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IMPROVEMENT OF SOIL FERTILITY THROUGH JACKFRUIT-BASED MULTISTORIED AGROFORESTRY PRACTICES IN TERRACE ECOSYSTEM

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Abstract

This study aimed to evaluate the soil chemical properties of a jackfruit-based multistoried agroforestry system of a farmer's field in Belabo upazila of Narsingdi district located in the central terrace ecosystem of Bangladesh. The three-storied of crops *viz*. upperstorey - jackfruit trees; middlestorey - papaya, lemon, mandarin and sweet orange and lowerstorey - seasonal vegetables such as eggplant, bottle gourd and ash gourd were included in the system. The experiment was conducted in a randomized complete block design with three replications. There were five treatments covering agroforestry with four orientations and sole cropping (jackfruit trees). The agroforestry system improved the chemical properties of top soil layer compared to the sole cropping with 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 recorded in the agroforestry systems that were higher than those of the soil properties of sole cropping (jackfruit trees). The result revealed that practicing agroforestry can help in improving the soil fertility status for successful sustainable crop production.

Keywords: Soil analysis, terrace, multistoried agroforestry, seasonal vegetables, sole cropping.

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 (Miah *et al*., 2002).

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 maintain the current organic matter status (Hossain *et al.,*

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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).

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 a plant, bottle gourd and ash gourd are very important and ancient crops of Bangladesh. These crops 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 evaluate the changes in soil properties after being practicing multistoried agroforestry system.

Materials and Methods

For this experiment represented soil samples were collected from the top soils (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. Each jackfruit tree was considered as a unit plot for a single replication. There were five agroforestry systems and sole cropping that means growing crops outside the agroforestry system. 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).

Soil Analysis

To know the present status of different elements in the study site, collected soil samples were analyzed at the Bangabandhu Sheikh Mujibur Rahman Agricultural University Laboratory.

Chemical analysis

Subsamples of collected soils 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:

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

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 (Fig. 1). In general, the soil in the study area is acidic in nature. The increase in soil pH in agroforestry system may 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. On the other hand, increase in soil pH in agroforestry system might be due to quick leaf decomposition and higher Ca levels (Miah *et al.,* 1997). Similarly increase in soil pH due to addition of organic matter like biomass of *G. sepium* were investigated by Akhter (2009), Gavine (1987) and Onim (1990).

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 (Fig. 2). The higher nitrogen content in agroforestry systems was probably due to quick leaf decomposition and nitrogen released during organic residues decomposition. Nitrogen is the most limiting nutrient for crop growth, development, flowering and fruiting particularly through participating in different

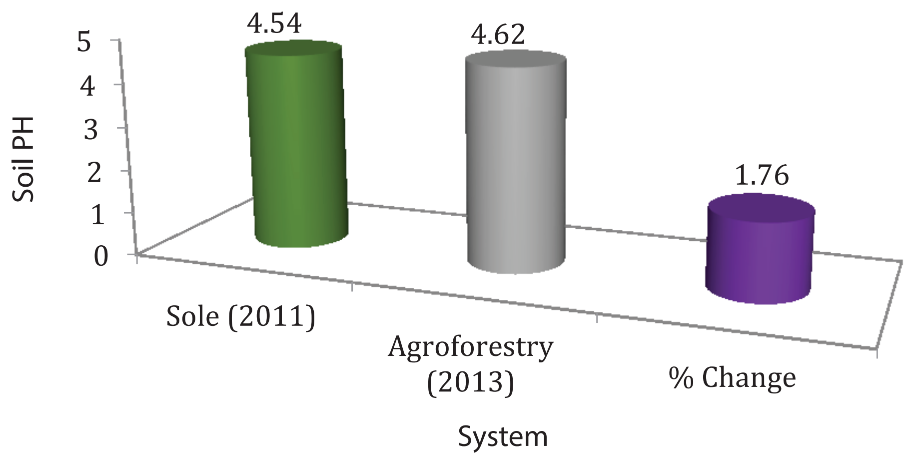

Fig. 1. Soil pH changes in multistoried agroforestry system under terrace ecosystem.

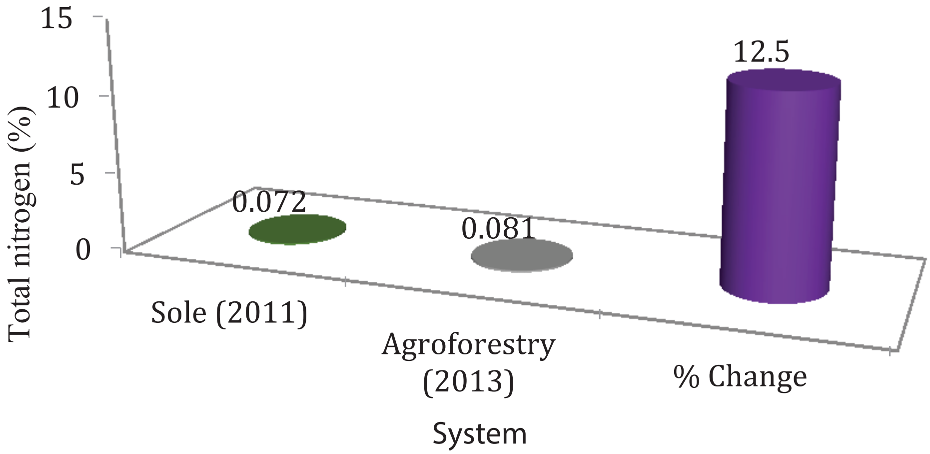

Fig. 2. Total N (%) changes in multistoried agroforestry system under terrace ecosystem.

physiological and metabolic processes of plants. In addition, nitrogen is an important ingredient of chlorophyll pyrrole ring. So, its adequate presence in plants is vital for chlorophyll and therefore, has a great role in photosynthesis. The nitrogen present in the soil environment is subjected to be lost in a very high rate through different pathways like denitrification, ammonia volatilization nitrate leaching etc. (Tonny, 2017 and Ferdush, 2014). As nitrogen is the most limiting nutrient in the tropical and sub-tropical production systems; judicious and balanced application of this macro nutrient as per the requirement of a particular crop concerned is always recommendable for better utilization of nitrogen in crop production system. Agroforestry practice like alley cropping was found to improve the nitrogen content of surface soil (Nwite *et al.*, 2008) which is in agreement with the present findings.

Organic carbon (C)

It was observed that organic C after the experimentation was increased by 3.38% over the values obtained before experimentation (Fig. 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. A good number of scientists observed higher organic carbon content in soil under agroforestry system like alley cropping compared to control (Akhter, 2009; Jones *et. al.*, 1996 and Mazzarino *et. al.*, 1993). Organic matter is thought to be the life of soil which regulates all physical, chemical and biological properties. So, for sustainable agriculture, regular supply of organic matter in soil is to be ensured using different sources. Agroforestry system may be one of the options that can contribute a lot in enhancing organic carbon level in soil and bring diversified benefits to the production system.

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% (Fig. 4.)

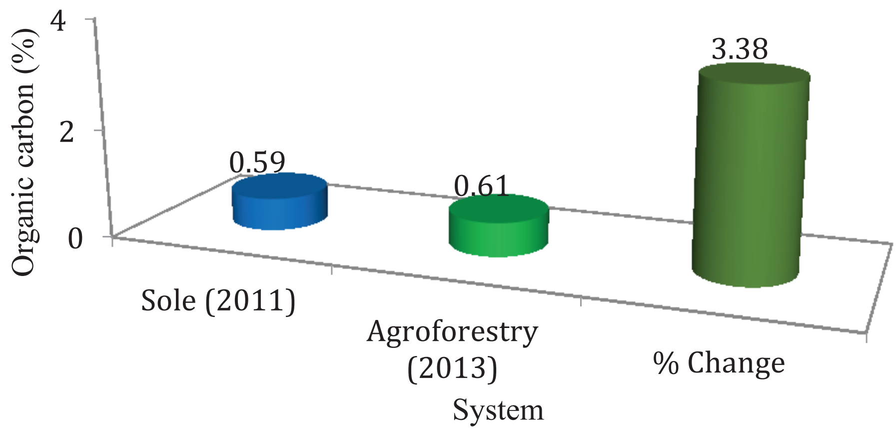

Fig. 3. Organic C (%) changes in multistoried agroforestry system under terrace ecosystem.

Available phosphorus (P)

Phosphorus is the most vital essential macro nutrient which is responsible for successful plant growth. Available phosphorus in soil imply the portion of the soil phosphorus which can easily be absorbed by the plant and that can be extracted by dilute acid solution. The P content in agricultural soil is low. On the other hand, P fertilizer that is applied in the field during crop production is subjected to rapid fixation with calcium in calcareous soil or with Fe, Al and Mn in acidic soil. After completing the experiment, changes in available phosphorus as a result of practicing agroforestry system showed that it was increased by 12.20% compared to control (Fig. 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

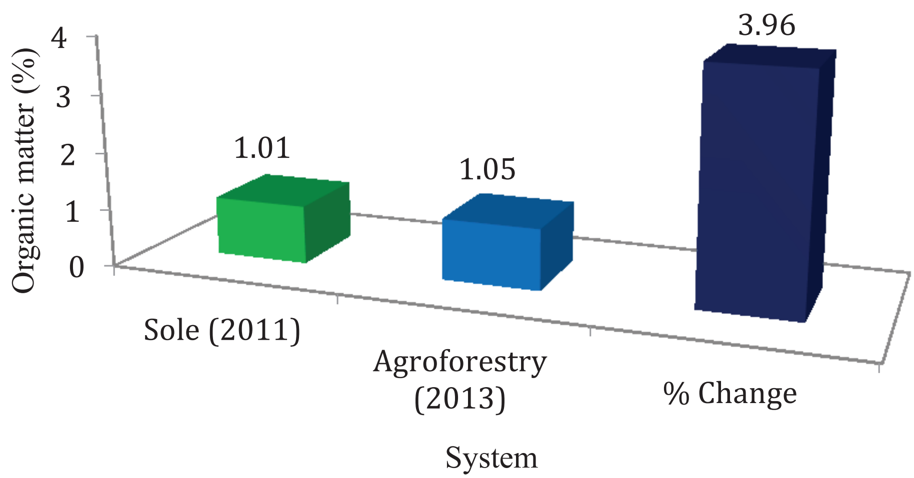

Fig. 4. Organic matter (%) changes in multistoried agroforestry system under terrace ecosystem.

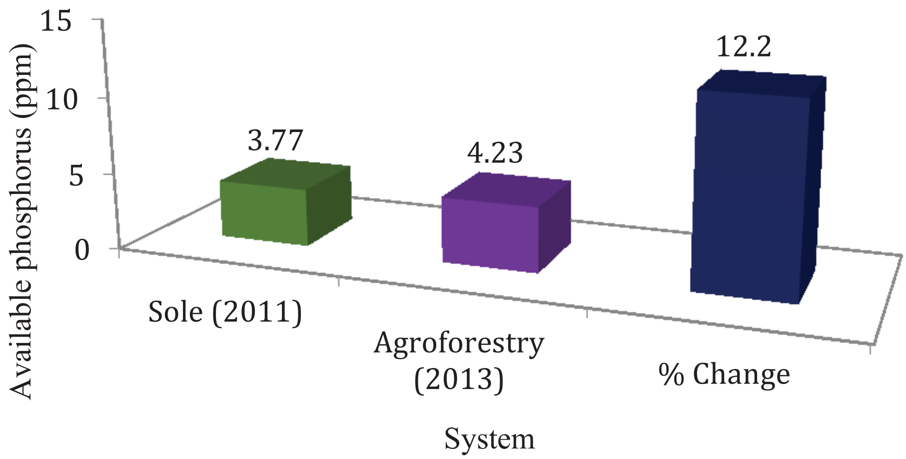

Fig. 5. Available P changes in multistoried agroforestry system under terrace ecosystem.

of P increased by decreasing acidity of the soil, and in addition P released during organic residues decomposition. In agroforestry system like alley cropping, decomposition of added organic matter in soil help in increasing the P level as reported by Tonny (2017) and Ferdush (2014). Similar results were also published by Agboola *et al*. (1982).

Available sulphur (S)

Available sulphur content followed a trend similar to that of available phosphorus. Available sulphur content after the experiment was increased by 12.62% (Fig. 6). Sulphur is required for the formation of proteins, enzymes, vitamins and chlorophyll in plants. Increase in Sulphur content of soil after agroforestry practices over control was also found by Alam *et al.* (2021).

Exchangeable calcium (Ca)

Calcium is an important mineral which regulates different physiological and metabolic activities in plants. 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 ; Soriano, 1991).

Exchangeable magnesium (Mg)

Magnesium is the most important essential plant nutrient which regulates directly or indirectly all physiological, biochemical and metabolic activities of the plant. More specifically, Mg is the key nutrient which is positioned in the center portion of the pyrrole ring of the chlorophyll molecule and if this Mg is deficient in plant, chlorophyll molecule will not be formed and thus photosynthesis will tremendously be hampered. The trend of soil exchangeable Mg content was similar to exchangeable Ca. Exchangeable Mg content

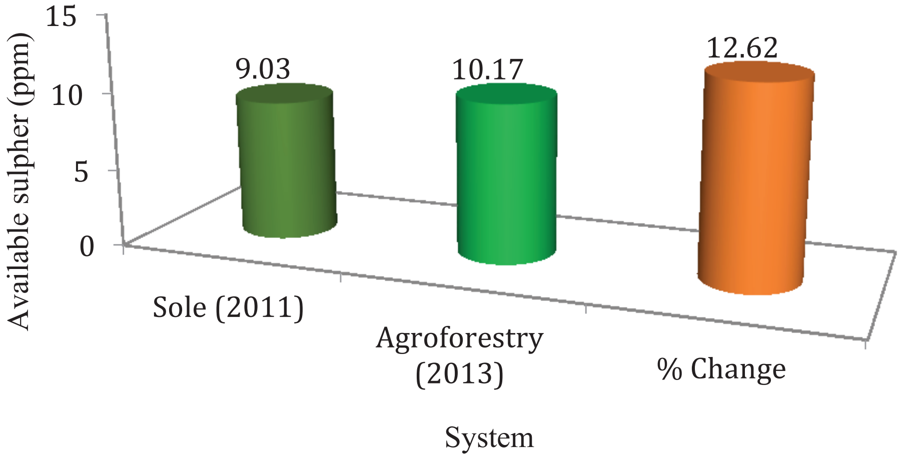

Fig. 6. Available S changes in multistoried agroforestry system under terrace ecosystem.

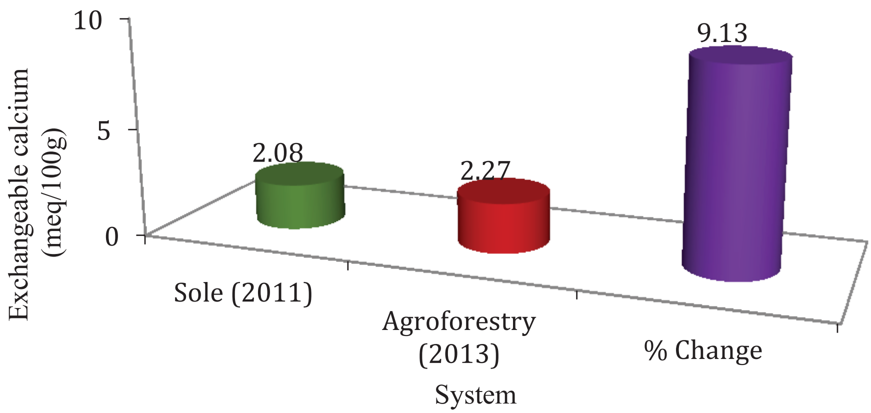

Fig. 7. Exchangeable Ca changes in multistoried agroforestry system under terrace ecosystem.

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 (Fig. 8). An increasing trend of exchangeable Mg content in soil was also reported by Tonny (2017) when cabbage was grown in agroforestry system (alley cropping).

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 (Fig. 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

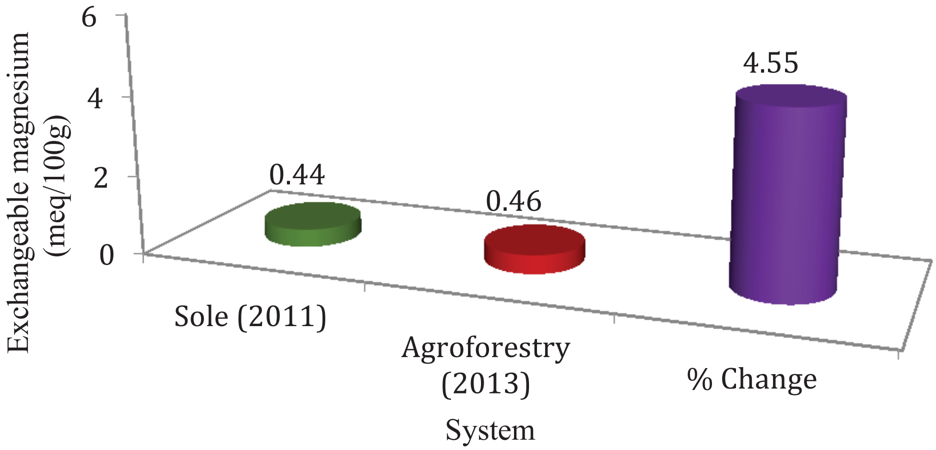

Fig. 8. Exchangeable Mg changes in multistoried agroforestry system under terrace ecosystem.

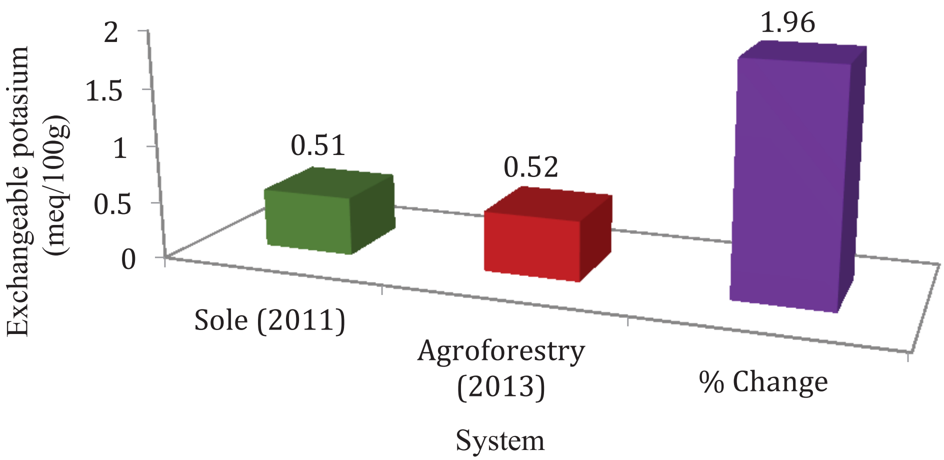

Fig. 9. Exchangeable K changes in multistoried agroforestry system under terrace ecosystem.

higher K in agroforestry system might be due to higher decomposition of leaf litter which further enhanced by fertilization and proper irrigation. Increased exchangeable K in plots of agroforestry systems might be due to the readition of K from agroforestry plots (Miah *et al.,* 1997). Ferdush (2014) also observed similar result with the addition of biomass from *G. sepium* in alley cropping system when wheat was cultivated in the alleys.

Conclusion

Results revealed that soils in the agroforestry systems tuned to more fertile than soil in the sole cropping. It clearly indicates that agroforestry systems are more suitable to build up soil fertility than the sole cropping.

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