Contribution of Tropical Fruit Plants and Soil Properties to the Potential of Carbon Sequestration in Open Land Utilization for Mixed Plantations

M V Oviantari[1] I K Sudiana[2] I D W K Sastrawidana[3] I A N G Suryaputra[1] I M Gunamantha[1,*]

[1] *Chemistry Analyst Study Program, Universitas Pendidikan Ganesha, Singaraja, Indonesia*
[2] *Chemistry Education Study Program, Universitas Pendidikan Ganesha, Singaraja, Indonesia*
[3] *Chemistry Study Program, Universitas Pendidikan Ganesha, Singaraja, Indonesia*
[*] *Corresponding author. Email: md_gunamantha@yahoo.com*

ABSTRACT

This study is planned to assess the future carbon storage potential of mixed garden systems for campus open spaces through an estimation approach by assessing 10 tropical fruit plants developed on community plantations around Buleleng district. Three trees were selected for each type. Each tree was measured for its physical dimensions including diameter at breast height (DBH) and tree height. Soquatil carbon was also using the Walkley–Black method in a subset of plots. The relationship between soil chemical properties and soil SOC potential was also analyzed. It was found that the potential carbon stock of trees ranged from 8 to 4915 Gg ha-1, with the smallest average potential value being soursop trees and the largest average value indicated by durian trees. The average soil carbon stock in the observed campus area is 440 Gg ha-1. If the combination of four tropical fruit crops with the highest carbon storage potential (durian, jackfruit, rambutan, and sapodilla) is selected and planted proportionally, it will provide a carbon storage potential of 2101 Gg ha-1 in trees. This study also found the relationship between physical and chemical properties of soil with SOC. The finer particles affect SOC. All soil chemical properties which were negatively correlated with SOC were also negatively correlated with CEC. Except for the N-total which is strongly positively correlated. N-total with other soil chemical properties is also negatively correlated. The low content of N-total and CEC of the soil resulted in the low SOC of the soil in the study area.

Keywords: *Carbon sequestration, Soil, Tropical fruit plants.*

1. INTRODUCTION

According to the reference [1], it is estimated that the concentration of CO2 in the atmosphere is increasing at a rate of 3.3 thousand million tons per year. Therefore, stabilizing the concentration of CO2 in the atmosphere is a very big goal that may not be achievable for a long time - hundreds of years, maybe thousands of years. What can be achieved, according to experts, is to control emissions that have not been widely recognized so far but come from land management, land use and land cover change. According to the report, about 50-100 thousand million tons of land and 100-150 thousand million tons of vegetation, bringing a total of 150-250 thousand million tons of CO2 emissions due to the management of these managements. The amount of emissions is quite large, around 1.6 to 2.0 thousand million tons per year caused by deforestation, poor land management and land degradation by resource-poor farmers [1].

On the other hand, [1] also suggests that these sources of emissions can be contained by intensifying agriculture on existing land, reducing deforestation and improving agricultural and forestry practices and by adopting conservation tillage. Therefore, carbon sequestration related to agricultural productivity is also related to poverty, especially rural poverty. However, the exact nature of the relationship is unclear, and will likely not be the same in different environments and societies. Furthermore, FAO emphasized that the problem needs to be narrowed down to reducing emissions from land and countering or reversing the effects of the emission process by absorbing carbon.

[1] provides two proposed options for reducing emissions from land use change [1]. The first option is to increase the absorption potential of forests and land use primarily to compensate for increased emissions in industrialized countries from the use of fossil energy. The second option is to capture atmospheric carbon through photosynthesis. For this second option, estimation of carbon stock and changes in tree biomass stock (above and below ground level) is required to estimate the potential of certain vegetation in carbon sequestration.

This has prompted the need for more knowledge about the effects of tropical fruit trees on soil organic carbon. Unfortunately, knowledge regarding agroforestry management based on tropical fruit trees or mixed gardens to increase soil carbon sequestration by selecting appropriate tree species/species is still limited. Therefore, this study will examine which plants or combinations of fruit crops provide the best option for maximizing the accumulation of carbon in the soil in order to increase the natural sinks of carbon emissions and optimize soil organic carbon. So that the area used can make an optimum contribution to global warming and climate change in addition to plant conservation.

Soil capacity to store carbon is also influenced by soil properties [2]. Physical properties such as soil texture are usually used to indicate the size distribution of mineral particles, and are considered as important factors influencing the accumulation of soil organic matter [3]. Chemical properties are usually related to the chemical bonding of SOC with mineral particles, reducing the ability of enzymes and decomposers [4] . Soil pH also regulates SOC significantly because it affects the turnover of organic matter. Several other studies have also shown that factors such as soil texture, temperature, humidity, pH, available C (labile and stable component of soil organic matter), and N content of soil affect CO2 production and emissions from soil [5]. According to [6], CO2 and CH4 fluxes are influenced by many environmental factors including the availability and amount of substrate C, temperature, rainfall and soil water content, redox potential and aeration, diffusion, soil texture, soil pH, salinity, sodicity and acidity, deficiency and ionic toxicity and high CO2 and N deposition in the atmosphere. Therefore, assessing the contribution of several environmental factors is very important in developing models or predicting C exchange between the atmosphere and the soil. Understanding the factors that affect SOC and key indicators of soil quality can help in better and more sustainable soil management.

Thus, studying the potential for carbon storage by agroforestry systems based on tropical mixed orchards and soil properties in relation to soil carbon emissions is important for the development of basic indicators for sustainable open land management. This study deals with the estimation of tropical fruit tree biomass, carbon storage and sequestration in various types of tropical fruit gardens as the basis for selecting tropical fruit crops to be developed in a small area. The relationship between the physical and chemical properties of the soil and the ability of the soil to store carbon was also observed.

2. METHOD

Soil carbon storage/sequestration potential (Mg C ha-1) was determined based on soil organic carbon content, soil density, and depth of soil sampling. To estimate carbon sequestration in selected fruit trees, circumference measurements were made at 1.37 m above ground level and tree height was recorded. Tree biomass was calculated using the equations provided in SNI.

2.1 Location

The location for collecting physical data on trees is carried out in fruit plantations owned by residents. The selected plantations cover various types and or species of tropical fruit plants. Three trees were selected for each type and/or plant species to be sampled. The selection was based on a purposive sampling technique. The location for collecting soil physical and chemical data was carried out on open land in the Undiksha Jineng Dalem Singaraja campus area. The last data is adopted from [7].

2.2. Research Steps

The data needed at this stage is tree biophysical data, namely height and chest diameter for each tree. The data was obtained from field measurements on tropical fruit trees that grow well in community plantations. Ten types of tropical fruit plants were selected from twenty-four fruit plants that had been analyzed for suitability [7]. This selection is based on the possibility to access the plant. In addition to the data required from measurements, secondary data is also needed which is adopted from the literature in the form of scientific articles published in reputable journals. In more detail, the stages of this research are described in the following sections.

Biophysical measurements included height and diameter at breast height (DBH) measured for each tree sample. Fruit tree height was measured by following the procedure of the Colinometer instrument. Tree diameter was measured at chest height (DBH) using a diameter measuring tape.

Estimated above ground biomass (AGB): (wood, bark, branches, twigs, leaves and fruits) is calculated by multiplying the volume of biomass and wood density (SNI). Volume is calculated based on diameter and height.

AGB (g) = Volume of biomass (cm3) × density of wood (g/cm3) (1)

Estimation of belowground biomass (roots): Belowground biomass (BGB) includes all biomass including all live root biomass excluding fine roots <2mm in diameter (SNI). BGB is calculated by multiplying the aboveground biomass by 0.26 as the root to shoot ratio (Pasquale et al., 2015).

BGB (tha-1) = 0.26 × aboveground biomass (tha-1) (2)

Carbon storage by trees (Mt) = Biomass × %Carbon (SNI). With reference to the factor used by IPCC (2006), 0.47 is used as the percent carbon in plants.

Total soil organic carbon storage (SOC) was measured at each depth (0-25cm, 25-50cm, and 50-75cm) and at a depth of 0–75 cm was obtained as the average SOC of the three depths. For each soil depth interval, the SOCS is calculated as:

SOCS = BD × CSOC × H × 10 (1) (3)

where SOCS is the storage area for SOC (Mg C ha-1), BD is the bulk density (g cm-3 or Mg/m3), Csoc is the concentration of SOC (g kg-1), and H is the thickness of the soil layer (cm). BD is determined based on the equation of Akpa et al. (2016) as follows:

BD = 1.177 + 0.00263Sand 0.043 9logSilt + 0.002 08Silt (4)

The CO2 equivalent is then calculated using the equation given below:

CO2(eq.) = (Carbon content × 44)/12 (5)

Soil properties. The main properties of the soil used refer to the results obtained in [7]. Soil samples were taken at a depth of 0-25cm, 25-50cm, and 50-75cm.

2.3. Data analysis

Data on the total biomass of each tropical fruit plant species/species, sequestration carbon by plants and soil are presented in tabular form. Quantitative descriptive analysis was used to describe the carbon storage potential of each tree. The relationship between soil carbon sequestration and soil properties was determined using correlation analysis at 5% (P=0.05) and 10% (P=0.1) significance. Correlational analysis was performed using SPSS version 16.0.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Carbon Stocks of Surveyed Trees

The method proposed by IPCC (2003) is used to calculate tree carbon above and below the soil surface on plantation land that has been developed to estimate the mixed garden system that will be developed in the observed system. This method requires measuring the diameter at breast height (1.37 m) of all trees above the minimum diameter for trees to be developed in the reference area for the survey, as well as other data such as tree height, wood density, and estimated carbon content. Subsurface biomass was calculated using the equations of Cairns, which includes the relationship between aboveground biomass as the independent variable and belowground biomass as the dependent variable. In this study, the belowground biomass (BGB) was calculated by multiplying the aboveground biomass by 0.26 as the root to shoot ratio. Table 1 shows a physical list of the selected trees and Table 2 shows their biomass and sequestration potential.

Table 1. Physical condition of selected trees observed

Plant name	No. of Plant replica	Circumference DBH (cm)	Diameter (DBH) (cm)	Tree heigh (TP) (m)	Tree Volume (m3)	Density of tree (gr/cm^3)	Age of tree (year)
1	2	3	4	5	6	7	8
Srikaya (*Annona squamosa*)	1	25	7.96	4	1.99	0.6135	5
	2	30	9.55	9	6.44	0.6135	10
	3	16	5.09	3	0.61	0.6135	10
Melinjo (*Gnetum gnemon LINN*)	1	65	20.70	17	57.18	0.7140	45
	2	19	6.06	8	2.31	0.7140	10
	3	23	7.32	9	3.79	0.7140	10
Rambutan (*Nephelium lappaceun LINN*)	1	85	27.07	14	80.53	0.570	20
	2	86	27.39	16	94.23	0.570	20
	3	80	25.48	18	91.74	0.570	20
Durian (*Durio zibethinus* MURR)	1	71	22.61	24,5	98.32	0.570	7
	2	266	84.71	35	1971.55	0.570	50

Plant name	No. of Plant replica	Circumference DBH (cm)	Diameter (DBH) (cm)	Tree heigh (TP) (m)	Tree Volume (m3)	Density of tree (gr/cm^3)	Age of tree (year)
	3	88	28.02	18,5	114.02	0.570	10
Duku (*Lansium domesticum* CORR)	1	82	26.11	17	90.98	0.390	10
	2	85	27.07	15	86.29	0.390	10
	3	80	25.48	12	61.16	0.390	10
Sirsak (*Annona muricata* LINN)	1	15	4.78	7	1.26	0.540	7
	2	9	2.87	4	0.26	0.540	5
	3	36	11.47	2	2.07	0.540	5
Sawo (*Marchas zapota*)	1	165	52.55	23	498.59	1.010	70
	2	94	29.94	19	133.70	1.010	30
	3	20	6.37	3,5	1.11	1.010	10
Manggis (*Garcinia mangostana* LINN)	1	25	7.97	4	1.99	0.870	6
	2	26	8.28	5	2.69	0.870	6
	3	30	9.56	12	8.61	0.870	8
Nangka (*Artocarpus integra* MERR)	1	108	34.40	20	185.79	0.610	15
	2	86	27.39	12	70.67	0.610	20
	3	115	36.62	20	210.54	0.610	40
Belimbing (*Averrhoa bilimbi*)	1	56	17.83	12	29.95	0.430	10
	2	60	19.11	9,5	27.23	0.430	15
	3	49	15.60	1,5	2.87	0.430	7

Note:

1. is the type of tree observed
2. Shows the serial number of the observed similar trees (observations are made on 3 trees for each type)
3. GBH - The circumference of each tree …measured at the main trunk of the tree about 1.37m from the ground.
4. Calculated from DBH = GBH/л
5. Tree height is estimated using theodolite or potentiometer
6. The volume of tree biomass is calculated from /4 x (DBH)2 x Tree height
7. Wood density data uses the average density data available in the database on the http://db.worldagroforestry.org/wd page.

Table 2. Tree biomass and carbon sequestration potential

Plant name	No. of Plant replica	AGB (kg	BGB (kg)	Total of Biomass (TB) (kg)	Carbon strotage (kg)	Carbon squestration potential (Gg/ha)
1	2	3	4	5	6	7
Srikaya (*Annona squamosa*)	1	1221	317	1538	723	22
	2	3953	1028	4981	2341	
	3	374	97	472	222	
Melinjo (*Gnetum gnemon LINN*)	1	40828	10615	51443	24178	178
	2	1647	428	2075	975	
	3	2703	703	3406	1601	
	1	45904	11935	57839	27184	600

Plant name	No. of Plant replica	AGB (kg	BGB (kg)	Total of Biomass (TB) (kg)	Carbon strotage (kg)	Carbon squestration potential (Gg/ha)
Rambutan (*Nephelium lappaceun LINN*)	2	53709	13964	67674	31807	
	3	52290	13595	65885	30966	
Durian (*Durio zibethinus* MURR)	1	56042	14571	70613	33188	4915
	2	1123782	292183	1415965	665503	
	3	64991	16898	81889	38488	
Duku (*Lansium domesticum* CORR)	1	35481	9225	44706	21012	367
	2	33651	8749	42401	19928	
	3	23851	6201	30053	14125	
Sirsak (*Annona muricata* LINN)	1	678	176	854	402	8
	2	140	36	176	83	
	3	1115	290	1405	661	
Sawo (*Marchas zapota*)	1	503575	130930	634505	298217	2526
	2	135036	35109	170145	79968	
	3	1126	293	1419	667	
Manggis (*Garcinia mangostana* LINN)	1	1735	451	2186	1028	46
	2	2341	609	2950	1386	
	3	7490	1947	9437	4436	
Nangka (*Artocarpus integra* MERR)	1	113330	29466	142796	67114	22
	2	43109	11208	54317	25529	
	3	128430	33392	161822	76056	
Belimbing (*Averrhoa bilimbi*)	1	12877	3348	16225	7626	178

Note:
1. is the type of tree observed?
2. Shows the serial number of the observed similar trees (observations are made on 3 trees for each type)
3. AGB (kg) is calculated from the volume of tree biomass multiplied by tree density (column 6 x column 7 …. Table 1)
4. BGB = 0.26 x AGB
5. TB = AGB + BGB
6. Carbon storage = TB x 0.47; CO2 (eq.) = (Carbon content × 44)/12
7. Sequestration potential is the average carbon storage for each tree species (the carbon storage value of each replica tree is divided by 3)

3.1.2. Stock of Soil Carbon (SOC)

Stock of soil organic carbon is estimated by taking soil samples on predefined sample plots. Soil samples were taken at three depths: 25, 50, and 75cm. To estimate SOC, soil bulk density was measured at each depth. The soil organic carbon concentration in the sample was determined using the Walkley – Black method (Gunamantha et al., 2021). This section focuses on presenting the potential SOC at each depth and over the entire surveyed area (Table 3).

3.3.3. Relationship between carbon stock and soil properties

Sandy loam textures with low fertility and varying degrees of alkalinity are common characteristics of soils in the study area [7]. Variations in the physical and chemical properties of the studied soils as indicated by the mean, median, SD and variance have been described in the previous report. Data relating carbon stock to soil properties are presented in Tables 4 and 5.

Table 3. Average SOC at each depth

Soil depth	Number of sampling	C –organik (g C/kg of soil sample)	Soil density (g/cm^3)	SOC (kg/ha)	Avg. SOC (kg/ha)
0 -25 cm	1	8.40	2.1065	442	50.94
	2	12.6	2.2642	713	
	3	12.6	2.3823	750	
	4	4.20	2.3878	251	
	5	8.30	2.9680	616	
	6	4.20	2.7034	284	
25-50cm	1	8.40	2.0541	431	42.40
	2	8.40	2.3288	489	
	3	8.40	2.4458	514	
	4	4.20	2.5935	272	
	5	8.40	2.5192	529	
	6	4.20	2.9385	309	
50-75cm	1	4.20	2.0999	221	38.72
	2	8.40	2.5780	541	
	3	12.7	2.2940	728	
	4	4.10	2.6652	273	
	5	4.20	2.4706	259	
	6	4.20	2.8628	301	

Table 4. Relationship between carbon stock and soil texture

Soil depth	Number of sampling	Soil density (g/cm^3)	Sand (%)	Silt (%)	Clay (%)	SOC
0 -25 cm	1	2.1065	35.01	37.45	27.55	44.24
	2	2.2642	41.5	28.72	29.78	71.32
	3	2.3823	46.05	27.6	26.36	75.04
	4	2.3878	45.56	39.82	17.62	25.07
	5	2.9680	68.91	13.87	17.23	61.59
	6	2.7034	58.77	16.34	24.89	28.39
25-50cm	1	2.0541	32.87	39.83	27.31	43.14
	2	2.3288	44.07	26.59	29.34	48.90
	3	2.4458	49.12	8.19	42.7	51.36
	4	2.5935	53.84	32.02	14.14	27.23
	5	2.5192	51.19	28.85	19.95	52.90
	6	2.9385	67.82	12.41	19.72	30.85
50-75cm	1	2.0999	34.63	39.54	25.83	22.05
	2	2.5780	54.06	14.59	31.36	54.14

Soil depth	Number of sampling	Soil density (g/cm^3)	Sand (%)	Silt (%)	Clay (%)	SOC
	3	2.2940	42.71	27.28	30.01	72.83
	4	2.6652	57.19	19.69	23.13	27.32
	5	2.4706	49.79	19.65	30.56	25.94
	6	2.8628	64.9	14.12	20.91	30.06

Table 5. Carbon stock data with soil quality

Soil Depth	Sampling Point Replicate	pH	DHL	N-Total	Available P	Available K	CEC	Alkaline Base	SOC
25	1	7.4	0.21	0.01	24.99	179.43	22,13	85.44	44.24
	2	6.8	0.18	1.26	0.05	3.94	83.82	22.15	77.67
	3	7.4	0.2	0.05	3.28	85.14	22.42	84.62	75.04
	4	7.6	0.49	0.04	2.58	84.71	22.31	7.24	25.07
	5	7.7	0.38	0.05	7.31	101.72	22.06	93.2	61.59
	6	7.3	0.24	0.03	5.96	102.71	21.61	95.05	28.39
50	1	7.3	0.21	0.05	18.33	168.82	23.81	87.27	43.14
	2	7.1	0.15	0.84	0.05	9.77	90.74	25.06	75.86
	3	7.1	0.21	0.04	1.92	81.99	19.42	97.78	51.36
	4	7.8	1.05	0.02	4.6	97.19	18.16	6.81	27.23
	5	7.9	0.39	0.01	13.08	109.38	21.45	92	52.90
	6	7.5	0.31	0.04	9.65	103.71	20.72	86.6	30.85
75	1	7.4	0.19	0.03	23.86	180.13	25.18	86.21	22.05
	2	7.1	0.21	0.06	3.61	87.19	23.47	88.07	54.14
	3	7.1	0.19	0.04	5.01	92.17	22.77	83.81	72.83
	4	7.7	0.2	0.02	5.22	97.32	17.77	5.79	27.32
	5	7.3	0.32	0.02	4.3	104.55	22.85	86.79	25.94
	6	7.8	0.39	0.02	7.29	104.62	18.15	98.82	30.06

3.2. Discussion

3.2.1. Potential carbon stock of surveyed trees

Referring to the tropical fruit crops to be planted in the study area, the ten specified trees were used to predict the carbon sequestration potential of the tree biomass (Table 2). Table 2 shows that the tree heights ranged from 1.5 to 25 meters, with diameters ranging from 1.5 to 52 centimetres.

Based on the calculation results, it was found that the average carbon stock of the selected trees ranged from 382 Gg to 245726 Gg. From the perspective of carbon sequestration efficiency, i.e. the amount of carbon absorbed in one ha, the most profitable options seem to be durian, sapodilla, jackfruit and rambutan trees. All of them are the most attractive options for open areas. This study shows that the C sequestration capacity of a tree is not always in line with the increase in the age of the tree. This of course depends on the growth of each tree. However, durian, jackfruit, rambutan, and sapodilla showed an increase in C-squestration with increasing tree age.

The Intergovernmental Panel on Climate Change (IPCC) 2006 recommends that the number of good carbon stocks in the primary, secondary and agroforestry forest land categories is 138 tons ha-1. For example, the selected fruit plant is durian. Based on the available land area of about 0.5 ha, about 20 durian trees can be grown. With the potential carbon stock in durian trees around 245726 per tree, the potential for carbon sequestration from trees on the land is 4915 Gg ha-1. The combination of the four plants (durian, jackfruit, rambutan, and sapodilla) will proportionally provide a carbon storage potential in trees of 2101 Gg ha-1. These conditions will go far beyond those set by the IPCC. Indeed, this yield will be smaller if durian is combined with other fruit crops, but the potential for sequestration is still greater than the good criteria set by the IPCC. Apart from being a store of carbon stocks, agroforestry mixed garden planting systems have several potential benefits. Although the role of agroforestry in maintaining carbon stocks on land is still lower than that of natural forests, this system can provide great promise in increasing carbon stocks on open or degraded lands.

3.2.2. Potential soil carbon stock

Soil's ability to store carbon decreases with depth. This is because organic matter decreases with depth. Figure 1. Shows the carbon stock profile by soil depth. Overall, the average carbon stock per ha of soil observed was 440 kg/ha.

3.2.3. Correlation between SOC and soil properties.

3.2.3.1. Soil physical properties and their relationship to SOC

The distribution of individual soil particles did not show a significant relationship with SOC (Table 6). Sand and silt particles have a very low and negative relationship to SCO, -17% and -8% for sand and silt, respectively. Sandy soils often have low organic C (OC) content due to limited plant growth and rapid decomposition due to low clay concentrations. However, clay particles showed the best and positive relationship (35%) to SOC compared to other particles which showed a negative relationship. This is in line with that reported by [8], that there is a positive correlation of 46% between SOC and the proportion of clay). Reference [8] also reported that the vertical distribution of clay within the 30 cm surface is a key factor for increasing organic carbon (OC) storage in clay-modified soils. The nature of the underground clay and the amount added to the 30 cm surface, as well as the depth of the undisturbed soil layer also affect the OC stock. The addition of subsoil clay to sandy soil has the potential to increase OC storage. The correlation matrix between soil physical properties and carbon sequestration at each depth is presented in Tables 7 – 9).

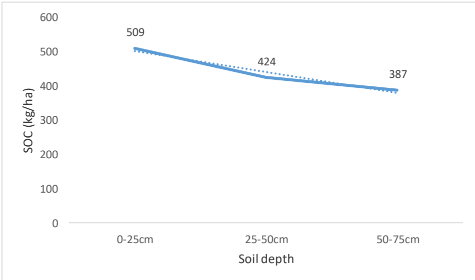

Figure 1. Effect of soil depth on SOC

In addition, soil management and addition of organic carbon through crop residues or manure are more important than soil texture in the case of sequestering more carbon in the soil. The highest positive correlation between clay distribution and SOC occurred at a depth of 0-50cm, followed by a depth of 0-75cm and 0-25cm. As reported by [7], the research area is part of the location where the rest of the building construction materials are piled up so that the sand content on the top of the soil is quite high. This shows that SOC increases or decreases with the same trend, namely increasing or decreasing clay %. It can be emphasized that the clay fraction of a soil type is a better predictor of SOC in soil, as previously reported.

Table 6. Correlation between soil physical properties and SOC

	Sand (%)	Silt (%)	Clay (%)	SOC
Sand (%)	1.00			
Silt (%)	-0.76	1.00		
Clay (%)	-0.42	-0.27	1.00	
SOC	-0.17	-0.08	0.35	1.00

Table 7. Correlation between soil physical properties and SOC for soil depth of 0-25cm

	Sand (%)	Silt (%)	Clay (%)	SOC
Sand (%)	1.00			
Silt (%)	-0.83	1.00		
Clay (%)	-0.56	0.01	1.00	
SOC	-0.15	-0.17	0.48	1.00

Table 8. Correlation between soil physical properties and SOC for soil depth of 25-50cm

	Sand (%)	Silt (%)	Clay (%)	SOC
Sand (%)	1.00			
Silt (%)	-0.35	1.00		
Clay (%)	-0.46	-0.67	1.00	
SOC	-0.68	-0.12	0.66	1.00

Table 9. Correlation between soil physical properties and SOC for soil depth of 50-75cm

	Sand (%)	Silt (%)	Clay (%)	SOC
Sand (%)	1.00			
Silt (%)	-0.84	1.00		
Clay (%)	-0.80	0.34	1.00	
SOC	-0.67	0.54	0.55	1.00

Table 10. Correlation matrix of soil chemical properties with SOC.

	pH	*DHL*	*N-Total*	*P Tersedia*	*K Tersedia*	*CEC*	*Alkaline base*	*SOC*
pH	1.00							
DHL	0.59	1.00						
N-Total	-0.59	-0.26	1.[00					
P-Tersedia	0.31	-0.07	-0.40	1.00				
K-Tersedia	0.43	0.09	-0.76	0.86	1.00			
CEC	-0.58	-0.30	0.96	-0.36	-0.74	1.00		
Alkaline Base	-0.04	-0.36	-0.44	0.40	0.47	-0.41	1.00	
SOC	-0.52	-0.39	0.57	-0.40	-0.60	0.58	0.04	1

3.2.3.2. Soil chemistry and its relationship to carbon sequestration

The relationships between these soil characteristics are shown using a correlation matrix (Table 7), all of which are described in the following sections. The pH value showed a negative correlation with carbon sequestration (r = -0.52) which was in line with the findings of Berhangoray. In addition, pH also has a negative correlation with N-Total, CEC, and base saturation with r values of -0.59, -0.58, and -0.04, respectively (Table 7). However, the pH correlation was positive with DHL, P-available and K-available. This indicates that these three soil properties play an important role in determining soil pH. Total N showed a very positive correlation (r = 0.57) with Cseq (Table 7). A positive and highly significant correlation was also found with CEC (r = 0.96). However, with pH, DHL, alkaline base, and P and K available, N-total had a negative correlation with r = -0.59, -0.26, -0.44, 0.40 and -0.70, respectively.

The available P has a negative correlation (r = -0.4) with SOC, as well as the available K shows a larger negative correlation (r = -0.6). This means that, the higher the levels of these two nutrients in the soil, the lower the capacity of the soil to store carbon. However, the availability of both plant nutrients showed a very positive correlation with each other (r = 0.86) as shown in Table 7. Total nitrogen and available phosphorus were the main plant nutrients, but they had different correlations with SOC respectively. are very positive and negative, respectively. The impact of these two nutrients on SOC accumulation at the study site is relatively small because their presence is in the low to very low range [7].

In this study CEC had a very positive correlation (r = -0.58) with SOC which is in line with the findings of Laopoolkit where a positive correlation between CEC and SOC was also reported. CEC even very positively correlated with N-Total (r-0.96). On the other hand, it was negatively correlated with pH (r=-0.58), DHL (r=-0.30), alkaline base (r = -0.41), and available P and K (r = -0.36 and r= -0.74). DHL has a negative correlation with SOC (r= -0.39). which contradicts the study conducted by Berhangoray, but an antagonistic relationship was observed between ECe and SOC. Except for P-available, DHL is also negatively correlated with other soil properties (Table 7). Percentage of exchangeable sodium (alkaline base) was weakly positively correlated (r = 0.04) with SOC, contrary to that also reported by Laura. AB also had a positive correlation with P and K-available, but negatively correlated with pH, DHL, and N-total (Table 7).

4. CONCLUSION

Durian, sapodilla, jackfruit, and rambutan fruit plants have greater potential for carbon storage than other plants. The combination of these four plants will proportionally provide a carbon storage potential in trees of 2101 Gg ha-1. In terms of the availability of land to be developed for mixed gardens, currently stored carbon is 440 GG ha-1. Thus, its use as mixed garden agroforestry will significantly increase its carbon storage potential. In terms of soil properties, finer particles positively affected SOC in the soil which was also observed for total N and CEC with a stronger relationship, but in a relatively weak relationship with alkaline base. On the other hand, the portion of sand and silt, pH, DHL, and available P and K content negatively affected SOC. All soil chemical properties which were negatively correlated with SOC were also negatively correlated with CEC. Except for the N-total which is strongly positively correlated. N-total with other soil chemical properties is also negatively correlated. The low content of N-total and CEC of the soil resulted in the low SOCseq of the soil in the study area.

ACKNOWLEDGMENT

This study was conducted with financial support from LPPM Ganesha University of Education. The authors thank the Chemical Analysis students of the Department of Chemistry, Faculty of Mathematics and Natural Sciences, Ganesha University of Education, for their assistance in collecting soil samples and physical data of tropical fruit crops.

REFFERENCE

[1] FAO, “Prevention of land degradation, enhancement of C-sequestration and conservation of biodiversity,” 1999.

[2] J. Li, M. Nie, J. Powell, A. Bissett, and E. Pendall, “Soil physico-chemical properties are critical for predicting carbon storage and nutrient availability across Australia,” Environ. Res. Lett, vol. 15, 2020, doi: https://doi.org/10.1088/1748-9326/ab9f7e.

[3] A. R. Dexter, Soil physical quality: part I. Theory, effects of soil texture, density, and organic matter, and effects on root growth Geoderma. 2004.

[4] J. Six, R. Conant, E. Paul, and K. Paustian, “Stabilization mechanisms of soil organic matter,” Implic. C-saturation soils Plant Soil, 2002.

[5] M. Rastogi, S. Singh, and H. Pathak, “Emission of Carbon Dioxide From Soil,” Curr. Sci., vol. 82, no. 5, 2002.

[6] H. Fang et al., “Effects of multiple environmental factors on CO2 emission and CH4 uptake from old-growth forest soils,” Biogeosciences, pp. 395–407, 7AD.

[7] I. Gunamantha, I. Sudiana, I. Satrawidana, and O. Suryaputra IGNA., “Pengembangan Agroforestri Berbasis Tanaman Buah Tropis di Area Kampus Undiksha Jineng Dalem untuk Mendukung Rencana Aksi Daerah Terhadap Perubahan Iklim,” 2020.

[8] A. Schapel, P. Marschner, and J. Churchman, “Clay amount and distribution influence organic carbon content in sand with subsoil clay addition,” Soil Tillage Res., vol. 184, pp. 253–260, 2018, doi: https://doi.org/10.1016/j.still.2018.08.001.