

## IMPACTS OF AGROFORESTRY ON SOIL CHEMICAL PROPERTIES IN DINAJPUR FOREST DIVISION OF BANGLADESH

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KUS-03/22-210503

Manuscript received: May 21, 2003    accepted: August 25, 2004

**Abstract:** An investigation was done to find out the impacts of agroforestry on soil chemical properties. The soil samples were collected from the alley cropped fields of *Acacia auriculiformis*, *Eucalyptus camaldulensis* and *Dalbergia sissoo* as well as from the adjacent mono cropped agriculture fields (control plots). Comparisons were made to find out the changes in soil chemical properties (pH, organic matter, electrical conductivity and nutrient status) in the alley cropping fields and to rank the changes in respect to tree species. Under agroforestry all the three tree species brought significant changes in the soil chemical properties except boron concentration. *Dalbergia sissoo* brought significant positive changes in organic matter, electrical conductivity, Ca, K, N, Fe, Mn, Cu, Zn and S and significant negative changes in pH and P. *Acacia auriculiformis* brought significant positive changes in organic matter, electrical conductivity, K, N, Mn and Cu and significant negative changes in pH, Ca, P, Zn and Fe. *Eucalyptus camaldulensis* brought significant positive changes in organic Matter, K, N and Mn and significant negative change in pH, Ca, Mg, P, Cu, Zn and Fe concentration. *Dalbergia sissoo* increased electrical conductivity, Ca, N, Fe, Cu, Zn and reduced pH most efficiently.

**Keywords:** Agroforestry, Soil Chemical Properties.

### Introduction

Agroforestry is a traditional practice of growing trees on farms for the benefit of the farm families. It has been in use for at least 1300 years according to pollen records although tree domestication probably started much earlier (Sanchez, 1995). Agroforestry is a collective name for land-use systems in which woody perennials (trees, shrubs etc.) are grown in association with herbaceous plants (crops, pastures) and/or livestock in a spatial arrangement or rotation or both, and in which there are both ecological and economic interactions between the tree and non-tree components of the system (Young, 1989). Role of agroforestry in improving soil fertility is well documented. Amelioration of soil by trees is mainly a consequence of increased organic matter inputs, nutrient recycling, protection of soils from erosion, and N<sub>2</sub> fixation, depending upon tree species (Nair, 1984; Prinsley and Swift, 1987; Vergara, 1989; Young, 1989).

With the help of leguminous trees, a considerable amount of N can be added to the soil, thus partly replacing mineral fertilizer. Subsequent nutrient release from leaves, twigs and roots may have an important influence on the organic matter and nutrient budget of the soil (Szott *et al.*, 1991; Young, 1989). Tree crowns in semi arid areas have often been found to create microhabitats of improved soil physical and nutrient status and reduced evapo-transpiration (Moyo *et al.*, 1998). The presence of tree canopies increases soil organic carbon content, moisture availability and nutrient status (Anil *et al.*, 1998). Trees reduce sodicity and improve fertilizer, which results in better growth and productivity of the agri-crop (Singh *et al.*, 1998). The biomass and the total amount of N, P, K, Ca and Mg of vegetation increases in tree-crop association (Sirois *et al.*, 1998).

Alley cropping is a relatively new agroforestry system, defined as the planting of crops in alleys between hedgerows of trees or shrubs which are periodically pruned to reduce shading and supply nutrients to soil (Atta-krah and Sumberg, 1988; Lal, 1989). It is a system that exploits the potential of leguminous trees for the maintenance of soil fertility to improve crop and forage production. Alley cropping has the best potential where use of inorganic fertilizer and pesticides is limited and soils are acidic (Kang and Ghuman 1989).

To reclaim the encroached forest lands from the encroachers by providing diversified products (including forest products) and to improve soil fertility agroforestry was initiated in Bangladesh in 1985 as a government sponsored program with eucalyptus (*Eucalyptus camaldulensis*), akashmomi (*Acacia auriculiformis*), ipil-ipil (*Leucaena leucocephala*), koroi (*Albizia lebbeck*) and sissoo (*Dalbergia sissoo*) in the lateritic soil of North Bengal. Research evidence in Bangladesh to evaluate the suitability and potentiality of these species for agroforestry in terms of soil fertility maintenance is hardly available. So experiment with trial of species should be carried out to specify the suitability of these species in terms of fertility maintenance in soil.

### Materials and Methods

The study was conducted at Prayagpur beat of Charkai range in Dinajpur Forest Division. It lies between 25° 23' to 25° 25' North latitude and 88° 58' to 88° 59' East longitude. 75% of Birampur belongs to Barind Tract and remaining 25% belongs to Tista Flood Plain (Anon, 1995). The soil of the study area is lateritic.

The study was conducted in 2000 in Prayagpur beat. In the study area agroforestry was started in 1985-86 and the plantation of the experimental plots were established in 1991-92 with akashmoni, eucalyptus and sissou. The experimental plots were taken from alley cropped fields. Here the agricultural crop was rice (*Oryza sativa*). There were also control plots of mono cropped fields (without tree) adjacent to each experimental plot where rice was cultivated. The alley cropping was practiced with 9.14m wide alley, 2 rows of trees at 1m x 1m spacing.

The experimental design was a Completely Randomized Design (CRD) with three treatments (eucalyptus, sissou and akashmoni) each replicated ten times. Soil samples from 30 experimental plots (10 plots for each treatment) were collected through randomization. Soil samples were also collected from the 30 control plots. Both the experimental and the control plots were equal in size (0.25 hac.) and were given equal amount of fertilizer.

The chemical analysis of the collected soil samples was done in soil Resource Development Institute (SRDI), Khulna to find out the contents of pH, organic matter, electrical conductivity, Ca, Mg, K, N, P, Fe, Cu, Zn, S, Mn and B in the soil samples. t-test was conducted to see whether the changes in soil chemical properties in experimental plots are significant from control plots (t, df = 9, P < 0.01). Specific treatment comparisons (to rank the treatment effects) was done through fisher's restricted Least Significance Difference (LSD, P < 0.01).

### Results and Discussions

**pH :** It was found that there was a significant change in soil pH in the experimental plots with all the three species from the control plots (P < 0.01), the observed t-values for acacia, eucalyptus and sissou were 17.64, 16.16 and 46.30 respectively. From the negative values of average changes (-0.76 in sissou, -0.53 in acacia and - 0.29 in eucalyptus), it was found that the species brought significant negative changes in soil pH. The LSD test (P < 0.01) concluded that Sissou reduces pH most efficiently, then acacia and then eucalyptus (Table 1 and Fig. 1).

**Organic Matter (OM):** It was found that there was a significant change in soil OM in the experimental plots with all the three species from the control plots (P < 0.01), t-values for the treatments acacia, eucalyptus and sissou were 27.9, 20.81 and 11.21 respectively. The LSD test (P < 0.01) concluded that agroforestry with acacia was most efficient, then with eucalyptus and then with sissou for improving OM concentration in the soil (Table 1 and Fig. 1).

**Electrical conductivity (EC):** From the t-test (Table 1) it was found that there was a significant change in EC in the experimental plots of acacia and sissou from the control plots (t = 11.17 and 13.09 respectively, P < 0.01) but there was no significant change for eucalyptus (t = 0.065). The LSD test (P < 0.01) concluded that agroforestry with sissou and acacia were similarly more effective for increasing EC than eucalyptus (Table 1, Fig. 3).

**Calcium (Ca):** There was a significant change in Ca in the experimental plots from the controls (P < 0.01). The t-values obtained were 8.126, 6.38 and 24.67 for acacia, eucalyptus and sissou respectively. The LSD test (P < 0.01) concluded that agroforestry with sissou was most effective to increase the soil Ca concentration. From the negative values of acacia and eucalyptus it was clear that these species decreased Ca-concentration (Table 1, Fig. 1).

**Potassium (K):** There was a significant change in K in the experimental plots of acacia and sissou from the controls (P < 0.01). The t-values for acacia and sissou were 27.429 and 9.32 respectively. But no significant change (t = 0.408) was found with eucalyptus. The LSD test (P < 0.01) concluded that acacia was more effective than eucalyptus and sissou and the later two species affects similarly (Table 1, Fig. 1).

**Magnesium (Mg):** There was a significant change in Mg in the experimental plots of eucalyptus (P < 0.01). The t-value obtained was 10.40. But acacia and sissou brought no significant change (t = 0.888 and 0.791 respectively). From the negative values of average changes it was found that the species brought significant negative changes in soil Mg. The LSD test (P < 0.01) concluded that eucalyptus has a highest negative effect and acacia and sissou had a similar negligible negative effect on soil Mg concentration (Table 1, Fig. 1).

**Nitrogen (N):** There was a significant change in soil N in the experimental plots with all the three species (P < 0.01). The t-values for acacia, eucalyptus and sissou were 26.247, 16.111 and 36.61 respectively. The LSD test (P < 0.01) concluded that sissou is most effective then acacia and then eucalyptus for improving soil N concentration successively (Table 1, Fig. 3).

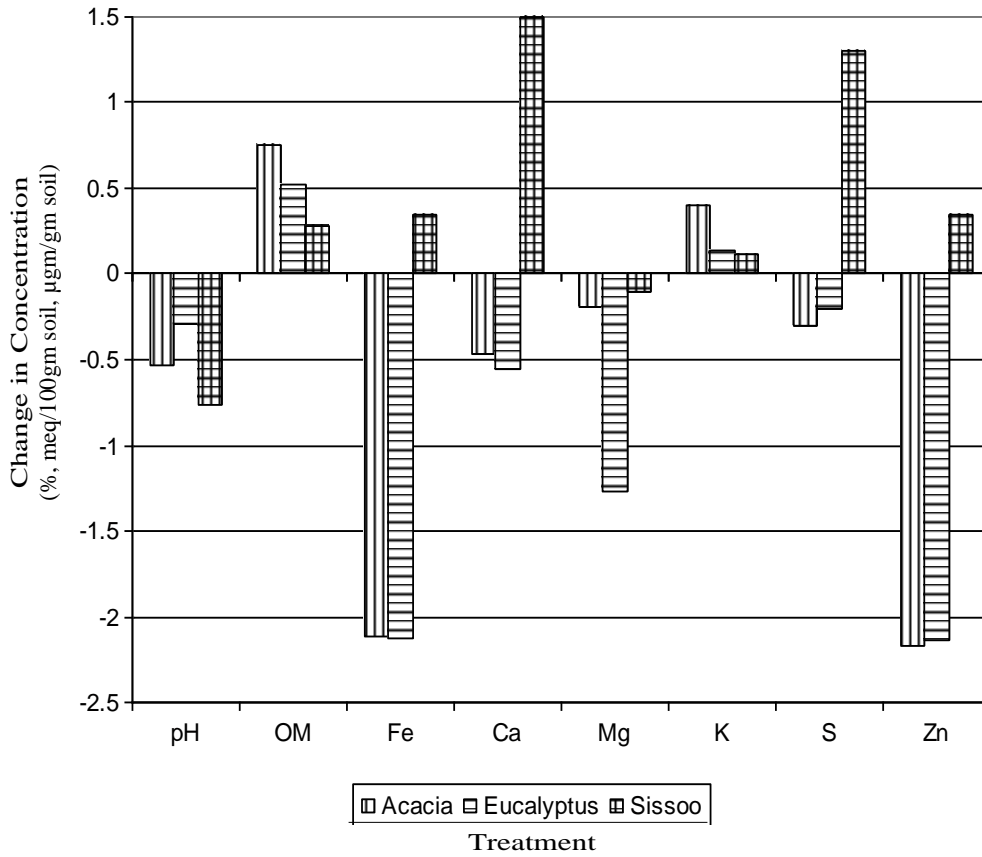


Fig.-1 . Change in concentration of pH, OM, Fe, Ca, Mg, K, S and Zn. The vertical bar represents LSD 0.01.

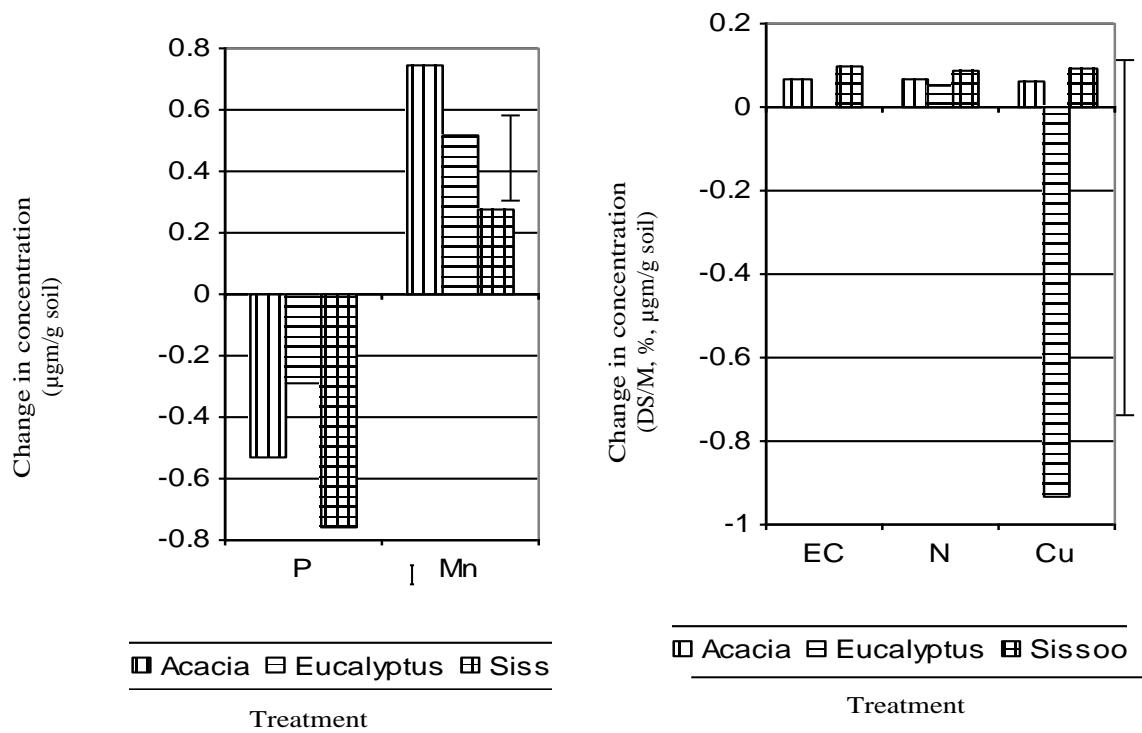


Fig.-2: Change in concentration of P and Mn. The vertical bar represents LSD 0.01.

Fig.-3 Change in concentration of EC, N and Cu. The LSD 0.01. Vertical bar represents

**Phosphorus (P):** There was a significant change in P in the experimental plots of all the three species ( $P < 0.01$ ). The t-values for acacia, eucalyptus and sissoo were 25.166, 18.938 and 22.21 respectively.

The LSD test ( $P < 0.01$ ) concluded that sissoo was superior to eucalyptus and acacia but eucalyptus and acacia were similar. The negative values of average change indicated that all these tree species reduced p-concentration. Therefore sissoo had lesser impact in reducing soil p-concentration than eucalyptus and acacia.

**Sulphur (S):** There was a significant change in S in the experimental plots of sissoo ( $P < 0.01$ ) only. The t-values were 0.05, 0.35 and 22.21 for acacia, eucalyptus and sissoo respectively. There were significant differences among the effects of tree species on soil S-concentration ( $P < 0.05$ ). The observed F value was 3.507. Here the  $LSD_{0.01}$  was 1.878 and the average changes for sissoo, eucalyptus and acacia were 1.303, -0.2 and -0.3 respectively. The LSD test ( $P < 0.01$ ) concluded that the treatments had a more or less similar impact (Table 1, Fig. 1).

**Boron (B):** No significant change was found ( $P < 0.05$ ). The t-values were 0.052, 0.927 and 1.138 for acacia, eucalyptus and sissoo respectively (Table 1).

**Copper (Cu):** There was a significant change in soil copper in the experimental plots of eucalyptus only ( $P < 0.01$ ). From the negative value of average change (-0.93), it can be concluded that the species had a significant negative impact on Cu-concentration. No significant change ( $t = 0.754$  and  $0.223$  respectively) was found for acacia and sissoo. The LSD test ( $P < 0.01$ ) concluded that sissoo and acacia had a similar insignificant positive effect and eucalyptus had a significant negative effect on Cu-concentration (Table 1, Fig. 3).

**Manganese (Mn):** There was a significant change in soil Mn in the experimental plots of all the species ( $P < 0.01$ ). The t-values were 10.74, 10.08 and 11.42 for acacia, eucalyptus and sissoo respectively. The LSD test ( $P < 0.01$ ) concluded that acacia was superior to eucalyptus and sissoo and later two species had similar effects (Table 1, Fig. 2).

**Zinc (Zn):** There was a significant change ( $t = 2.48, 19.56$  &  $4.91$  for acacia, eucalyptus & sissoo respectively) in soil Zn in the experimental plots of all the species (For acacia,  $P < 0.05$  and for eucalyptus and sissoo,  $P < 0.01$ ). But for acacia and eucalyptus, the average changes were negative (acacia -2.166 and eucalyptus -2.128). Hence these two species had a significant negative effect. Whereas the average change for sissoo was positive (0.34). Therefore sissoo had a significant positive effect. The LSD test ( $P < 0.01$ ) concluded that sissoo was superior to eucalyptus and acacia and had a positive impact but eucalyptus and acacia had a similar negative impact (Table 1, Fig. 1).

**Iron (Fe):** There was a significant change in soil Fe in the experimental plots with all the three species ( $P < 0.01$ ). The t-values found were 12.289, 31.08 and 4.896 for acacia, eucalyptus and sissoo respectively. But acacia and eucalyptus brought negative average changes (-2.114 for acacia and -2.119 for eucalyptus) and sissoo brought positive average change (0.34). So acacia and eucalyptus brought negative significant change and sissoo brought positive significant change. The LSD test ( $P < 0.01$ ) concluded that sissoo was superior to acacia and eucalyptus and the later two species had similar negative effects (Table 1, Fig. 1).

The species *Dalbergia sissoo* had increased concentrations of OM, EC, Ca, K, N, S, Mn, Zn, Cu and Fe in soil significantly. Other authors also found evidence of increasing these parameters in agroforestry with *D. sissoo*. Mongia et al. (1998), Garg (1998), Shukla and Misra (1993), Hosur and Dasog (1995) found that alley cropping with *D. sissoo* increases soil OM, Fe, Mn, Ca, K and N significantly. Laskar and Datta (1992) found that this species increase soil EC significantly. In this case the inclination of the above properties may be due to the ability of the species to return higher rate of nutrients through litter fall (Hosur and Dasog, 1995), capacity of the species to produce wider root spread and deep penetration (Garg and Jain, 1996), increased water holding capacity and hydraulic conductivity (Garg, 1998; Shukla and Misra, 1993) and due to higher activities of dehydrogenase (Chander et al., 1998). Increase in Fe, Mn, Zn and S may be due to low soil pH (Brady, 1984) and increase in N-concentration is due to the capacity of the species to fix atmospheric  $N_2$  through symbiotic association (Tewari, 1994). *Dalbergia sissoo* has decreased soil pH significantly. The findings of Mongia et al. (1998), Hosur and Dasog (1995) agreed with this conclusion. This might be due to higher organic matter decomposition (Brady, 1984), increased bulk density and penetration resistance (Hulugalle and Kang, 1990; Kang and Ghuman, 1989) and increased water holding capacity and hydraulic conductivity. (Shukla and Misra, 1993; Kang, 1998). This species also decreased P-concentration significantly. This might be due to constant use of nitrogen fertilizers (Dalland, et al., 1993) and due to removal of Phosphorus by crops through continuous cropping (Brady, 1984; Lal, 1989).

Agroforestry with *Acacia auriculiformis* increased the OM, EC, K, N, and Mn content significantly in the soil. This finding resembles with the findings of other authors. George and Kumar (1988), Osman et al., (1995) and Marothia (1988) also found the improvement of soil OM, N, K through alley cropping with this

species. Chakraborty and Chakraborty (1989) found an increase in electrical conductivity (EC) by alley cropping with this species. These might be due to the production of higher litter input, increased soil moisture by the species, litter input by tree roots (Singh *et al.*, 1995) in association with the improvement of physical properties by increasing silt and clay content and decreasing sand content (Yamoah *et al.*, 1986). The increase in Mn might be due to low pH (Brady, 1984) and the increase in N-concentration was due to the capacity of the species to fix atmospheric nitrogen by symbiotic association (Siddiqi and Ali, 1994). Alley cropping with *A. auriculiformis* has reduced pH, Ca, P, Fe and Zn significantly. The declination of pH might be due to higher organic matter decomposition (Brady, 1984) and increased moisture content caused by this species (Mathew *et al.*, 1997). Though Singh *et al.*, (1995) and Osman *et al.*, (1995) found an increase in Ca, Mg and P contents by alley cropping with this species. From the study it was found that the species had decreased the Ca, P, Fe and Zn significantly. The Ca and P content declination might be due to constant use of nitrogen fertilizers by the farmers (Dalland *et al.*, 1993) and might be due to continuous cropping (Lal, 1989 and Brady, 1984). Ca declination also might be due to low pH. Fe and Zn might be unavailable due to formation of chelates (compounds in which certain metallic cation are complexed or bound to an organic molecule) or might be unavailable due to decreasing of sand content as these nutrients are tightly bound or fixed to certain silicate clays (Brady, 1984). The reduction of these nutrients may also be due to use of leaves of this species by the villagers as fuel.

Alley cropping with *Eucalyptus camaldulensis* increased OM, N and Mn significantly. This findings agreed with the findings of Singh *et al.*, (1998), Louppe *et al.*, (1998) and Chaturvedi and Behl (1996). This might be due to the improvement of soil structure by penetrating previously impermeable layers and by drawing up nutrients from deep in the soil through "nutrient pumping" (Davidson, 1973). On treeless sites eucalyptus improves soil fertility through decayed leaves and litters. Increase in Mn might be due to low soil pH (Brady, 1984). On the other hand, it was found that the species reduced pH, Ca, Mg, P, Cu, Zn, Fe concentration in the soil Sankar *et al.* (1999) also concluded that the species decreases soil pH heavily. Osman *et al.* (1992) found that the species reduces available P concentration in poor fertile eroded hill soils. Zheng *et al.* (1988) concluded that the species declines soil fertility and yields. The above mentioned declination of nutrients might be due to the higher nutrient use efficiency of the species and production of litter that is poor in nutrients than most tropical trees (O'connell *et al.*, 1997). Soil pH might be reduced due to higher organic matter decomposition. Ca and Mg might be decreased due to low soil pH (Brady, 1984). The Ca, Mg and P content might also be reduced due to continuous cropping (Lal, 1989) and constant use of nitrogenous fertilizers (Dalland *et al.*, 1993). Fe, Zn and Cu may be reduced due to decrease of sand content as these nutrients are tightly bound or fixed to certain silicate clays. These nutrients might also be unavailable due to formation of chelates (Brady, 1984). The villagers also reduced these nutrients by removing the leaves.

### **Conclusions**

Besides diversified products, agroforestry plays vital role in soil fertility improvement and it is world wide proved by various researchers that agroforestry may be an alternative solution to reclaim the fertility status of soil. But agroforestry with any tree species can not improve or even maintain soil fertility of every place. So this positive effect of agroforestry on soil is related to site. This study focussed on the effects of alley cropping with akashmoni, eucalyptus and sissoo on the lateritic soil of Dinajpur. Here sissoo increased OM, EC, Ca, K, N, Fe, Mn, Cu, S and Zn and decreased pH and P significantly. Akashmoni increased OM, EC, K, N, M and Cu and decreased pH, Ca, P, Zn and Fe significantly. Eucalyptus increased OM, K, N and Mn and decreased pH, Ca, Mg, P, Cu, Zn and Fe significantly. Hence this study reveals that sissoo performed best in respect to soil fertility maintenance. But it has been observed that eucalyptus and akashmoni are better in relation to growth performance, tree form, stem stability and least shading interference. The survival rate of sissoo was tolerable but growth was unsatisfactory. From farmer's point of view, akashmoni and eucalyptus has got more preference in agroforestry than sissoo. It is important to select the best species for agroforestry in North Bengal. Both soil fertility and productive capacity are to be considered for the effectiveness of agroforestry programs. So, further detailed study with these species and other potential agroforestry species in this regard is necessary.

### **Acknowledgement**

The authors would like to acknowledge Dinajpur Forest Division and Soil Resources Development Institute (S.R.D.I.) Khulna for their co-operation during fieldwork and soil analysis.

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