indicate that availability of both carbon and moisture content is important for the microbial growth in soil.

Results of the present study also showed that the deforested sites did not support any undergrowth vegetation as like as in the natural *Sal* forests site although the deforested sites were planted by *A. menjium* and *S. mahagoni* about 20 years ago. These results thus suggest that development of undergrowth vegetation in *Sal*

forests has ecological association with *S. robusta*. It was also suggested that the microclimatic differences in temperature, light and air due to canopy occupied by *S. robusta* has influence on the growth and establishment of undergrowth vegetation.⁽¹⁸⁾ The results also suggest that clear cutting of *S. robusta* will consequently cause loss of plant diversity in this typical forest. Changes in vegetation structure due to deforestation have also been reported by some workers.⁽¹⁹⁾

Overall, the results of the present study showed that deforestation significantly altered the physico-chemical and microbial properties of the soil of *Sal* forests. Data also showed that plantation by different exotics might also have significant influence on soil properties. The results of this study thus suggest that the changes in soil properties due to deforestation and plantation by exotics should be taken into consideration while attempts are made for the management of the *Sal* forests.

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