International Journal of Natural and Social Sciences
Print: 2617-6637 < ISSN > Online: 2313-4461

Transition to agroforestry significantly improves soil quality for increased food production and food security in the terrace ecosystem of Bangladesh

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ARTICLE INFO

Article history

Received: 21March 2022
Accepted: 28 April 2022

Keywords

Agroforestry, Soil quality, Food production, Food security

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ABSTRACT

The study was aimed to evaluate soil chemical properties in jackfruit based multistoried agroforestry system in the central terrace ecosystem of Bangladesh. The study was conducted at a farmer's field under Belabo upazila of Narsingdi district of Bangladesh from September, 2011 to January, 2014. Jackfruit trees were kept as upperstorey; papaya, lemon, mandarin and sweet orange were at middlestorey and seasonal vegetables such as eggplant, bottle gourd and ash gourd were grown as lowerstorey crops.The experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications. There were five treatments covering agroforestry with four orientations and sole cropping (jackfruit trees). Positive changes of the chemical properties of top soil layer were observed in agroforestry over sole cropping (jackfruit trees). Soil pH (4.62), total nitrogen (0.081%), organic carbon (0.61%), organic matter (1.05%), phosphorus (4.23 ppm), Sulphur (10.17 ppm), calcium (2.27 meq/100g), magnesium (0.46 meq/100g) and potassium (0.52 meq/100g) were found higher in agroforestry systems than that of sole cropping (jackfruit trees). Results revealed that soils in the agroforestry systems tuned to more fertile than soil in the sole cropping (jackfruit trees). The results clearly indicated that agroforestry systems are more suitable to build up soil fertility than the sole cropping (jackfruit trees).

INTRODUCTION

The existing land use systems with separate allocation to agriculture and forest are insufficient to meet the demands for food, fuel, fodder, timber and other minor products in the 21st century. One should follow effective and compatible cultivation approaches where fruits and vegetables can be grown combined in the limited land. In this regard, the multistoried agroforestry system may be the best substitute cultivation approach. By practicing this cultivation system, one can efficiently amplify the production of fruits and vegetables simultaneously from the same piece of land.

Bangladesh agriculture has been suffering from acute shortage of biomass to regenerate her soil from depletion of organic matter due to intensive cropping. The scale of reduction (0.01% year^{-1}) of organic matter contained in crop land is alarming. It is estimated that huge amount (9 t ha^{-1} dry matter) of organic materials would be needed to

How to cite this article: Islam MM, Ali ME, Khan MH, Zobair KR, Eivy FZ, Islam MA, Mondol GK and Das SK (2022). Transition to agroforestry significantly improves soil quality for increased food production and food security in the terrace ecosystem of Bangladesh. International Journal of Natural and Social Sciences, 9(1): 31-37. DOI: 10.5281/zenodo.6965359

maintain the current organic matter status (Hossain et al., 1997). This problem could be solved partially through the leaf litter of perennial plant species by an agroforestry system.

Agroforestry system is such a practice which offers great scope to improve soil fertility for sustainable crop production. Agroforestry, as a multifunctional land use strategy has attracted considerable attention in recent years because of its potential to reduce poverty, improve food security, mitigate climate change and reduce land degradation. The potentiality of agroforestry as a sustainable land use system to improve soil quality has been greatly recognized as a major advantage since its inception (Young, 1989; Nair, 2011). Both poplar and guava-based agroforestry systems increased SOC than under sole crop system (Dhaliwal et al., 2018). In agroforestry system tree species on farm lands may bring improvement in soil physical conditions and chemical properties (Nair, 1984). The surging interest in agroforestry to search solution for global problem of climate change and food security is based on the scientific revelations that the tree components of agroforestry not only supplement and compliment growth of agro-components by improving soil health but also contribute toward mitigation of climate changes and food security (Prasad et al., 2016).

Madhupur tract is recognised as one of the most exalted areas for agroforestry, because farmers of these areas have been widely practiced different types of agroforestry systems from ancient time (Rahman et al., 2018; Miah et al., 2018). Jackfruit based agroforestry is the most dominant one in Madhupur tract. The soil of Madhupur tract is strongly acidic with low organic matter and poor fertility status. Papaya, Lemon, Sweet Orange and Mandarin as middle-storey; and seasonal vegetables such as aplant, bottle gourd and ash gourd are very important and ancient crops of Bangladesh; which are extensively grown as compatible agroforestry component in Madhupur tract. Considering the growing interest in Jackfruit based agroforestry systems in Madhupur tract and very limited information on the changing soils fertility status, the present study was conducted to test the changes in soil properties after being practicing multistoried agroforestry system.

MATERIALS AND METHODS

For this experiment representing soil sample was collected from top soil (0-15 cm). Samples collected before and after experiment, were analyzed to understand the changes occurred due to agroforestry practices. The experiment was conducted in a Randomized Complete Block Design (RCBD) with three replications. The data were statistically analyzed using the "Analysis of Variance" (ANOVA) technique with the help of computer package "Statistix 10.0" to examine the significant variation of the results due to different treatments. The mean differences were adjusted by Least Significant Different (LSD) at 5% level of significance (Gomez and Gomez, 1984). Each jackfruit tree was considered as a unit plot for a single replication. There were five treatments covering agroforestry (four orientations i.e., north, south, east and west) and sole cropping (jackfruit trees).

Soil analysis

To know the present status of different elements in the study site, collected soil samples were analyzed in the Bangabandhu Sheikh Mujibur Rahman Agricultural University Laboratory. The samples were analyzed for knowing the specific elements using the following methods:

Chemical analysis

Subsamples of collected soil for analysis were used for chemical analysis of pH, organic carbon (%), total nitrogen (%), available phosphorus (ppm), exchangeable potassium (meq/100 g), exchangeable magnesium (meq/100 g) and exchangeable calcium (meq/100 g). Soil samples were collected before and after the experimentation from the experimental field. Soil samples of respective treatments from the three replications were combined and mixed thoroughly to make composite samples. The composite soil samples were analyzed for properties same as mentioned above. The soil samples were analyzed by the following standard methods as follows:

Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 (Jackson, 1962).

Organic matter and organic carbon

Organic carbon in soil sample was determined by wet oxidation method of Walkley and Black (1934). The underlying principle was used to oxidize the organic matter with an excess of $K_2Cr_2O_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with I N $FeSO_4$ to obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen Factor) and the results were expressed in percentage (Page et al., 1982).

Total nitrogen

Total N content of soil was determined by Micro Kjeldahl method. One gram of oven dried ground soil sample was taken into micro kjeldahl flask to which 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated at 200 °C and added 3 ml H_2O_2 and then heated at 360 °C and it was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page et al., 1982).

Then 20 ml digest solution was transferred into the distillation flask, then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which was marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end remains dipped in the acid. Sufficient amount of l0 N-NaOH solutions was added in the container connecting with distillation apparatus. Water flowed through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate. The conical flask was then removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally, the distillates were titrated with standard 0.01 N H_2SO_4 until the colour changes from green to pink. The amount of N was calculated using the following formula:

$$\% N = (T-B) x N x 0.014 x 100 / S$$

Where, T = Sample titration (ml) value of standard H_2SO_4, B = Blank titration (ml) value of standard H_2SO_4, N = Strength of H_2SO_4, and S = Sample weight in gram.

Available phosphorus

Available P was extracted from the soil with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen et al., 1954). Phosphorus in the extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity was measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page et al., 1982).

Exchangeable potassium

Exchangeable K was determined by 1 N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Page et al., 1982).

Exchangeable calcium, magnesium and sulphur

Exchangeable Ca, Mg and S were normally determined in ammonium acetate extracts of soils by direct titration with EDTA (Hesse, 1971).

RESULTS AND DISCUSSION

Changes in soil chemical properties

The chemical properties of the top soil (0-15 cm) samples, it was observed that all the studied parameters were changed in a positive direction after the experimentation over the initial values which have been presented below.

Soil pH

Soil pH was increased by 1.76% after the completion of study (Figure 1). In general, the soil in the study area is acidic in nature. The increase in soil pH in agroforestry systemmay be explained by relatively higher decomposition of leaves and application of lime and cowdung as organic matter. The decomposition was relatively higher due to application of irrigation water and fertilizers.

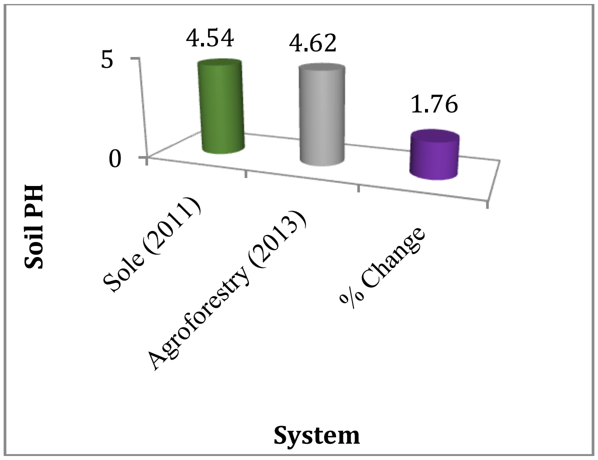

Figure 1: Soil pH changes in multistoried agroforestry system under terrace ecosystem.

Total nitrogen (N): Total N content of soil followed a trend similar to that of Soil pH. Soil total N content after the experimentation was increased by 12.5% over the values obtained before experimentation (Figure 2). The higher nitrogen content in agroforestry systems was probably due to quick leaf decomposition and nitrogen released during organic residues decomposition.

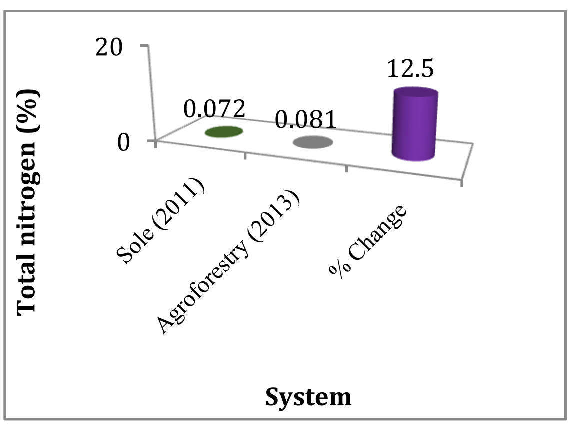

Figure 2: Total N (%) changes in multistoried agroforestry system under terrace ecosystem.

Organic carbon (C)

It was observed that organic C after the experimentation was increased by 3.38% over the values obtained before experimentation (Figure 3). The increased organic C could be attributed to the addition of leaf litters, root biomass and their decomposition. Sing et al., (1989) showed significantly higher organic C in different agroforestry systems than in sole crops.

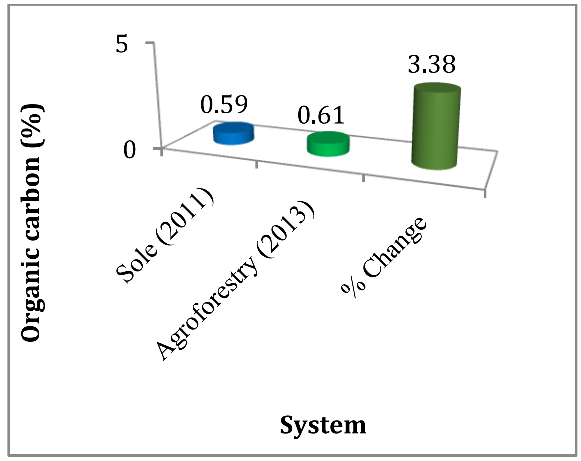

Figure 3: Organic C (%) changes in multistoried agroforestry system under terrace ecosystem.

Organic matter

Changes of organic matter (%) as a result of practicing agroforestry system was positive. Initially the soil organic matter content was 1.01%, which rose to 1.05% after the experimentation and the overall increment rate was 3.96% (Figure 4.)

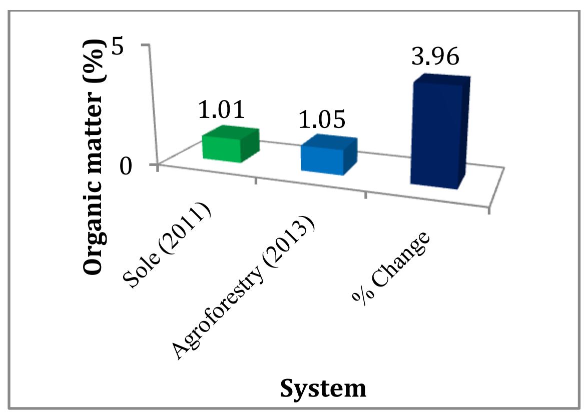

Figure 4: Organic matter (%) changes inmultistoried agroforestry system under terrace ecosystem.

Available phosphorus (P)

After completing the experiment, changes in available phosphorus as a result of practicing agroforestry system showed that it was increased by 12.20% before then (Figure 5).The higher phosphorus availability under agroforestry plots might be due to higher organic matter content of the soil which acted as a buffer of soil and availability of P increased by decreasing acidity of the soil, and in addition P released during organic residues decomposition.

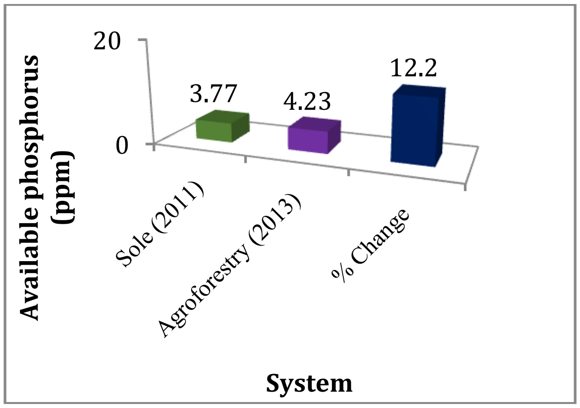

Figure5: Available P changes in multistoried agroforestry system under terrace ecosystem.

Available sulphur (S)

Available sulphurcontent followed a trend similar to that of available phosphorus. Available sulphur content after the experiment was increased by 12.62% (Figure 6).

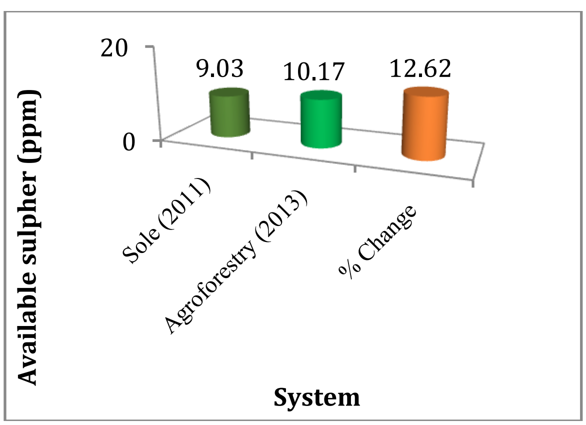

Figure 6: Available S changes in multistoried agroforestry system under terrace ecosystem.

Exchangeable calcium (Ca)

Exchangeable Ca increased due to practicing agroforestry system. The incremental rate of exchangeable Ca after completing the experiment was 9.13% (Fig. 7). The higher soil exchangeable calcium level in agroforestry system might be due to accumulation of calcium in the surface layer. Similar results regarding increase of calcium on surface soil in agroforestry systems have been reported in other experiments (Lal, 1989, Onim et al., 1990 and Soriano, 1991).

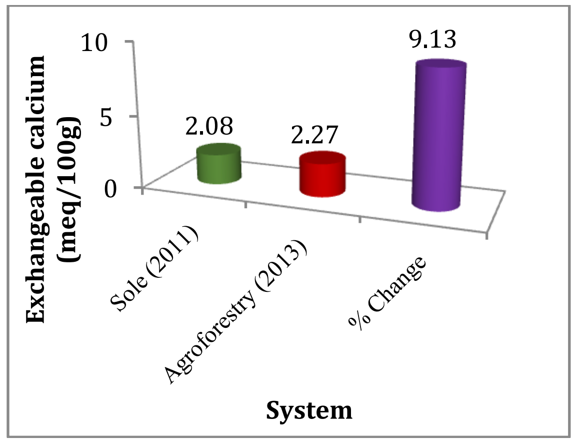

Figure 7: Exchangeable Ca changes in multistoried agroforestry system under terrace ecosystem.

Exchangeable magnesium (Mg)

The trend of soil exchangeable Mg content was similar to exchangeable Ca. Exchangeable Mg content was higher after experiment as compared to before experiment. Soil exchangeable Mg content before and after the experimentation were 0.44 (meq/100g) and 0.46(meq/100g) and it was increased by 4.55% over the values obtained before experimentation (Figure 8).

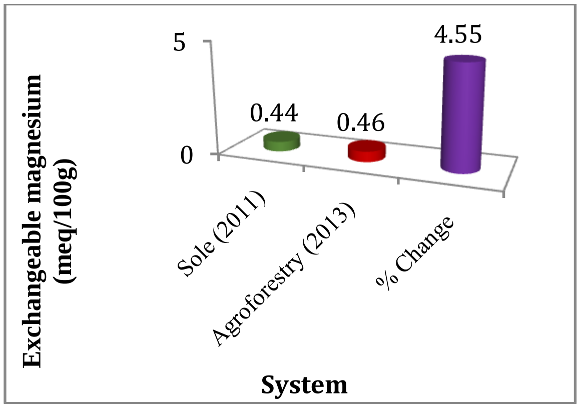

Figure 8: Exchangeable Mg changes in multistoried agroforestry system under terrace ecosystem.

Exchangeable potassium (K)

The exchangeable K content of the top soil layer was slightly increased due to practicing agroforestry system. The exchangeable K content after the experimentation was increased by 1.96% over the values obtained before experimentation (Figure 9). The increase of exchangeable potassium content in the agroforestry treatments was probably due to K return via leaf litter fall to the soil surface. The higher K in agroforestry system might be due to higher decomposition of leaf litter which further enhanced by fertilization and proper irrigation.

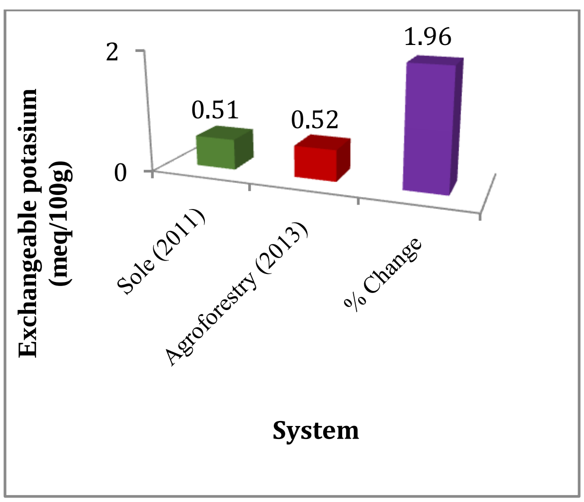

Figure 9: Exchangeable K changes in multistoried agroforestry system under terrace ecosystem.

CONCLUSION

Generally, soil in terrace ecosystem is hard, compact and rich in toxic elements like Al and Fe. Before experimentation, the fields were almost fallow and crops were grown sporadically with very poor management. During experimentation, sufficient compost, fertilizers, lime and irrigation were applied for crop production. All these might accelerate in changing the soil properties in positive direction. Moreover, favorable soil environment was created due to agroforestry practice that also ensured the availability of the nutrients. The chemical properties of the top soil (0-15 cm) layer after the experimentation showed positive changes in fertility. More pronounced changes occurred in agroforestry than in sole cropping (jackfruit trees). There was an increase in pH by 1.76%, total nitrogen by 12.5%, organic C by 3.38%, organic matter by 3.96%, available P by 12.2%, available S by 12.62%, exchangeable Ca by 9.13%, and exchangeable Mg by 4.54% and exchangeable K by 1.96%. Results revealed that soils in the agroforestry systems tuned to more fertile than soil in the sole cropping (jackfruit trees). The results clearly indicated that agroforestry systems are more suitable to build up soil fertility than the sole cropping (jackfruit trees).

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