Influence of fruit based agroforestry systems on soil properties for sustainable soil health in hill zone of West Bengal, India

ABSTRACT

A field experiment on fruit based agroforestry systems comprising of one silvi (*Alnus nepalensis*), two fruit trees, (*Citrus reticulata* Blanco. and *Pyrus communis*) and ten intercrops *viz* maize, rice, french bean, pea, and pumpkin during *kharif* and potato, cabbage, cauliflower, mustard and onion during *rabi* season of two consecutive years (2013-2015) was conducted at Dalapchand Science Farm, Krishi Vigyan Kendra (KVK), Kalimpong, West Bengal. The experiment was laid out in randomized block design (RBD) with three replications. The fruit plant grafts were planted at spacing of 10m x 10m. The silvi saplings were planted in between the two fruit plants and boundary at spacing of 2.5m during *kharif* 2011. The intercrops were grown in the interspaces between the two fruit trees during two consecutive years. Depth wise (0-15cm, 15-30cm and 30-60cm) soil samples were collected from the field twice, once at initial (before intercropping) and next at final (at the end of two years of intercropping) by using screw auger. Results revealed that higher improvement in soil physico-chemical properties at 0-15 cm,15-30 cm and 30-60 cm soil depth recorded *viz*. bulk density (1.26, 1.34, 1.37gm^{-}cm^{3}), water holding capacity (39.44, 35.78, 33.29%), soil pH (5.90, 6.23, 6.34), organic carbon (2.04, 1.07, 0.81%), available N (517, 416, 319 kg ha^{-1}), P (14.38,12.18, 9.52 kg ha^{-1}), and K (535, 349, 289 status kg ha^{-1}) respectively were found under ***Alnus nepalensis* + *Citrus reticulata* + pea + mustard** plot at the end of two years of study. However, among the different treatment combination, integrating silvi (*Alnus nepalensis*) and fruit trees (*Citrus reticulata* Blanco. and *Pyrus communis*) with intercrops (*kharif + rabi)* showed significant improvement in soil physico-chemical properties than silvi and fruit trees alone or sole crops plots.

Keywords: *Intercrops, Alder, Mandarin, Asian pear, silvi.*

1. INTRODUCTION

Agroforestry is an ideal scientific approach for restoration of degraded lands and sustainable resource management. The importance of tree based land use systems in restoring soil fertility and improving the economy of farmers having small land holdings has been realized during the last two decades [1, 2, 3]. Improvement of soil fertility under agroforestry systems occurs mainly through addition of plant biomass. However, in certain situations trees may have an adverse effect on soils. The magnitude of benefits or adverse effect depends on the number of site-specific factors and attributes of associated tree species. The fertility of soil improves under the tree cover, which checks soil erosion, adds soil organic matter, available nutrients and replenishes the nutrients through effective recycling mechanisms. The pressure on the agricultural lands has increased manifolds due to overpopulation, urbanization and industrialization process. These factors have not only affected the agricultural production but the environmental conditions have also got degraded. There is a global crisis of energy and man is striving hard to find out some alternative source of energy [4]. Fuel wood is one of the established sources to meet energy requirement [5].

Agro-forestry has both productive and protective potential and it can play an important role in enhancing the productivity of the lands to meet the demand of ever-growing human and livestock population [6, 7]. The role of trees in soil conservation and erosion control is one of the most widely acclaimed and compelling reasons for including trees on farm lands prone to erosion hazards [8].

In hill zone of West Bengal (India) where cultivable lands has been degraded by erosion hazard, agroforestry has a great potential of both restoring and maintaining soil fertility and increasing agricultural production [9]. In this region about 70 % of population is dependent on agriculture. The major factors that are adversely affecting agricultural production are age-old practice of traditional cultivation, sloppy topographical condition and highly eroded soil due to heavy rainfall. Under such socio-environmental conditions, practice of agroforestry can play an important role in checking soil erosion and improving soil fertility by conserving moisture and nutrients, which in turn may enhance the agricultural production and livelihood of marginal farmers. In view of the above, the present paper deals with the effect of selected fruit based agroforestry systems on improving physico-chemical properties of soil for sustainable soil health after two years period of study.

2. MATERIALS AND METHODS

2.1 Description of Study site

Field trial was conducted during the year 2013-2015 at the Dalapchand Science Farm, Krishi Vigyan Kendra (KVK), Kalimpong, West Bengal, India. The experimental site is located at 27.06^{o} N latitude and 88.47^{o} E longitudes at an elevation ranging between 979.93 m. to 1257.30 m. above mean sea level [10]. The average annual rainfall of this area generally varies between 2000 to 3000 mm, about

80% of which are usually precipitated between June and September (monsoon period). Even within this short period, the rainfall may be unevenly distributed. In the month of July to August the heavy rains are likely to occur. Rainfall is not certain from the month of November to March. Partial or even total crop failures are the usual feature of the rainfed agriculture in this region. In this area, mean annual maximum and minimum temperatures vary from 15 to 24˚C and 7.5˚ C to 9˚C respectively during the whole period of experimentation. The intensity of sunlight is low, particularly in the monsoon and winter months, which in addition to altitude lowers the temperature. The summer temperature is generally high and during winter temperature remains moderately low. The climate of the site varies from sub-tropical to temperate type. The crop season of this region are broadly classified as summer or *pre- kharif* (March to May), rainy season or monsoon *kharif* (June to October) and winter or *rabi* (November to February). The mean relative humidity was found to vary from 70 to 80% depending on the locality and season of the year. The soils of the site are mostly categorized as red lateritic and brown forest soil. Organic matter content (1.07-0.12%), light and high sandy loam or clay textured, porous with poor water holding capacity. Low pH due to strong (pH below 4.9) to (moderately acidic pH 5.0-5.9) reaction, available phosphorus (9.9-15.8 kg ha^{-1}), and potassium content (488-592 kg ha^{-1}).

2.2. Intercropping under plantation in field

The experiment was fitted in randomized block design (RBD) which was replicated thrice. The grafted saplings of two fruit species (*Citrus reticulata* Blanco and *Pyrus communis*) were planted at 10m x 10m and one year old silvi sapling of *Alnus nepalensis* D. Don. were planted in the third week of June 2011, planted in between the fruits species and boundary at spacing 2.5 m. Suitable varieties of ten intercrops viz. maize (RCM-I-I), rice (Kalimpong-I), french bean (RCMFB-I), pea (Pusa Pragati) and pumpkin (Pusa Vishwas) during *kharif* and potato (Kufri Jyoti), cabbage (Pusa Drumhead), cauliflower (Pusa Snow Ball K-I), mustard (Pusa mustard 27(EJ-17) and onion (Pusa White Round) during *rabi* season of two consecutive years (2013-2015) were grown in between the two fruit trees and different growth parameters of intercrops were recorded for the consecutive two years. The entire field was given equal cultural practices and raised under rainfed condition. The control plots were taken as area devoid of trees and fruit trees.

2.3 Soil sampling methods

Initial soil samples (before intercropping) were collected from entire experimental plot at three different soil depth (0-15cm, 15-30cm and 30-60cm) by using screw auger. The depth wise soil samples were completely air dry in shade at room temperature for laboratory determination of physio-chemical properties of soil *viz*. bulk density($gm^{-}cm^{3}$), water holding capacity (%), soil pH, organic carbon (%), available N, P and K status. The standard methods were followed for the analysis of soil. Similarly, soil samples were again collected from both the intercropped and control plots at the end of two years of study after harvesting of different arable intercrops. Plot wise soil samples on depth basis were collected from (0-15cm, 15-30cm and 30-60 cm) by using screw auger. The soil samples were completely dried at room temperature and analysis was done as initially to determine the influence of fruit based agroforestry system on soil physico-chemical properties at the end of experimentation.

2.4 Laboratory methods

The collected soil samples were completely air dried and were grinded by a wooden mortar to break the soil aggregates and passed through a 2 mm sieve and analysed for the soil physico-chemical properties of soil and recorded. The bulk density and water holding capacity of soil was determined by Keen Raczkowski Box method. The pH of the soil was determined after equilibrating the soil sample with distilled water (soil: water:: 1: 2.5 % w/v) by means of a glass electrode pH meter as suggested by Beckman's pH method as described by [11]. The organic carbon status of the soil was determined by wet digestion method as proposed by Walkey and Black as described by [11]. Organic matter was calculated by multiplying the organic carbon percent by value of Von Bemmelen factor 1.724. The available potassium status of the soil was determined with 1 normal neutral ammonium acetate solution (1 *N* CH_3COONH_4) as described by [11] using flame photometer and available phosphorus status of the soil was determined by Bray and Kurz No. 1 as described by [12] and then "P" was determined by calorimetrically using 660mμ wavelength. The available nitrogen status of the soil was determined by alkaline potassium permanganate method as described by [12].

3. RESULTS AND DISCUSSION

3.1. Effect on soil physical properties

3.1.1 Bulk density

The results revealed at 0-15 cm soil depth the effect of fruit based agroforestry on soil bulk density was found significant at 5% level of significance (Table.1). It is shows that decreasing effect in soil bulk density under fruit based agroforestry as compared to initial value (before intercropping) in all soil depths. Furthermore, sole fruit tree system does not show that effective as compared to silvi (*Alnus nepalensis*) + fruit tree (*Citrus reticulata* & *Pyrus communis*) + intercrops (*kharif* and *rabi*) system. Similar trend was observed in other depth of soil too. In all soil depth higher decrease in soil bulk density was recorded under *Alnus nepalensis* + *Citrus reticulata* + pea (*kharif*) + mustard (*rabi*) followed by *Alnus nepalensis* + *Pyrus communis* + pea (*kharif*) + mustard (*rabi*) and least in sole fruit tree. It was observed that at initial (before intercropping) the soil bulk density gm^{-}cc was found at soil depth 0-15cm, 15- 30 cm and 30-60 cm were 1.64, 1.96 and 2.24 gm^{-}cm^{3} respectively. The decrease in bulk density is corroborating with tillage operation during crop cultivation during the intercropping of agroforestry system. The soil compaction is phenomenal that involves significant interrelationship between physical and biological properties of soil. The improvement in bulk density of the top soil from as a result of tillage operation, intercultural operation and leaf litter accumulation under agroforestry system [13]. Under agroforestry system bulk density increases significantly with soil depths [14]

3.1.2 Water holding capacity

The study on the soil water holding capacity (%) at different soil depths under different treatment combination is presented in (Table 1). The result revealed that at initial (before intercropping) the soil water holding capacity (%) was higher at surface soil depth (0-15 cm) (33.01 %) and decreases as the increase in soil depth. At the end of field experimentation, in all soil depths the soil water holding capacity (%) was found increase significantly. At soil depth 0-15cm higher WHC(%) was recorded in *Alnus nepalensis* + *Citrus reticulata* + pea (*kharif*) + mustard (*rabi*) (39.44 %) intercrops treatment followed by *Alnus nepalensis* + *Pyrus communis* + pea (*kharif*) + mustard (*rabi*) (38.15%) intercrops treatment and was lowest in sole fruit trees (35.43 and 34.10 %) respectively. This might be due to more litter production and subsequent litter decomposition under trees favouring higher soil moisture retention capacity [15]. More or less similar, trend was observed in other depth of soil with same intercrop treatment. Respective of silvi (*Alnus nepalensis*) and fruit species (*Citrus reticulata.* Blanco and *Pyrus communis*) it was observed that the soil water holding capacity (%) was found significantly higher in case of mandarin (*Citrus reticulata*) plantation with pea + mustard intercrop treatment followed by french bean + cauliflower intercrop treatment than the Asian pear (*Pyrus communis*) plantation with different intercrops treatment combination. On average, legume tree and crops enrich the more organic carbon into the soil as compared to non-leguminous species. Water holding capacity of soil was high in woodlots as compared to control. In multi-storey plots, soil moisture was two to three folds higher as compared to control [16].

3.2. Effect on soil chemical properties

3.2.1 Soil reaction (pH)

Silvi (*Alnus nepalensis*) + fruit trees (*Citrus reticulata* + *Pyrus communis*) and intercrops show significant effect on soil pH in all soil depths (Table.2). At soil depth 0-15 cm, revealed that soil pH vary from 5.81 to 5.90 in case of *Alnus nepalensis* + *Citrus reticulata* + intercrops and in *Alnus nepalensis* + *Pyrus communis* + intercrops ranges from 5.78 to 5.87. The less change in pH was notice in both sole fruit trees plantation (5.78 and 5.75). In *Alnus nepalensis* + fruit trees (*Citrus reticulata* and *Pyrus communis*) + intercrops study revealed that more or less similar rise in soil pH. *Alnus nepalensis* + *Citrus reticulata* + maize + potato and *Alnus nepalensis* + *Citrus reticulata* + pumpkin + onion were found at par. Similarly, *Alnus nepalensis* + *Pyrus communis* + maize + potato and *Alnus nepalensis* + *Pyrus communis* pumpkin + onion were also found at par. Above all *Alnus nepalensis* + *Citrus reticulata* + pea + mustard showed higher increase in pH value i.e. 5.90 in 0-15 cm soil depth.

It was observed in soil depth 15-30 cm that soil pH vary from 6.06 to 6.23 in case of *Alnus nepalensis* + *Citrus reticulata* + inter crops and in *Alnus nepalensis* + *Pyrus communis* + intercrops ranges from 5.96 to 6.19. The less change in pH was notice in both sole fruit tree plantations (5.95 and 5.89). Like the 0-15cm depth in *Alnus nepalensis* + fruit trees (*Citrus reticulata* and *Pyrus communis*) + intercrops study revealed that more or less similar rise in soil pH. Above all *Alnus nepalensis* + *Citrus reticulata* + pea + mustard showed highest mean pH value i.e. 6.23 in 15-30 cm soil depth. In soil depth 30-60 cm the result revealed that soil pH varies from 6.19 to 6.34. in case of *Alnus nepalensis* + *Citrus reticulata* + intercrops and in *Alnus nepalensis* + *Pyrus communis* + intercrops ranges from 6.13 to 6.29. The less change in pH was notice in both sole fruit tree plantations (6.09 and 6.05). Study revealed that *Alnus nepalensis* + fruit trees + intercrops show more or less similar rise in soil pH. *Alnus nepalensis* + *Pyrus communis* + rice + cabbage and pumpkin + onion were found at par. Similarly, *Alnus nepalensis* + *Citrus reticulata* + maize + potato and *Alnus nepalensis* + *Citrus reticulata* + pumpkin + onion were also found at par. Above all *Alnus nepalensis* + *Citrus reticulata* + pea + mustard showed highest mean pH value i.e. 6.34 at 30-60 cm soil depth. Results of different treatments in agroforestry system showed tremendous effect with respect to soil pH. The increasing in soil pH corroborates with biomass accumulation of trees species and intercrop residues decomposition neutralize soil pH. Soil pH found to increase in upper soil depth then lower soil depths. In agroforestry system, silvi spices with different intercrops helps to reduce acidic condition of soil the reason may be that increase in availability of nutrients and organic matter. Lowest soil pH is also associated with penetration and percolation of surface material to the subsurface soil depths due to heavy rain during the monsoon season [17].

3.2.2 Organic carbon (OC)

The result presented in (Table 2) on the effect of soil depth on organic carbon content reveals that the organic carbon (%) was found to increase significantly among the treatments. However, the highest (2.04 %) of organic carbon was found at 0-15 cm depth in *Alnus nepalensis* + *Citrus reticulata* + pea + mustard followed by *Alnus nepalensis* + *Pyrus communis* + pea + mustard (1.93 %). It was (1.69%) in sole *Citrus reticulata*. It also revealed that lowest (1.63 %) organic carbon was recorded in sole *Pyrus communis* fruit tree. Similar observation of highest and lowest organic carbon was recorded in the same combination in all the depth studied. Therefore, it can be seen that the organic carbon content was highly increase in different depth due to the intercropping of pea + mustard and french bean + cauliflower in the present study. However, the soil organic carbon content was found to increase in all the combination of tree + fruit trees and intercrops and in all the depth (0-15 cm, 15-30 cm and 30-60 cm) which was statistically at par.

Study also reveals the organic matter content was found highest in *Alnus nepalensis* + *Citrus reticulata* + pea + mustard (2.25 %) followed by *Alnus nepalensis* + *Citrus reticulata* + french bean + cauliflower and *Alnus nepalensis* + *Pyrus communis* + pea + mustard (2.13 %). Soil organic carbon estimated in surface soil concomitant rise under agro forestry system as compared under open land. The higher soil organic carbon content was found under silvi plantation than open grass rooted trees and shrubs which recycle plant nutrient from lower soil strata and build up the soil organic matter [18]. The higher soil organic matter content in top soil under agroforestry than open area. Agroforestry remain a vital instrument to conserve soil organic carbon to increase the fertility status of the hill region [19].

3.3 Effect on soil nutrient status

3.3.1 Available nitrogen (N)

The effect of fruit based agroforestry on soil available nitrogen is significant in different depths (Fig.1). The available N at the end of experimentation in fruit based agroforestry system revealed that the highest available nitrogen (517.00 kg ha^{-1}) was observed in *Alnus nepalensis* + *Citrus reticulata* + pea + mustard followed by *Alnus nepalensis* + *Pyrus communis* + pea + mustard (514.00 kg ha^{-1}) at 0-15 cm depth. The lowest nitrogen content was recorded in sole fruit trees (456.00 and 449.00) kg ha^{-1} in *Citrus reticulata* and *Pyrus communis* respectively.

At 15-30 cm soil depth, highest available nitrogen was recorded in *Alnus nepalensis* + *Citrus reticulata* + pea + mustard (416.00 kg ha^{-1}) which was followed by *Alnus nepalensis* + *Pyrus communis* + pea + mustard (412.00 kg ha^{-1}). It was again recorded highest in the same combination at 30-60 cm soil depth. Moreover, there was a significant rise in level of available nitrogen in all the treatments and in all the depth studied as compared to the initial observed amount of available nitrogen. Among the intercrops showed tremendous effect in increasing soil nitrogen but also concomitant with nature of plant growth. It also observed that pea and mustard was the best intercropped along with silvi species (*Alnus nepalensis*) + fruit trees (*Citrus reticulata* and *Pyrus communis*) regarding increasing soil nitrogen.

In agroforestry system when trees species intercropping with leguminous crops can fix atmospheric nitrogen through symbiotic association (plant and bacteria) in plant roots which ultimately helps to build soil nitrogen. Soil nitrogen was found to increase when leguminous tree inter cropping with maize [20]. Intercropped trees not only take up nutrient from top soil but also contribute to an increase in nitrogen concentration under agroforestry system then in open land. The ground litter decomposition is slight and contributes little to the overall nitrogen content in soil [21]. The nitrogen concentration of the upper 15cm soil was 0.019% in gum forest then exhausted soil with 0.009% [22]. Suitable silvi species and their complimentary crops always contribute to conserver soil nitrogen in surface soil than lower depths. *Alnus nepalensis* + *Citrus reticulata* and *Alnus nepalensis* + *Pyrus communis* when intercropped with pea and mustard found best result in this respect.

3.3.2 Available phosphorus (P)

The effect of silvi (*Alnus nepalensis*) + fruit tree (*Citrus reticulata* and *Pyrus communis*) + intercrops (*kharif* + *rabi*) (Fig.2) indicates that the phosphorus content differ significantly at different depths. At 0-15 cm the available phosphorous was found highest in *Alnus nepalensis* + *Citrus reticulata* + pea + mustard (14.38 kg ha^{-1}) followed by *Alnus nepalensis* + *Pyrus communis* + pea + mustard (14.26 kg ha^{-1}). The lowest phosphorous content was found in sole fruit trees (13.51 kg ha^{-1} and 13.37 kg ha^{-1})

in *Citrus reticulata* and *Pyrus communis* plot respectively. Mean of *Citrus reticulata* and *Pyrus communis* shows that highest content of available phosphorous was also found in *Citrus reticulata* combination (13.99 kg ha^{-1}) than *Pyrus communis* combination (13.83 kg ha^{-1}).
At soil depth 15-30 cm phosphorous content was lower as compared with 0-15 cm depth (Fig.2). It again revealed that the available phosphorous was highest in the *Alnus nepalensis* + *Citrus reticulata* + pea + mustard (12.18 kg ha^{-1}) followed by *Alnus nepalensis* + *Pyrus communis* + pea + mustard (12.13 kg ha^{-1}). The sole fruit (*Citrus reticulata* and *Pyrus communis*) shows the lowest phosphorous content (11.67 kg ha^{-1}) and (11.59 kg ha^{-1}). Treatment mean shows that *Citrus reticulata* plot obtained higher phosphorous content (11.91 kg ha^{-1}) as compared with *Pyrus communis* plot (11.81 kg ha^{-1}). Similar results were also obtained in depth (30-60 cm) where the treatment mean of available phosphorous was recorded (9.25 kg ha^{-1}) in *Alnus nepalensis* + *Citrus reticulata* + intercrops and in *Alnus nepalensis* + *Pyrus communis* with intercrops (9.18 kg ha^{-1}).
Available phosphorous in different soil depths (0-15 cm, 15-30 cm and 30-60 cm) was found affected by different tree species along with different intercrops combination helps to enrich available phosphorous content in soil. There was consistently little potential of trees to capture phosphorous from beneath root depth of crops presumably because the plant extractable phosphorous concentration was normally low in subsoil [23]. The phosphorous at soil depth 0-15 cm was found increase under trees. Both trees and intercrops contribute to raise soil phosphorous content and help to conserve through leaching [24]. In soil profile most of the phosphate is usually located in the surface soil strata because of its recycling through vegetation and deposition litter. Hence circulation that leads to increase in soil organic matter content also generally leads to increase in soil phosphorous concentration because of biochemical transformation from crops residue and leaf litter [25].

3.3.3 Available potassium (K)

The effect of silvi (*Alnus nepalensis*) + fruit tree (*Citrus reticulata* and *Pyrus communis*) + intercrops (*kharif* and *rabi)* (Fig.3) on the available potassium content was found significant. At 0-15 cm depth *Alnus nepalensis* + *Citrus reticulata* + pea + mustard showed highest available potassium content (535.00 kg ha^{-1}) followed by *Alnus nepalensis* + *Citrus reticulata* + french bean + cauliflower (524.00 kg ha^{-1}). Lowest soil potassium content was observed in sole *Citrus reticulata* and *Pyrus communis* (476.00 and 469.00) kg ha^{-1} plots. Inter cropping with pea + mustard followed by french bean and cauliflower as observed suitable treatments irrespective of soil potassium in both fruit species. Soil available potassium content was found to increase with these combinations as compare with initial value (342.00 kg ha^{-1}.).Similar trend was found in soil depth (15-30 cm) and (30-60 cm). Study made clear that soil potassium was found higher in 0-15 cm depth and subsequently decrease with decreasing soil depth.
Factors like soil depths, silvi species and intercrop influence in increase in soil potassium content. The accumulation of soil potassium (K) was found significant in two years old plant. The available K decrease with increase in depth as the age of trees is increased [26]. The nutrient content increases with the increase of the plantation age due to an increase in dry matter accumulation in upper surface [27]. The nutrient storage mainly depends on the rate of biomass accumulation and nutrient concentration of different component of agroforestry system [28].

4. CONCLUSION

The following conclusion can be made from the results of the study.

a. One silvi (*Alnus nepalensis*) and two fruit tree (*Citrus reticulata* Blanco. *and Pyrus communis*) based agroforestry system have significant influence on improving and restoring soil health.
b. Among the different intercrops under fruit based agroforestry systems, pea and mustard crops have shown great influence on building of soil physico-chemical characteristics.
c. Integrating silvi and fruit trees with legume crops could be grown in hilly region without deteriorating the soil and environment for sustainable soil health.

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Table

Table.1 Influence of different fruit based agroforestry systems on soil physical properties at the end of experimentation.

Treatments	Bulk density($gm^{-}cm^{3}$)						Water holding capacity (%)					
	Soil depth(cm)						Soil depth(cm)					
	0-15		15-30		30-60		0-15		15-30		30-60	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Initial Value	1.64	1.64	1.96	1.96	2.24	2.24	33.01	33.01	31.41	31.41	29.38	29.38
Sole fruit tree(F)	1.44	1.46	1.49	1.51	1.54	1.54	35.43	34.10	34.13	33.83	31.07	30.93
Alnus nepalensis(T) + Fruit tree(F)	1.41	1.43	1.46	1.48	1.51	1.52	36.72	36.30	35.06	34.94	32.64	32.09
Alnus nepalensis(T) + Fruit tree(F)+ Maize(*kharif*)+ Potato(*rabi*)	1.38	1.41	1.39	1.42	1.44	1.46	36.96	36.78	35.27	34.98	32.95	32.56
Alnus nepalensis(T)+ Fruit tree(F)+ Rice(*kharif*)+ Cabbage(*rabi*)	1.34	1.37	1.41	1.43	1.47	1.48	37.21	37.00	35.33	34.63	32.81	32.42
Alnus nepalensis(T)+ Fruit tree(F)+ French bean(*kharif*) + Cauliflower(*rabi*)	1.32	1.34	1.37	1.38	1.41	1.44	37.92	37.80	35.66	35.14	33.11	33.21
Alnus nepalensis(T)+ Fruit tree(F)+ Pea(*kharif*) + Mustard(*rabi*)	1.26	1.29	1.34	1.36	1.37	1.39	39.44	38.15	35.78	35.33	33.29	33.82
Alnus nepalensis(T)+Fruit tree(F)+ Pumpkin (*kharif*) + Onion(*rabi*)	1.35	1.37	1.36	1.39	1.42	1.43	36.34	35.41	35.29	34.54	32.06	32.86
Mean	**1.33**	**1.36**	**1.37**	**1.40**	**1.42**	**1.45**	**37.15**	**36.51**	**35.22**	**34.77**	**32.56**	**32.56**
SEm(±)	**0.03**	**0.02**	**0.03**	**0.02**	**0.03**	**0.02**	**0.03**	**0.03**	**0.03**	**0.18**	**0.03**	**0.03**
CD (P=0.05)	**0.09**	**0.05**	**0.08**	**0.05**	**0.08**	**0.05**	**0.09**	**0.10**	**0.08**	**0.54**	**0.09**	**0.09**

Where, F_1 = *Citrus reticulata* Blanco. and F_2= *Pyrus communis*

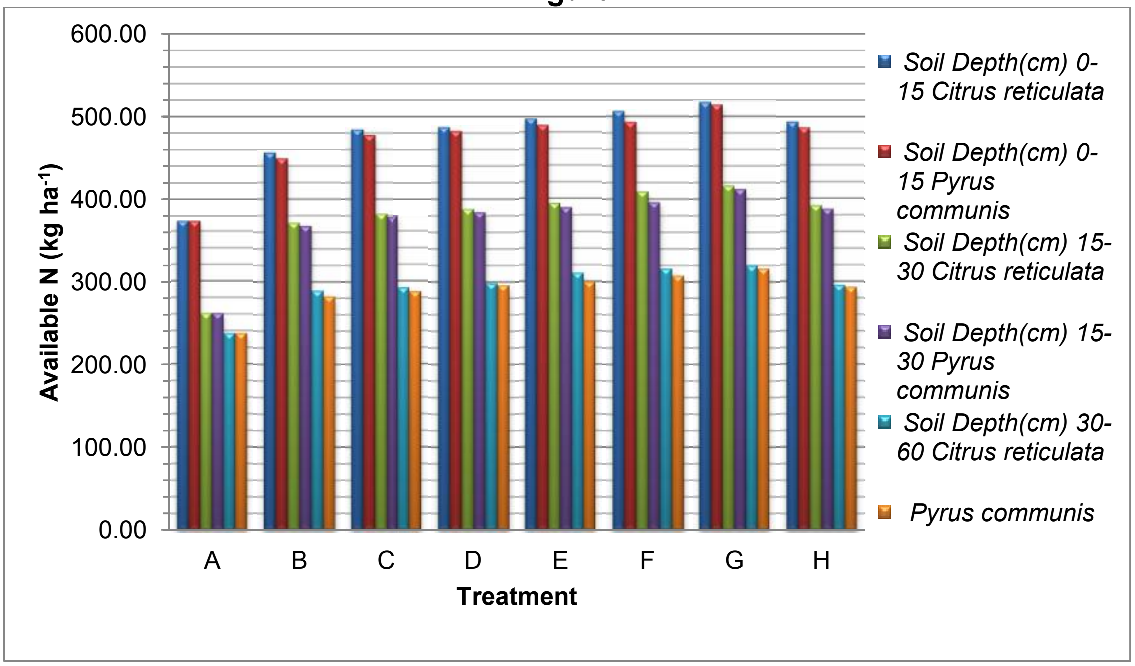
Table. 2 Influence of different fruit based agroforestry systems on soil chemical properties at the end of experimentation.

Treatment	pH						Organic carbon (%)					
	Soil depth(cm)						Soil depth(cm)					
	0-15		15-30		30-60		0-15		15-30		30-60	
	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2	F_1	F_2
Initial Value	5.66	5.66	5.80	5.80	5.98	5.98	1.50	1.50	0.72	0.72	0.61	0.61

Sole fruit tree(F)	5.78	5.75	5.95	5.89	6.09	6.05	1.69	1.63	0.82	0.79	0.69	0.67
Alnus nepalensis(T) + Fruit tree(F)	5.82	5.78	6.09	5.97	6.19	6.13	1.76	1.72	0.89	0.87	0.75	0.73
Alnus nepalensis(T) +Fruit tree(F)+ Maize(*kharif*)+ Potato(*rabi*)	5.84	5.81	6.11	6.02	6.26	6.18	1.82	1.77	0.93	0.89	0.78	0.76
Alnus nepalensis(T)+Fruit tree(F)+ Rice(*kharif*)+ Cabbage(*rabi*)	5.81	5.79	6.06	5.99	6.23	6.14	1.86	1.75	0.87	0.85	0.76	0.75
Alnus nepalensis(T)+Fruit tree(F)+ French bean(*kharif*) + Cauliflower(*rabi*)	5.87	5.84	6.17	6.14	6.29	6.24	1.97	1.88	0.96	0.94	0.79	0.79
Alnus nepalensis(T)+ Fruit tree(F)+ Pea(*kharif*) + Mustard(*rabi*)	5.90	5.87	6.23	6.19	6.34	6.29	2.04	1.93	1.07	0.98	0.81	0.82
Alnus nepalensis(T)+Fruit tree(F)+ Pumpkin (*kharif)* + Onion(*rabi*)	5.83	5.80	6.04	5.96	6.27	6.15	1.88	1.79	0.91	0.91	0.70	0.71
Mean	**5.84**	**5.81**	**6.09**	**6.02**	**6.24**	**6.17**	**1.86**	**1.78**	**0.92**	**0.89**	**0.75**	**0.75**
SEm(±)	**0.02**	**0.02**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.02**
CD (P=0.05)	**0.06**	**0.06**	**0.08**	**0.09**	**0.08**	**0.08**	**0.09**	**0.08**	**0.08**	**0.09**	**0.07**	**0.05**

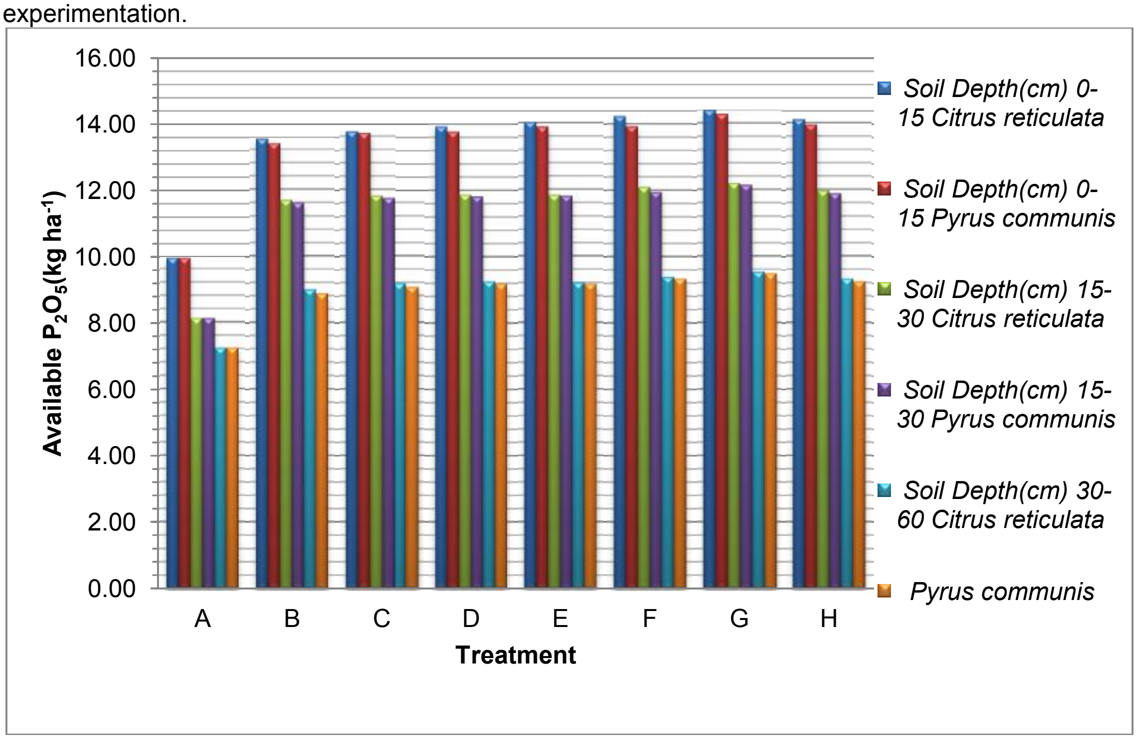
Where, F_1 = *Citrus reticulata* Blanco and F_2 = *Pyrus communis*

Figure



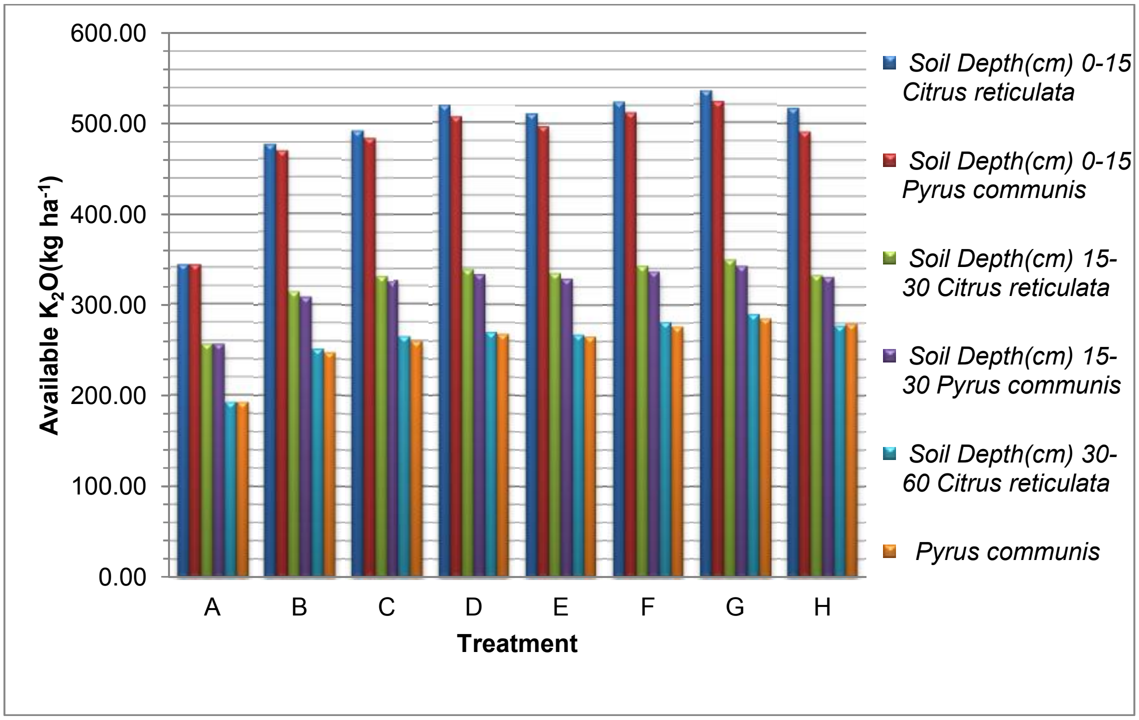
Where, A=Initial value, B= Sole Fruit Tree, C= Silvi + Fruit tree, D= Silvi + Fruit tree + Maize (*kharif*) + Potato (*rabi*), E= Silvi +Fruit tree + Rice (*kharif*) + Cabbage (*rab*i), F= Silvi + Fruit tree + French bean (*kharif*) + Cauliflower (*rabi*), G= Silvi + Fruit tree + Pea (*kharif* + Mustard (*rabi*), H= Silvi + Fruit Tree + Pumpkin (*kharif*) + Onion (*kharif*).

Fig.1. Influence of fruit based agroforestry systems on soil available N (kg ha^{-1}) at the end of experimentation.



Where, A=Initial value, B= Sole Fruit Tree, C= Silvi + Fruit tree, D= Silvi + Fruit tree + Maize (*kharif*) + Potato (*rabi*), E= Silvi +Fruit tree + Rice (*kharif*) + Cabbage (*rab*i), F= Silvi + Fruit tree + French bean (*kharif*) + Cauliflower (*rabi*), G= Silvi + Fruit tree + Pea (*kharif* + Mustard (*rabi*), H= Silvi + Fruit Tree + Pumpkin (*kharif*) + Onion (*kharif*).

Fig.2. Influence of fruit based agroforestry systems on soil available P_2O_5 (kg ha^{-1}) at the end of experimentation.



Where, A=Initial value, B= Sole Fruit Tree, C= Silvi + Fruit tree, D= Silvi + Fruit tree + Maize (*kharif*) + Potato (*rabi*), E= Silvi +Fruit tree + Rice (*kharif*) + Cabbage (*rab*i), F= Silvi + Fruit tree + French bean (*kharif*) + Cauliflower (*rabi*), G= Silvi + Fruit tree + Pea (*kharif* + Mustard (*rabi*), H= Silvi + Fruit Tree + Pumpkin (*kharif*) + Onion (*kharif*).

Fig.3. Influence of fruit based agroforestry systems on soil available K_2O (kg ha^{-1}) at the end of experimentation.

Plate

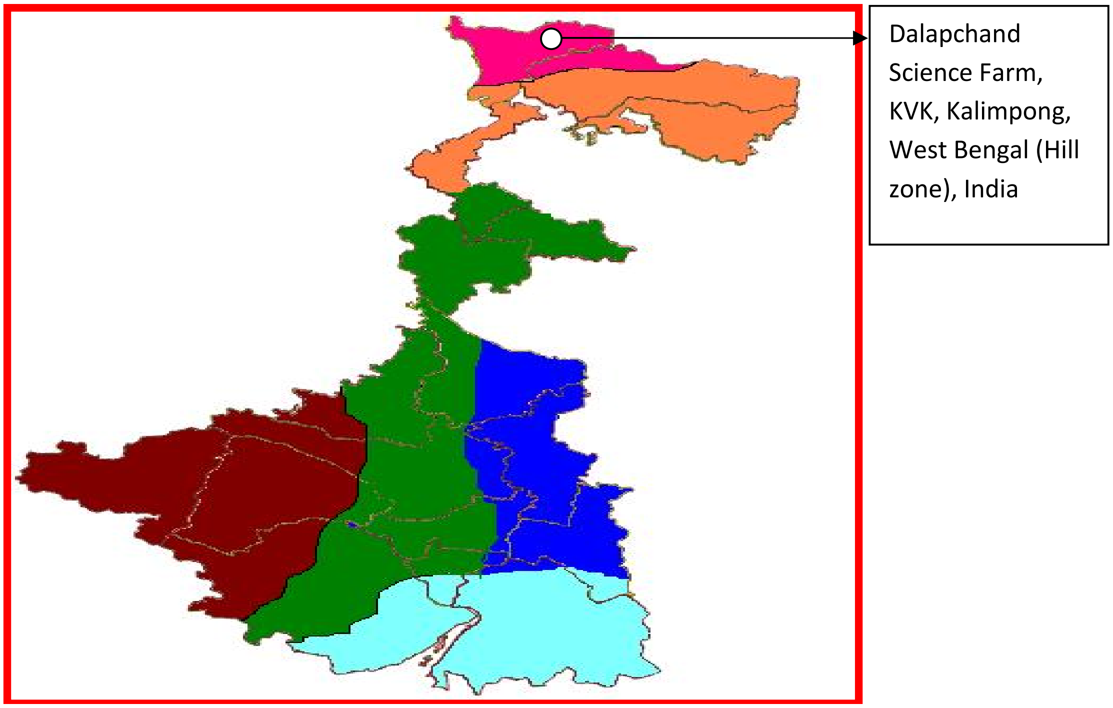


Plate. Map of experimental site (Agro-climatic zonal map of West Bengal, India).