

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Plant characteristics, soil properties and carbon storage

4.1.1 Lumpini park

4.1.1.1 Plant characteristics

The number of tree was studied 549 trees, which was classified to 18 plant species and 9 families. *Pterocarpus indicus* was the most common plant species, followed by *Tabebuia rosea*, *Swietenia macrophylla* and *Pterospermum littorale* was the minimum plant species were 186, 70, 45 and 3 trees, respectively (Table 4.1).

The study of the average diameter at breast height (DBH) of trees in each plot was found that LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest average DBH, followed by LN11 (*Samanea saman*), LN06 (*Acacia auriculiformis*) and LN07 (*Swietenia macrophylla*) had the lowest average DBH were 71.76, 69.01, 36.04 and 13.30 cm, respectively (Table 4.2).

The study of the average height of trees in each plot was found that LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest average height, followed by LN11 (*Samanea saman*), LN02 (mixed 7 species) and LN07 (*Swietenia macrophylla*) had the lowest average height were 17.89, 17.30, 13.51 and 6.82 m, respectively (Table 4.2).

The study of tree density in each plot was found that LN08 (*Plumeria* spp.) had the highest tree density, followed by LN05 (*Pterocarpus indicus*), LN04 (*Tabebuia rosea*) and LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the lowest tree density were 396.05, 267.65, 250.36 and 59.71 trees ha⁻¹, respectively (Table 4.2).

The study of total basal area in each plot was found that LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest total basal area, followed by LN11 (*Samanea saman*), LN08 (*Plumeria* spp.) and LN07 (*Swietenia macrophylla*) had the lowest total basal area were 27.15, 25.97, 24.09 and 2.78 m² ha⁻¹, respectively (Table 4.2).

Table 4.1 Plant species were studied in Lumpini park

Scientific name	Family name	Number of tree
<i>Acacia auriculiformis</i> A.Cunn. Ex Benth.	Mimosoideae	38
<i>Alstonia scholaris</i> R. Br.	Apocynaceae	10
<i>Caesalpinia coriaria</i> (Jacq.) Willd.	Caesalpinaceae	5
<i>Callistemonlan ceolatus</i> DC.	Myrtaceae	7
<i>Cerbera odollam</i> Gaertn.	Apocynaceae	26
<i>Delonix regia</i> (Bojer ex Hook.) Raf.	Caesalpinaceae	5
<i>Lagerstroemia speciosa</i> (L.) Pers.	Lythraceae	11
<i>Millingtonia hortensis</i> L.f.	Bignoniaceae	21
<i>Peltophorum pterocarpum</i> (DC.) Back. ex Heyne	Caesalpinaceae	31
<i>Plumeria</i> spp.	Apocynaceae	33
<i>Pterocarpus indicus</i> Willd	Papilionoideae	182
<i>Pterospermum littorale</i> Craib var. Ittorale	Sterculiaceae	3
<i>Samanea saman</i> (Jacq.) Merr.	Fabaceae	28
<i>Swietenia macrophylla</i> King.	Meliaceae	45
<i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	11
<i>Tabebuia argentea</i> Britt.	Bignoniaceae	10
<i>Tabebuia rosea</i> (Bertol.) DC.	Bignoniaceae	70
<i>Tamarindus indica</i> Linn.	Fabaceae	13
Total		549

Table 4.2 Quantitative characteristics of plant in each plot in Lumpini park

Plot	Plant species	Number of tree	Area (ha)	DBH (cm)	H (m)	TD (trees ha ⁻¹)	BA (m ² ha ⁻¹)
LN01	Mixed 9 species	95	0.65	27.59±17.10	8.92±3.69	145.73	12.05
LN02	Mixed 7 species	82	0.93	34.25±14.15	13.51±3.83	88.20	9.49
LN03	Mixed 8 species	122	2.01	26.26±17.00	7.83±3.66	60.65	2.95
LN04	<i>Tabebuia rosea</i>	70	0.28	28.64±13.81	7.54±3.07	250.36	17.19
LN05	<i>Pterocarpus indicus</i>	32	0.12	20.26±5.75	7.96±2.29	267.65	8.11
LN06	<i>Acacia auriculiformis</i>	33	0.35	36.04±19.73	11.80±3.96	93.38	12.41
LN07	<i>Swietenia macrophylla</i>	25	0.13	13.30±2.75	6.82±1.74	187.31	2.78
LN08	<i>Plumeria</i> spp.	24	0.06	25.66±7.25	10.66±1.25	396.05	24.09
LN09	<i>Peltophorum pterocarpum</i> <i>Samanea saman</i>	39	0.65	71.76±25.14	17.89±3.22	59.71	27.15
LN10	<i>Pterocarpus indicus</i>	27	0.16	27.93±12.62	12.62±4.12	167.76	12.48
LN11	<i>Samanea saman</i>	4	0.06	69.01±16.33	17.30±2.54	69.13	25.97

Note: diameter at breast height (DBH), height (H), tree density (TD) and total basal area (BA)

4.1.1.2 Soil properties

The study of soil properties in tree-planting area was found that texture was silty clay loam, very dark grayish brown. Soil reaction was neutral (6.6-7.3), organic matter was neutral (1.5-2.5) and total nitrogen was low (0.1-0.2). The average C:N ratios was 11.66 in range of 8.58-16.77 and the average soil bulk density was 1.20 g cm^{-3} . Percentage of the average organic matter and total nitrogen per area were 47.51 and 2.40 t ha^{-1} , respectively.

Soil in turf was silty clay loam, very dark grayish brown. Soil reaction was neutral (6.6-7.3), organic matter was neutral (1.5-2.5) and total nitrogen was very low (less than 0.1). The average C:N ratios was 13.10 in range of 8.61-17.61 and the average soil bulk density was 1.00 g cm^{-3} . Percentage of the average organic matter and total nitrogen per area were 38.18 and 1.74 t ha^{-1} , respectively.

Soil properties in tree-planting area and turf were showed in Table 4.3. To compare the difference of the average of soil properties between these area was found that there was significant difference in soil bulk density and C:N ratios.

Table 4.3 Soil properties of tree-planting area and turf in Lumpini park

Soil properties	Tree-planting area	Turf
Texture	Silty clay loam	Silty clay loam
BD (g cm^{-3})	1.20 ± 0.14	1.00 ± 0.17
pH	6.20 ± 1.34	5.73 ± 1.11
OM (%)	2.69 ± 1.11	2.67 ± 1.23
TN (%)	0.14 ± 0.06	0.12 ± 0.07
C:N ratios	11.66 ± 1.59	13.10 ± 2.55

Note: soil bulk density (BD), soil reaction (pH), organic matter (OM), total nitrogen (TN) and carbon to nitrogen ratios (C:N ratios)

To compare soil properties in each plot in tree-planting area was found the detail following (Table 4.4).

1) Soil bulk density (BD)

The average BD in tree-planting area was 1.20 g cm^{-3} , which was in the range of $0.90\text{--}1.47 \text{ g cm}^{-3}$. The results was found that LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest average BD, followed by LN02 (mixed 7 species), LN04 (*Tabebuia rosea*), LN10 (*Pterocarpus indicus*) and LN05 (*Pterocarpus indicus*) had the lowest average BD were 1.32, 1.25, 1.25, 1.25 and 0.94 g cm^{-3} , respectively. The statistical analysis found that the mean difference of BD in each plot were statistical significant at the level of 0.05 (Table 4.4 and Figure 4.1).

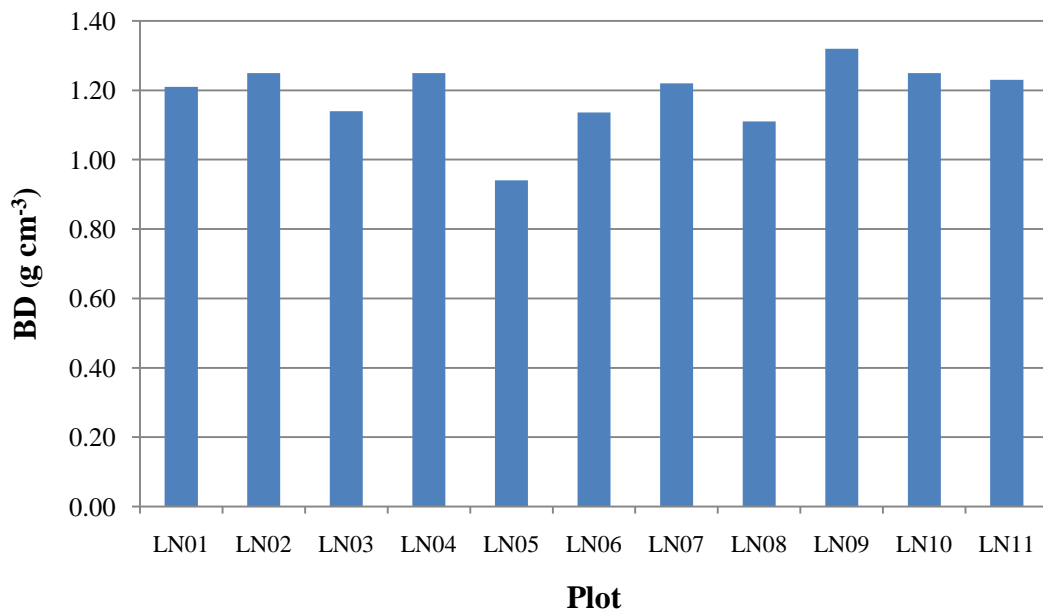


Figure 4.1 The average BD in each plot in Lumpini park

2) Soil reaction (pH)

The average pH in tree-planting area was 6.19, which was in the range of 3.78–7.80. The results was found that LN08 (*Plumeria* spp.) had the highest average pH, followed by LN07 (*Swietenia macrophylla*), LN10 (*Pterocarpus indicus*) and LN04 (*Tabebuia rosea*) had the lowest average pH were 7.60, 7.52, 7.27 and 4.73, respectively. The statistical analysis found that the mean difference of pH in each plot were statistical significant at the level of 0.05 (Table 4.4 and Figure 4.2).

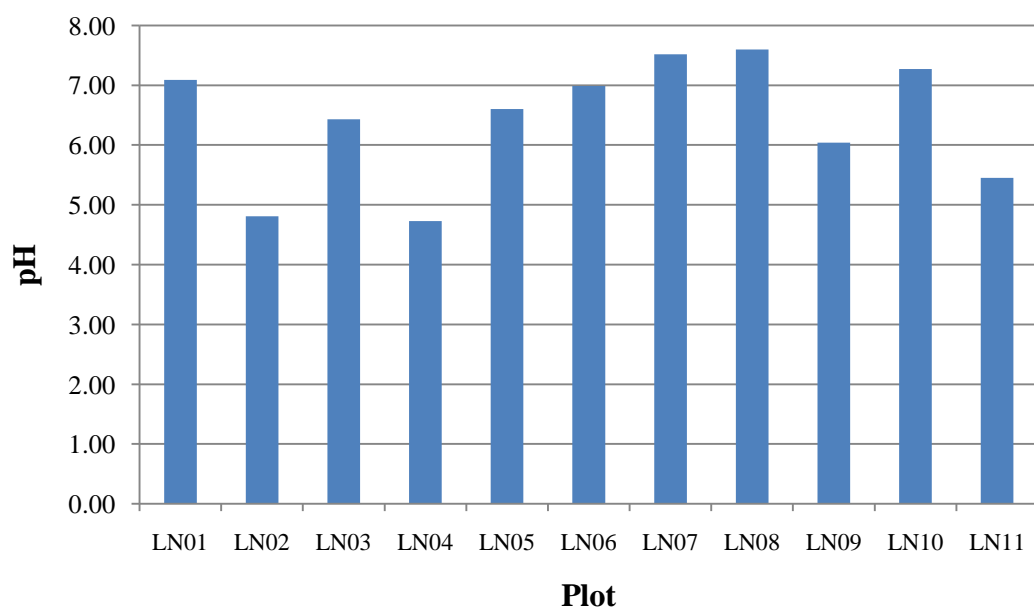


Figure 4.2 The average pH in each plot in Lumpini park

3) Organic matter (OM)

The average OM in tree-planting area was 2.69 percent, which was in the range of 0.79–6.61 percent. The results was found that LN06 (*Acacia auriculiformis*) had the highest average OM, followed by LN05 (*Pterocarpus indicus*), LN07 (*Swietenia macrophylla*) and LN04 (*Tabebuia rosea*) had the lowest average OM were 4.21, 3.72, 3.70 and 2.16 percent, respectively. The statistical analysis found that the mean difference of percentage of OM in each plot were statistical significant at the level of 0.05 (Table 4.4 and Figure 4.3).

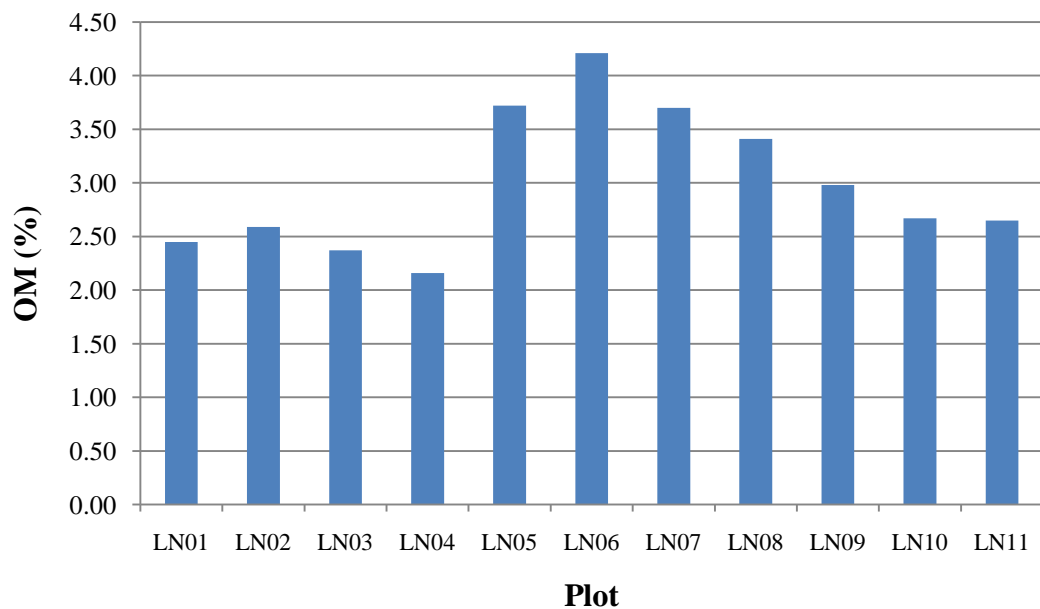


Figure 4.3 The average OM in each plot in Lumpini park

4) Total nitrogen (TN)

The average TN in tree-planting area was 0.14 percent, which was in the range of 0.04-0.33 percent. The results was found that LN06 (*Acacia auriculiformis*) had the highest average TN, followed LN07 (*Swietenia macrophylla*), LN08 (*Plumeria spp.*), LN05 (*Pterocarpus indicus*) and LN04 (*Tabebuia rosea*) had the lowest average TN were 0.21, 0.18, 0.18, 0.17 and 0.10 percent, respectively. The statistical analysis found that the mean difference of percentage of TN in each plot were statistical significant at the level of 0.05 (Table 4.4 and Figure 4.4).

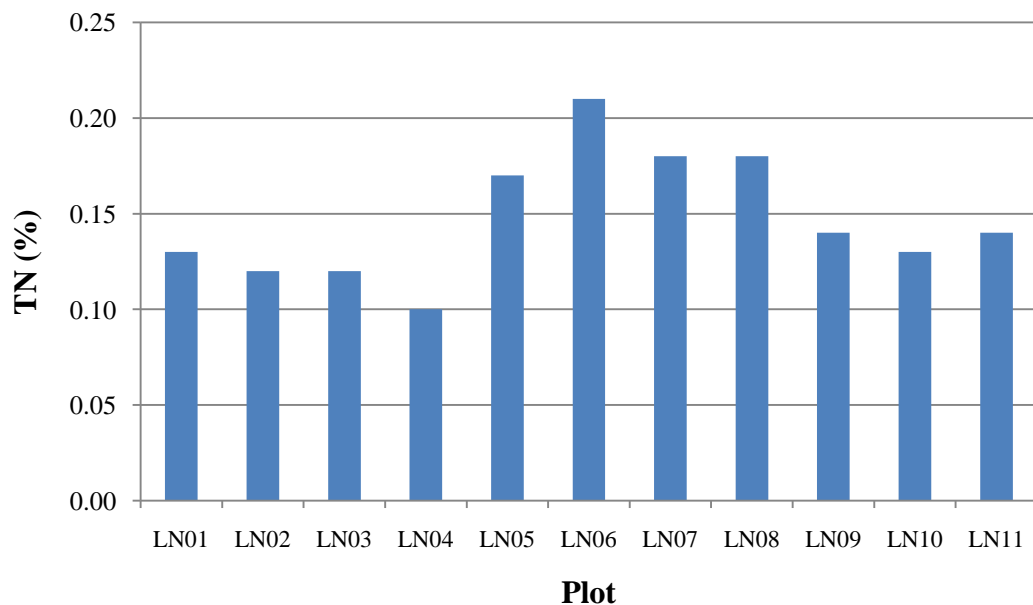


Figure 4.4 The average TN in each plot in Lumpini park

5) Carbon to nitrogen ratios (C:N ratios)

The average C:N ratios in tree-planting area was 11.66, which was in the range of 8.58–16.77. The results was found that LN04 (*Tabebuia rosea*) and LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest average C:N ratios, followed by LN02 (mixed 7 species), LN07 (*Swietenia macrophylla*) and LN08 (*Plumeria* spp.) had the lowest average C:N ratios were 12.55, 12.31, 12.02 and 10.81, respectively. The statistical analysis found that the mean difference of C:N ratios in each plot were statistical significant at the level of 0.05 (Table 4.4 and Figure 4.5).

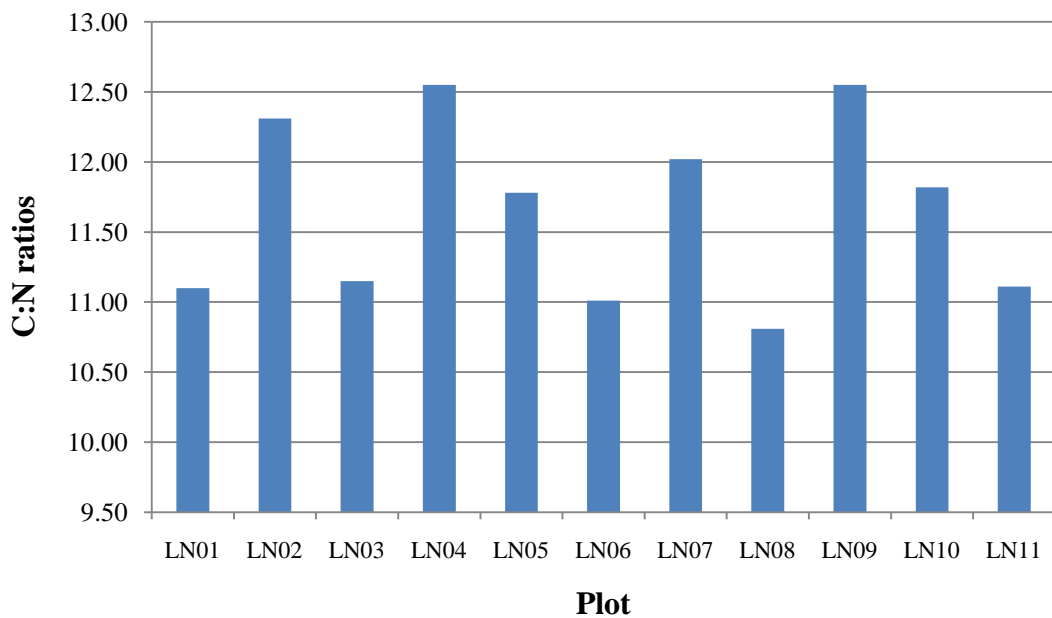


Figure 4.5 The average C:N ratios in each plot in Lumpini park

Table 4.4 Soil properties of tree-planting area in each plot in Lumpini park

Plot	Texture	Soil color		BD (g cm ⁻³)	pH	OM (%)	TN (%)	C:N ratios
		name	code					
LN01	silty clay loam	very dark grayish brown	10 YR 3/2	1.21±0.11	7.09±0.49	2.45±0.61	0.13±0.03	11.10±1.46
LN02	silty clay loam	dark grayish brown	10 YR 4/2	1.25±0.10	4.81±1.06	2.59±1.14	0.12±0.05	12.31±1.37
LN03	silty clay loam	very dark grayish brown	10 YR 3/2	1.14±0.15	6.43±1.32	2.37±1.21	0.12±0.08	11.15±1.42
LN04	silty clay loam	very dark grayish brown	10 YR 3/2	1.25±0.05	4.73±0.53	2.16±0.49	0.10±0.02	12.55±2.23
LN05	silty clay loam	very dark grayish brown	10 YR 3/2	0.94±0.04	6.60±0.73	3.72±2.32	0.17±0.08	11.78±1.88
LN06	silty clay	very dark grayish brown	10 YR 3/2	1.13±0.15	6.99±0.28	4.21±1.98	0.21±0.09	11.01±0.59
LN07	clay loam	very dark grayish brown	10 YR 3/2	1.22±0.22	7.52±0.39	3.70±0.71	0.18±0.05	12.02±1.07
LN08	silty clay loam	very dark grayish brown	10 YR 3/2	1.11±0.16	7.60±0.17	3.41±0.08	0.18±0.00	10.81±0.05
LN09	silty clay loam	very dark grayish brown	10 YR 3/2	1.32±0.07	6.04±1.78	2.98±0.07	0.14±0.05	12.55±2.42
LN10	clay loam	very dark grayish brown	10 YR 3/2	1.25±0.10	7.27±0.07	2.67±0.05	0.13±0.00	11.82±0.66
LN11	silty clay loam	very dark grayish brown	10 YR 3/2	1.23±0.18	5.45±1.22	2.65±0.46	0.14±0.04	11.11±1.63

Note: soil bulk density (BD), soil reaction (pH), organic matter (OM), total nitrogen (TN) and carbon to nitrogen ratios (C:N ratios)

4.1.1.3 Carbon storage

1) Carbon storage in above-ground biomass

The results of above-ground biomass (AGB) estimation were found that LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest AGB, followed by LN11 (*Samanea saman*), LN04 (*Tabebuia rosea*) and LN07 (*Swietenia macrophylla*) had the lowest AGB were 168.29, 162.46, 100.75 and 9.14 t ha⁻¹, respectively (Table 4.5).

The similar trend was found for above-ground carbon (AGC) storage, LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest AGC storage, followed by LN11 (*Samanea saman*), LN04 (*Tabebuia rosea*) and LN07 (*Swietenia macrophylla*) had the lowest AGC storage were 79.01, 76.39, 47.35 and 4.27 t ha⁻¹, respectively (Table 4.5 and Figure 4.6).

Table 4.5 Above-ground biomass and carbon storage in each plot in Lumpini park

Plot	Above-ground biomass		Above-ground carbon storage	
	(kg tree ⁻¹)	(t ha ⁻¹)	(kg tree ⁻¹)	(t ha ⁻¹)
LN01	390.31±709.65	56.88	183.44±333.54	26.74
LN02	624.55±746.16	55.08	293.54±350.70	25.89
LN03	327.66±536.57	19.87	154.00±252.19	9.34
LN04	402.38±258.73	100.75	189.12±121.60	47.35
LN05	125.72±76.23	29.44	59.09±35.83	13.80
LN06	692.21±1,059.86	64.63	325.34±498.14	30.39
LN07	48.90±26.86	9.14	22.98±12.62	4.27
LN08	192.76±172.14	76.41	90.59±80.91	35.81
LN09	2,818.42±1,881.13	168.29	1,324.66±884.13	79.09
LN10	434.98±590.63	72.94	204.44±277.60	34.30
LN11	2,349.27±1,122.77	162.46	1,104.16±527.70	76.39
Average	-	74.17±52.25	-	34.85±24.57

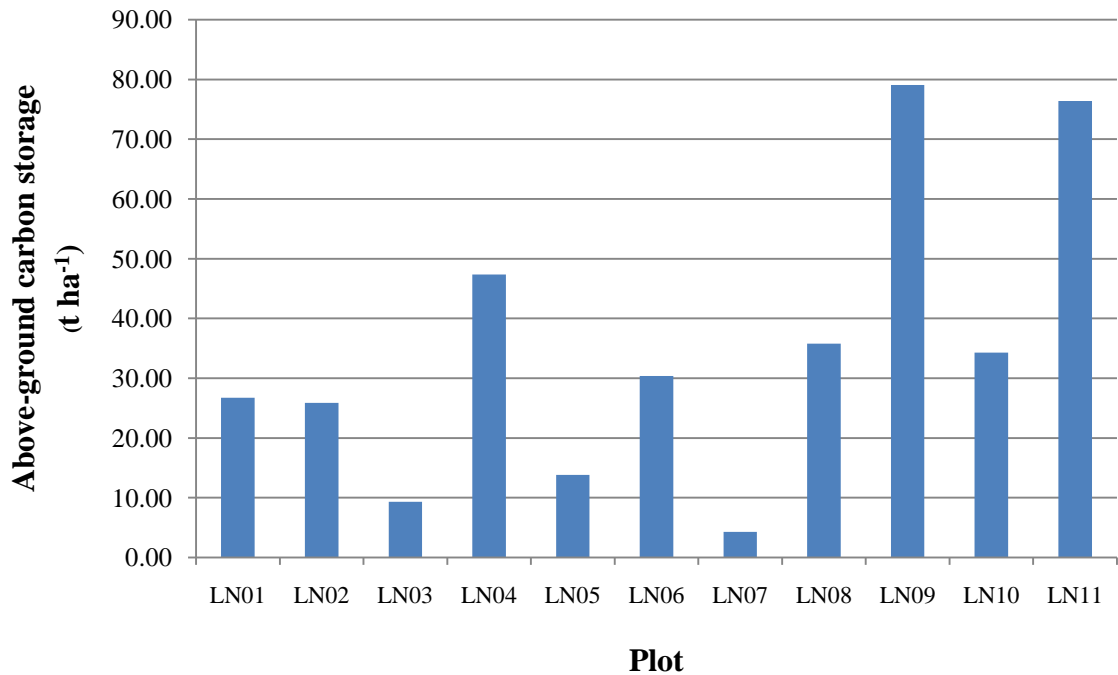


Figure 4.6 Above-ground carbon storage in each plot in Lumpini park

2) Carbon storage in litter

The results of litter fall biomass were found that LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest biomass, followed by LN01 (mixed 9 species), LN02 (mixed 7 species) and LN10 (*Pterocarpus indicus*) had the lowest biomass were 10.62, 8.82, 7.85 and 1.37 t ha⁻¹, respectively (Table 4.6).

The similar trend was found for litter fall carbon storage, LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest carbon storage, followed by LN01 (mixed 9 species), LN02 (mixed 7 species) and LN10 (*Pterocarpus indicus*) had the lowest carbon storage were 4.99, 4.17, 3.69 and 0.64 t ha⁻¹, respectively (Table 4.6 and Figure 4.7).

Table 4.6 Litter fall biomass and carbon storage in each plot in Lumpini park

Plot	Biomass		Carbon storage	
	(g m ⁻²)	(t ha ⁻¹)	(g m ⁻²)	(t ha ⁻¹)
LN01	882.00±870.36	8.82±8.70	414.53±409.08	4.15±4.09
LN02	785.27±674.73	7.85±6.74	369.07±317.12	3.69±3.17
LN03	504.76±598.93	5.05±6.00	237.23±281.49	2.37±2.81
LN04	253.03±83.45	2.53±0.83	118.92±39.22	1.19±0.39
LN05	239.93±73.67	2.40±0.74	112.76±34.62	1.13±0.35
LN06	257.63±101.13	2.58±1.01	121.08±47.53	1.21±0.48
LN07	491.70±246.89	4.92±2.47	231.10±116.04	2.31±1.16
LN08	242.30±97.28	2.42±0.97	113.90±45.72	1.14±0.46
LN09	1,061.63±1,148.50	10.62±11.49	498.96±539.79	4.99±5.40
LN10	137.09±47.90	1.37±0.48	64.43±22.50	0.64±0.23
LN11	383.90±105.74	3.84±1.06	180.34±49.70	1.80±0.50
Average	-	4.76±3.06	-	2.24±1.44

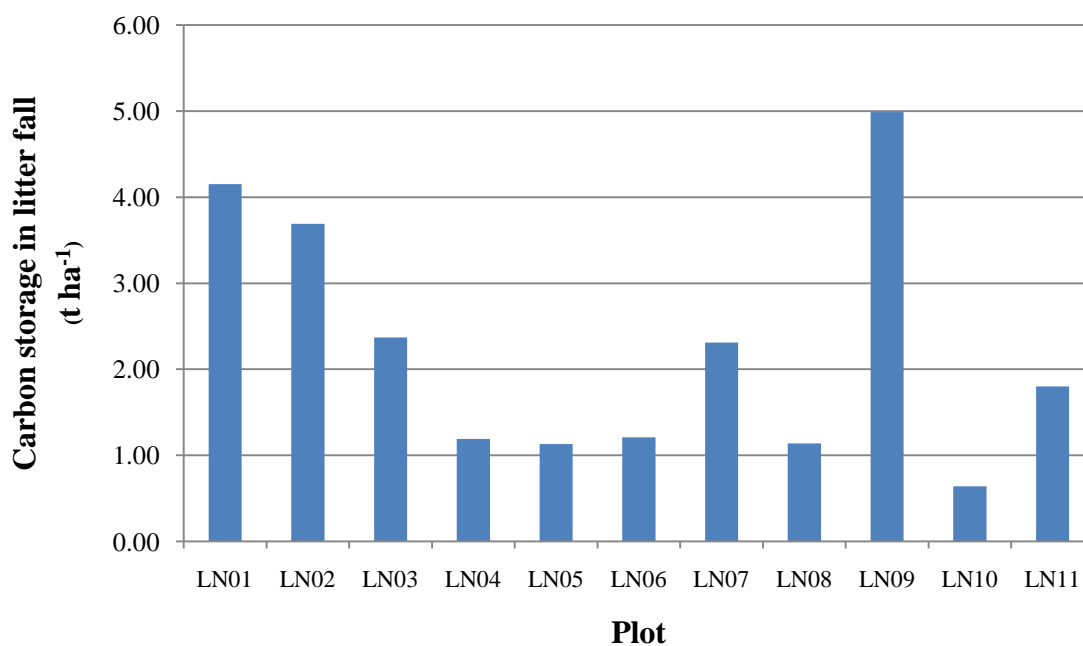


Figure 4.7 Carbon storage in litter fall in each plot in Lumpini park

The results of grass litter biomass were found that *Zoysia japonica* had higher biomass than *Axonopus compuuressus* were 0.91 and 0.42 t ha⁻¹, respectively (Table 4.7). Similar to carbon storage in grass litter, *Zoysia japonica* had higher carbon storage than *Axonopus compuuressus* were 0.36 and 0.17 t ha⁻¹, respectively (Table 4.7).

Table 4.7 Grass litter biomass and carbon storage in Lumpini park

Species	Biomass		Carbon storage	
	(g m ⁻²)	(t ha ⁻¹)	(g m ⁻²)	(t ha ⁻¹)
<i>Zoysia japonica</i>	90.73±20.95	0.91±0.21	36.29±8.38	0.36±0.08
<i>Axonopus compuuressus</i>	42.43±0.65	0.42±0.01	16.97±0.26	0.17±0.00
Average	66.58±29.24	0.67±0.29	26.63±11.70	0.27±0.12

3) Carbon storage in soil

The results of soil organic carbon (SOC) storage showed that LN06 (*Acacia auriculiformis*) had the highest SOC storage, followed by LN07 (*Swietenia macrophylla*), LN09 (*Peltophorum pterocarpum* and *Samanea saman*) and LN03 (mixed 8 species) had the lowest SOC storage were 38.32, 34.75, 32.61 and 23.11 t ha⁻¹, respectively (Table 4.8 and Figure 4.8).

Table 4.8 Soil organic carbon storage in each plot in Lumpini park

Plot	Carbon content	Carbon storage
	(g kg ⁻¹)	(t ha ⁻¹)
LN01	13.73±3.51	24.65±5.77
LN02	14.98±5.96	28.01±10.98
LN03	13.99±7.32	23.11±10.64
LN04	13.22±3.52	24.90±6.25
LN05	19.10±10.14	27.06±14.34
LN06	23.24±9.23	38.32±10.53
LN07	19.34±4.87	34.75±2.68
LN08	18.39±0.42	30.70±5.21
LN09	16.36±4.57	32.61±10.19
LN10	14.68±0.88	27.60±0.50
LN11	13.64±2.97	25.58±9.17
Average	14.98±5.90	25.39±9.26

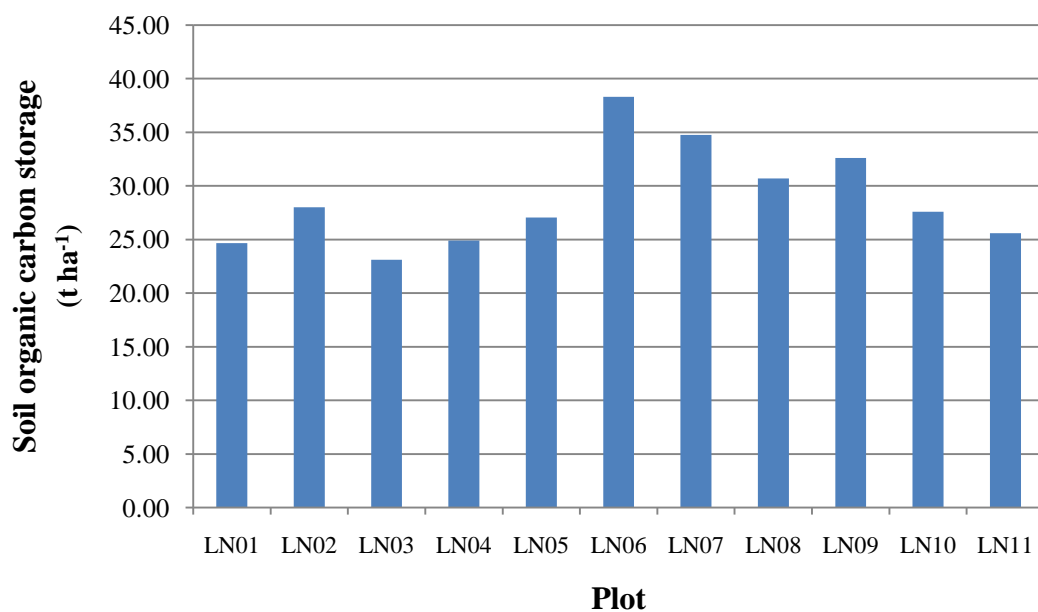


Figure 4.8 Soil organic carbon storage in each plot in Lumpini park

The results of SOC storage in turf were found that *Axonopus compuuressus* had higher SOC storage than *Zoysia japonica* were 20.85 and 20.48 t ha⁻¹, respectively (Table 4.9).

Table 4.9 Soil organic carbon storage in turf in Lumpini park

Species	Carbon storage	
	(g kg ⁻¹)	(t ha ⁻¹)
<i>Zoysia japonica</i>	12.63±4.84	20.48±6.84
<i>Axonopus compuuressus</i>	16.19±7.14	20.85±7.76
Average	14.41±6.23	20.67±7.16

4) Total carbon storage

The results of total carbon storage in each plot were found that LN09 (*Peltophorum pterocarpum* and *Samanea saman*) had the highest total carbon storage, followed by LN11 (*Samanea saman*), LN04 (*Tabebuia rosea*) and LN03 (mixed 8 species) had the lowest total carbon storage were 116.61, 103.77, 73.44 and 34.82 t ha⁻¹, respectively (Table 4.10 and Figure 4.9).

Table 4.10 Total carbon storage in each plot in Lumpini park

Plot	Carbon storage (t ha ⁻¹)				
	AGB	Litter fall	Soil	Total	Total (+GL)
LN01	26.74	4.15	24.65	55.54	55.71
LN02	25.89	3.69	28.01	57.59	57.76
LN03	9.34	2.37	23.11	34.82	34.99
LN04	47.35	1.19	24.90	73.44	73.61
LN05	13.80	1.13	27.06	41.99	42.16
LN06	30.39	1.21	38.32	69.92	70.09
LN07	4.27	2.31	34.75	41.33	41.50
LN08	35.81	1.14	30.70	67.65	67.82
LN09	79.09	4.99	32.61	116.69	116.86
LN10	34.30	0.64	27.60	62.54	62.71
LN11	76.39	1.80	25.58	103.77	103.94
Average	34.85±24.57	2.24±1.44	28.84±4.74	65.93±25.34	66.10±25.34

Note: above-ground biomass (AGB), grass litter (GL)

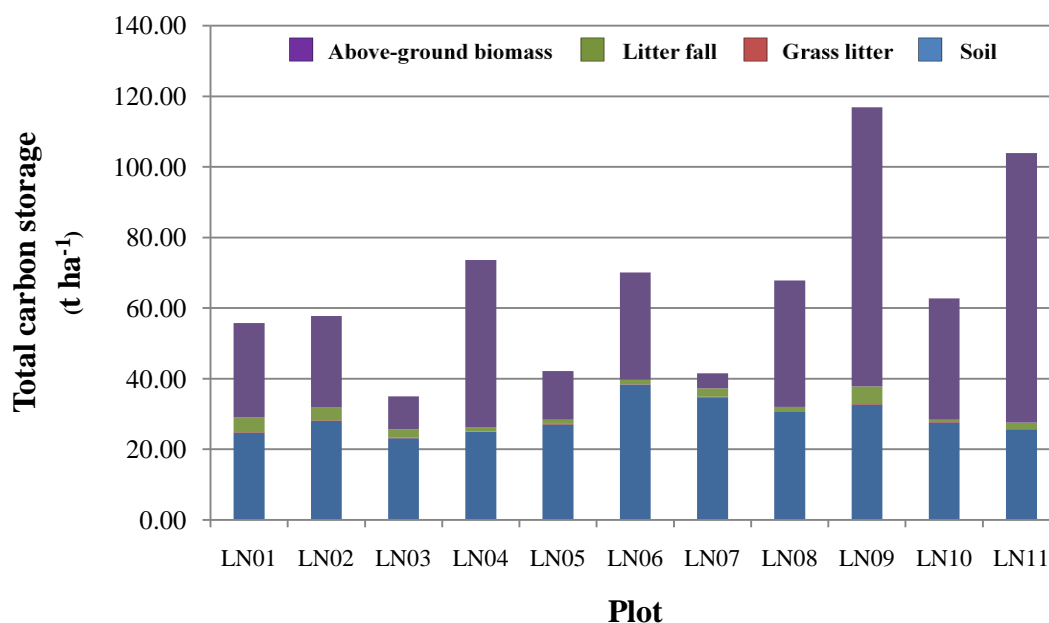


Figure 4.9 Total carbon storage in each plot in Lumpini park

The average total carbon storage in tree-planting area in Lumpini park was 66.10 t ha^{-1} , which was separated into the carbon storage in above-ground biomass, litter fall, grass litter and soil were 34.85 , 2.24 , 0.17 and 28.84 t ha^{-1} , respectively. The average total carbon storage in turf was 20.98 t ha^{-1} , which was separated into the carbon storage in grass litter and soil were 0.31 and 20.67 t ha^{-1} , respectively (Table 4.11).

Table 4.11 Total carbon storage of tree-planting area and turf in Lumpini park

Land cover	Carbon storage (t ha^{-1})				Total
	AGB	LF	GL	Soil	
Tree-planting area	34.85	2.24	0.17	28.84	66.10
Turf	-	-	0.27	20.67	20.93

Note: above-ground biomass (AGB), litter fall (LF), grass litter (GL)

4.1.2 Vachirabenjatas park

4.1.2.1 Plant characteristics

The number of tree was studied 592 trees, which was classified 8 plant species and 7 families. *Peltophorum pterocarpum* was the most common plant species, followed by *Pterocarpus indicus*, *Tabebuia rosea* and *Samanea saman* was the minimum plant species were 219, 138, 95 and 9 trees, respectively (Table 4.12).

Table 4.12 Plant species were studied in Vachirabenjatas park

Scientific name	Family name	Number of tree
<i>Acacia auriculiformis</i> A. Cunn. Ex Benth.	Mimosoideae	70
<i>Alstonia scholaris</i> R. Br.	Apocynaceae	27
<i>Peltophorum pterocarpum</i> (DC.) Back. ex Heyne	Caesalpinaceae	219
<i>Pterocarpus indicus</i> Willd	Papilionoideae	138
<i>Samanea saman</i> (Jacq.) Merr.	Fabaceae	3
<i>Streblus asper</i> Lour.	Moraceae	27
<i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	29
<i>Tabebuia rosea</i> (Bertol.) DC.	Bignoniaceae	79
Total		592

The study of the average diameter at breast height (DBH) of tree in each plot was found that VT08 (*Samanea saman*) had the highest average DBH, followed by VT12 (*Peltophorum pterocarpum*), VT09 (*Acacia auriculiformis*) and VT10 (*Pterocarpus indicus*) had the lowest of the average DBH were 102.77, 62.40, 53.11 and 20.09 cm, respectively (Table 4.13).

The study of the average height of tree in each plot was found that VT06 (*Peltophorum pterocarpum*) had the highest average height, followed by VT12 (*Peltophorum pterocarpum*), VT08 (*Samanea saman*) and VT05 (*Alstonia scholaris*) had the lowest average height were 23.13, 22.95, 22.79 and 10.34 m, respectively (Table 4.13).

The study of tree density in each plot was found that VT07 (*Peltophorum pterocarpum*) had the highest tree density, followed by VT01 (*Syzygium cumini*), VT06 (*Peltophorum pterocarpum*) and VT08 (*Samanea saman*) had the lowest tree density were 354.17, 322.22, 296.88 and 15 trees ha⁻¹, respectively (Table 4.13).

The study of total basal area in each plot was found that VT09 (*Acacia auriculiformis*) had the highest total basal area, followed by VT01 (*Syzygium cumini*), VT15 (*Tabebuia rosea* and *Peltophorum pterocarpum*) and VT03 (*Pterocarpus indicus*) had the lowest total basal area were 33.84, 26.90, 25.52 and 6.79 m² ha⁻¹ (Table 4.13).

Table 4.13 Quantitative characteristics of plant in each plot in Vachirabenjatas park

Plot	Plant species	Number of tree	Area (ha)	DBH (cm)	H (m)	TD (trees ha⁻¹)	BA (m² ha⁻¹)
VT01	<i>Syzygium cumini</i>	29	0.09	30.72±11.13	13.67±2.21	322.22	26.90
VT02	<i>Streblus asper</i>	27	0.12	29.61±7.72	14.40±2.87	225.00	16.50
VT03	<i>Pterocarpus indicus</i>	29	0.22	24.98±5.76	11.58±1.85	131.82	6.79
VT04	<i>Alstonia scholaris</i>	18	0.13	32.27±10.77	16.20±3.30	138.46	12.51
VT05	<i>Alstonia scholaris</i>	9	0.04	22.54±7.25	10.34±2.04	225.00	9.80
VT06	<i>Peltophorum pterocarpum</i>	95	0.32	31.00±7.87	23.13±4.17	296.88	23.32
VT07	<i>Peltophorum pterocarpum</i>	85	0.24	28.46±6.65	20.34±3.22	354.17	23.73
VT08	<i>Samanea saman</i>	3	0.20	102.77±10.87	22.79±2.01	15.00	12.53
VT09	<i>Acacia auriculiformis</i>	26	0.20	53.11±22.69	20.28±8.45	130.00	33.84
VT10	<i>Pterocarpus indicus</i>	79	0.32	20.09±5.79	15.13±2.93	246.88	8.46
VT11	<i>Pterocarpus indicus</i>	56	0.23	31.47±14.63	16.82±4.31	243.48	22.94
	<i>Tabebuia rosea</i>						

Note: diameter at breast height (DBH), height (H), tree density (TD), total basal area (BA)

Table 4.13 Quantitative characteristics of plant in each plot in Vachirabenjatas park (Cont.)

Plot	Plant species	Number of tree	Area (ha)	DBH (cm)	H (m)	TD (tree ha⁻¹)	BA (m² ha⁻¹)
VT12	<i>Peltophorum pterocarpum</i>	36	0.73	62.40±25.61	22.95±6.62	49.32	17.54
VT13	<i>Acacia auriculiformis</i>	19	0.25	39.33±17.64	17.01±4.30	76.00	10.99
VT14	<i>Tabebuia rosea</i>	64	0.78	43.55±22.02	19.02±4.47	82.05	15.29
	<i>Acacia auriculiformis</i>						
VT15	<i>Tabebuia rosea</i>	19	0.18	46.52±31.08	17.05±3.21	105.56	25.52
	<i>Peltophorum pterocarpum</i>						

Note: diameter at breast height (DBH), height (H), tree density (TD), total basal area (BA)

4.1.2.2 Soil properties

To study of soil in tree-planting area was found that texture was sandy clay loam, very dark grayish brown. Soil reaction was slightly alkaline (7.4-7.8), soil organic matter was neutral (1.5-2.5) and total nitrogen was very low (less than 0.1). The average C:N ratios was 12.91 in range of 3.56-18.00 and the average soil bulk density was 1.30 g cm^{-3} . The percentage of average organic matter and total nitrogen per area were 39.06 and 1.83 t ha^{-1} , respectively.

Soil in turf was found texture was sandy clay loam, very dark grayish brown. Soil reaction was neutral (6.6-7.3), organic matter was neutral (1.5-2.5) and total nitrogen was low (0.1-0.2). The average C:N ratios was 13.47 in range 8.98-19.25 and the average soil bulk density was 1.18 g cm^{-3} . The percentage of average organic matter and total nitrogen per area were 42.59 and 1.87 t ha^{-1} , respectively.

Soil properties in tree-planting area and turf were showed in Table 4.14. To compare the difference of the average of soil properties between these area was found that there was significant difference in soil bulk density.

Table 4.14 Soil properties of tree-planting area and turf in Vachirabenjatas park

Soil properties	Tree-planting area	Turf
Texture	Sandy clay loam	Sandy clay loam
BD (g cm^{-1})	1.30 ± 0.13	1.18 ± 0.16
pH	7.17 ± 0.87	7.16 ± 0.70
OM (%)	2.12 ± 1.19	2.45 ± 1.12
TN (%)	0.10 ± 0.06	0.11 ± 0.05
C:N ratios	12.91 ± 2.36	13.47 ± 2.33

Note: soil bulk density (BD), soil reaction (pH), organic matter (OM), total nitrogen (TN) and carbon to nitrogen ratios (C:N ratios)

The compare of soil properties in each plot in tree-planting area was found the detail following (Table 4.15).

1) Soil bulk density (BD)

The average BD in tree-planting area was 1.29 g cm⁻³, which was in the range of 1.10-1.55 g cm⁻³. The results was found that VT02 (*Streblus asper*) had the highest average BD, followed by VT07 (*Peltophorum pterocarpum*), VT01 (*Syzygium cumini*), VT06 (*Peltophorum pterocarpum*) and VT04 (*Alstonia scholaris*) had the lowest average BD were 1.42, 1.37, 1.35 and 1.10 g cm⁻³, respectively. The statistical analysis found that the mean difference of BD in each plot were statistical significant at the level of 0.05 (Table 4.15 and Figure 4.10).

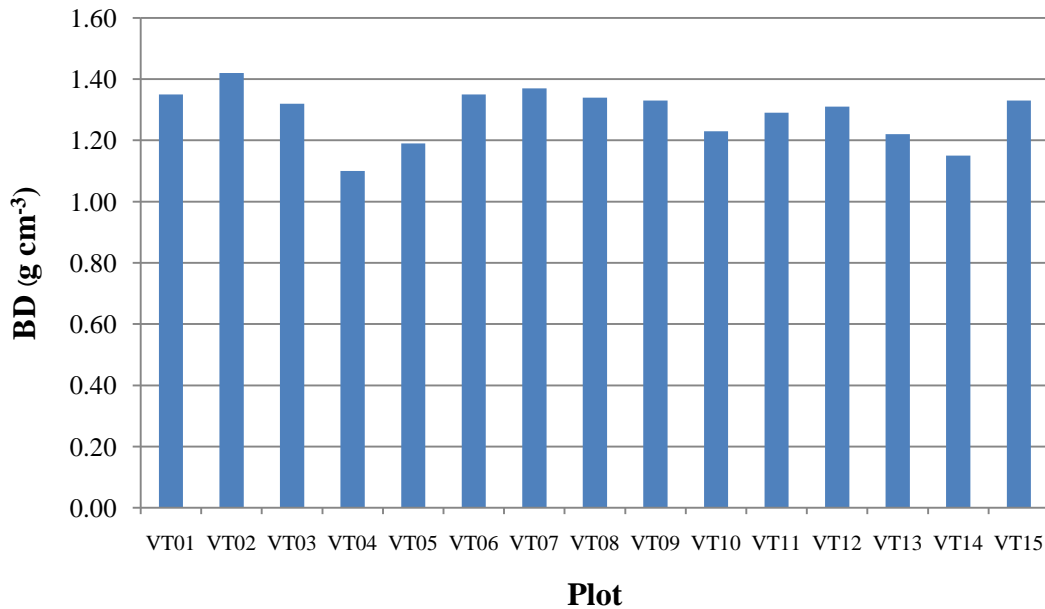


Figure 4.10 The average BD in each plot in Vachirabenjatas park

2) Soil reaction (pH)

The average pH in tree-planting area was 7.17, which was in the range of 4.53-8.34. The results was found that VT01 (*Syzygium cumini*) had the highest average pH, followed by VT06 (*Peltophorum pterocarpum*), VT05 (*Alstonia scholaris*) and VT13 (*Acacia auriculiformis*) had the lowest average pH were 8.09, 7.76, 7.64 and 5.90, respectively. The statistical analysis found that the mean difference of pH in each plot were statistical significant at the level of 0.05 (Table 4.15 and Figure 4.11).

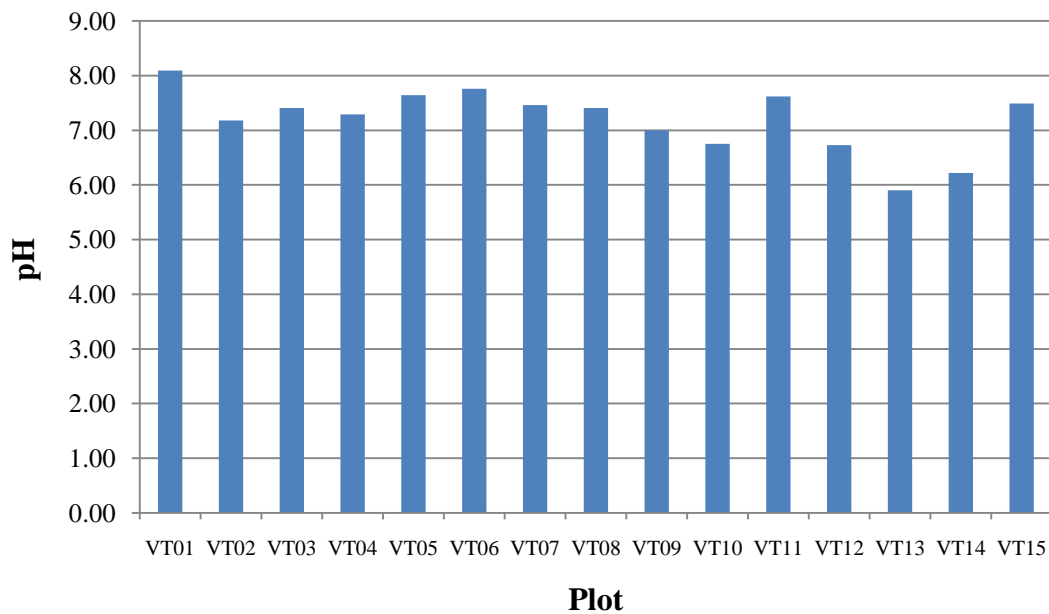


Figure 4.11 The average pH in each plot in Vachirabenjatas park

3) Organic matter (OM)

The average OM in tree-planting area was 2.05 percent, which was in the range of 0.44-5.97 percent. The result was found that VT14 (*Tabebuia rosea*) and (*Acacia auriculiformis*) had the highest average OM, followed by VT09 (*Acacia auriculiformis*), VT13 (*Acacia auriculiformis*) and VT01 (*Syzygium cumini*) had the lowest average OM were 3.89, 2.95, 2.84 and 0.77 percent, respectively. The statistical analysis found that the mean difference of percentage of OM in each plot were statistical significant at the level of 0.05 (Table 4.15 and Figure 4.12).

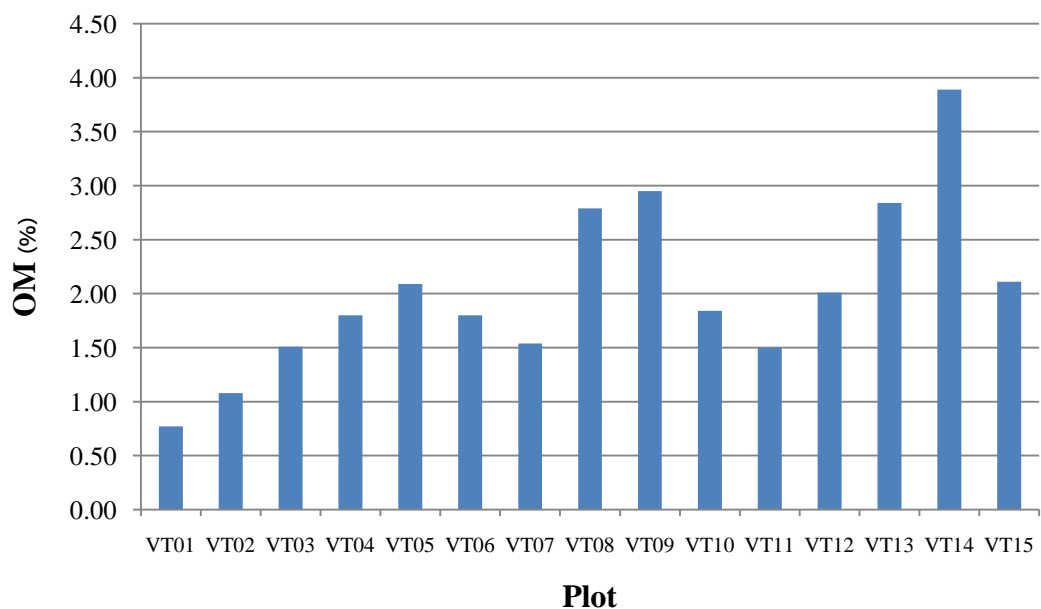


Figure 4.12 The average OM in each plot in Vachirabenjatas park

4) Total nitrogen (TN)

The average TN in tree-planting area was 0.10 percent, which in the range of 0.01-0.27 percent. The result was found that VT14 (*Tabebuia rosea* and *Acacia auriculiformis*) had the highest average TN, followed by VT09 (*Acacia auriculiformis*), VT13 (*Acacia auriculiformis*), VT08 (*Samanea saman*) and VT01 (*Syzygium cumini*) had the lowest average TN were 0.19, 0.16, 0.14, 0.14 and 0.03 percent, respectively. The statistical analysis found that the mean difference of percentage of TN in each plot were statistical significant at the level of 0.05 (Table 4.15 and Figure 4.13).

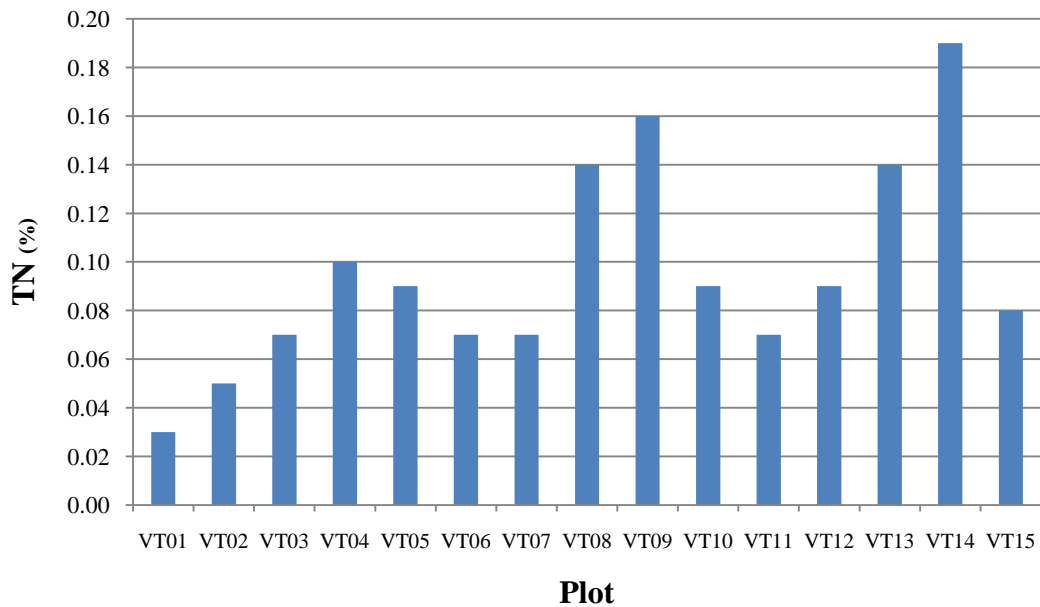


Figure 4.13 The average TN in each plot in Vachirabenjatas park

6) Carbon to nitrogen ratios (C:N ratios)

The average C:N ratios in tree-planting area was 12.91, which in the range of 3.56-18.00. The results was found that VT01 (*Syzygium cumini*) had the highest average C:N ratios, followed by VT15 (*Tabebuia rosea* and *Peltophorum pterocarpum*), VT06 (*Peltophorum pterocarpum*) and VT13 (*Acacia auriculiformis*) had the lowest average C:N ratios were 17.42, 14.84, 14.09 and 10.86, respectively. The statistical analysis found that the mean difference of C:N ratios in each plot were statistical significant at the level of 0.05 (Table 4.15 and Figure 4.14).

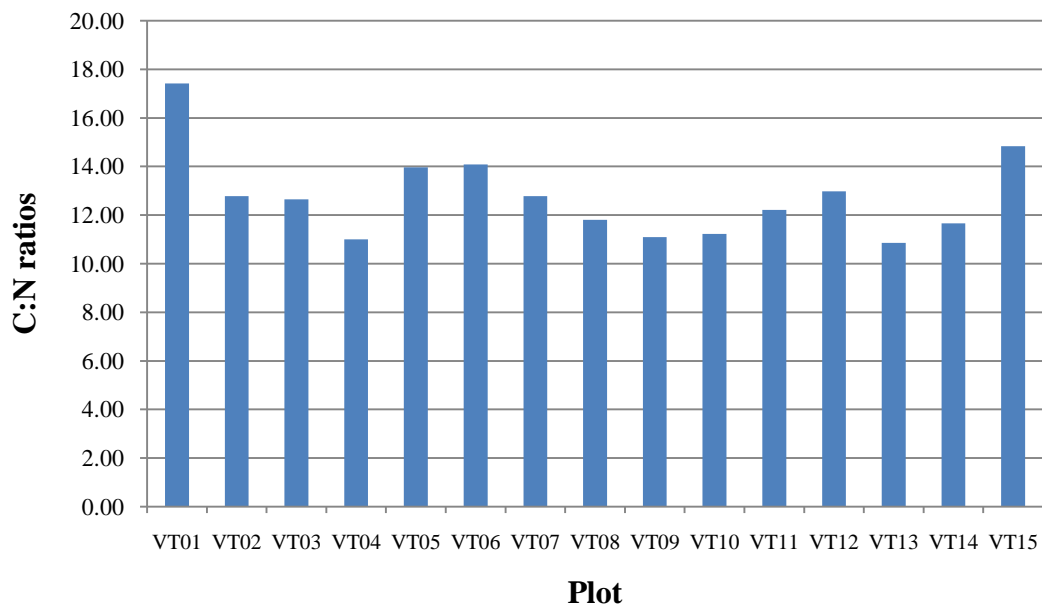


Figure 4.14 The average C:N ratios in each plot in Vachirabenjatas park

Table 4.15 Soil properties of tree-planting area in each plot in Vachirabenjatas park

Plot	Texture	Soil color		BD (g cm ⁻³)	pH	OM (%)	TN (%)	C:N ratios
		name	code					
VT01	sand	dark yellowish brown	10 YR 4/4	1.35±0.08	8.09±0.26	0.77±0.30	0.03±0.01	17.42±0.77
VT02	Sandy Clay Loam	dark brown	10 YR 3/3	1.42±0.09	7.18±0.64	1.08±0.17	0.05±0.01	12.78±1.81
VT03	Sandy Clay Loam	dark brown	10 YR 3/3	1.32±0.13	7.41±0.54	1.51±0.60	0.07±0.02	12.65±1.98
VT04	Sandy Clay Loam	brown	10 YR 4/3	1.10±0.08	7.29±0.41	1.80±1.05	0.10±0.05	11.00±2.69
VT05	Loamy Sand	dark yellowish brown	10 YR 4/4	1.19±0.17	7.64±0.10	2.09±0.08	0.09±0.02	13.97±3.09
VT06	Sandy Clay Loam	very dark grayish brown	10 YR 3/2	1.35±0.10	7.76±0.24	1.80±0.74	0.07±0.03	14.09±1.65
VT07	Sandy Loam	dark brown	10 YR 3/3	1.37±0.15	7.46±0.32	1.54±0.58	0.07±0.02	12.78±1.79
VT08	Sandy Clay Loam	very dark grayish brown	10 YR 3/2	1.34±0.20	7.41±0.30	2.79±0.04	0.14±0.01	11.80±0.90
VT09	Sandy Clay Loam	very dark grayish brown	10 YR 3/2	1.33±0.08	7.00±0.87	2.95±1.81	0.16±0.07	11.09±4.34
VT10	Clay Loam	very dark grayish brown	10 YR 3/2	1.23±0.11	6.75±0.44	1.84±0.89	0.09±0.05	11.23±1.12

Note: soil bulk density (BD), soil reaction (pH), organic matter (OM), total nitrogen (TN) and carbon to nitrogen ratios (C:N ratios)

Table 4.15 Soil properties of tree-planting area in each plot in Vachirabenjatas park (Cont.)

Plot	Texture	Soil color		BD (g cm ⁻³)	pH	OM (%)	N (%)	C:N ratios
		name	code					
VT11	Loamy Sand	dark yellowish brown	10 YR 4/4	1.29±0.08	7.62±0.30	1.50±0.57	0.07±0.03	12.21±1.64
VT12	Silty Clay	very dark grayish brown	10 YR 3/2	1.31±0.12	6.73±1.26	2.01±0.85	0.09±0.03	12.98±1.72
VT13	Silty Clay	very dark grayish brown	10 YR 3/2	1.22±0.07	5.90±0.78	2.84±0.54	0.14±0.03	10.86±0.79
VT14	Silty Clay	very dark grayish brown	10 YR 3/2	1.15±0.04	6.22±0.24	3.89±1.75	0.19±0.07	11.66±1.39
VT15	Sandy Clay Loam	brown	10 YR 4/3	1.33±0.13	7.49±0.67	2.11±2.02	0.08±0.07	14.84±1.08

Note: soil bulk density (BD), soil reaction (pH), organic matter (OM), total nitrogen (TN) and carbon to nitrogen ratios (C:N ratios)

4.1.2.3 Carbon storage

1) Above-ground carbon storage

The results of above-ground biomass (AGB) estimation were found that VT09 (*Acacia auriculiformis*) had the highest AGB, followed by VT06 (*Peltophorum pterocarpum*), VT07 (*Peltophorum pterocarpum*) and VT03 (*Pterocarpus indicus*) had the lowest AGB were 244.55, 211.56, 190.20 and 33.90 t ha⁻¹, respectively (Table 4.16). Similar to above-ground carbon (AGC) storage, VT09 (*Acacia auriculiformis*) had the highest AGC storage, followed by VT06 (*Peltophorum pterocarpum*), VT07 (*Peltophorum pterocarpum*) and VT03 (*Pterocarpus indicus*) had the lowest AGC storage were 114.93, 99.43, 89.39 and 15.93 t ha⁻¹, respectively (Table 4.16 and Figure 4.15).

Table 4.16 Above-ground biomass and carbon storage in each plot in Vachirabenjatas park

Plot	Above-ground biomass		Above-ground carbon	
	(kg tree ⁻¹)	(t ha ⁻¹)	(kg tree ⁻¹)	(t ha ⁻¹)
VT01	462.77±373.50	142.36	217.50±175.55	66.94
VT02	431.51±244.04	94.00	202.81±114.70	44.22
VT03	256.75±137.39	33.90	120.67±64.57	15.93
VT04	608.77±493.60	82.57	286.12±231.99	38.80
VT05	192.62±123.21	47.00	90.53±57.91	22.01
VT06	716.81±380.75	211.56	336.90±357.90	99.43
VT07	546.49±282.69	190.20	256.85±132.87	89.39
VT08	6,236.76±1,626.84	94.47	2,931.28±764.61	44.38
VT09	1,900.29±1,662.67	244.55	893.14±781.45	114.93
VT10	228.62±162.99	56.08	107.45±76.60	26.36
VT11	673.72±621.93	161.28	316.65±292.31	75.79
VT12	3,053.90±2,563.09	150.07	1,435.33±1,204.65	70.53
VT13	997.76±921.37	76.42	468.95±433.04	35.91
VT14	1,388.66±1,676.30	113.21	652.67±787.86	53.21
VT15	1,616.17±2,158.97	168.96	759.60±1,014.72	79.39
Average	-	124.44±62.98	-	58.48±29.61

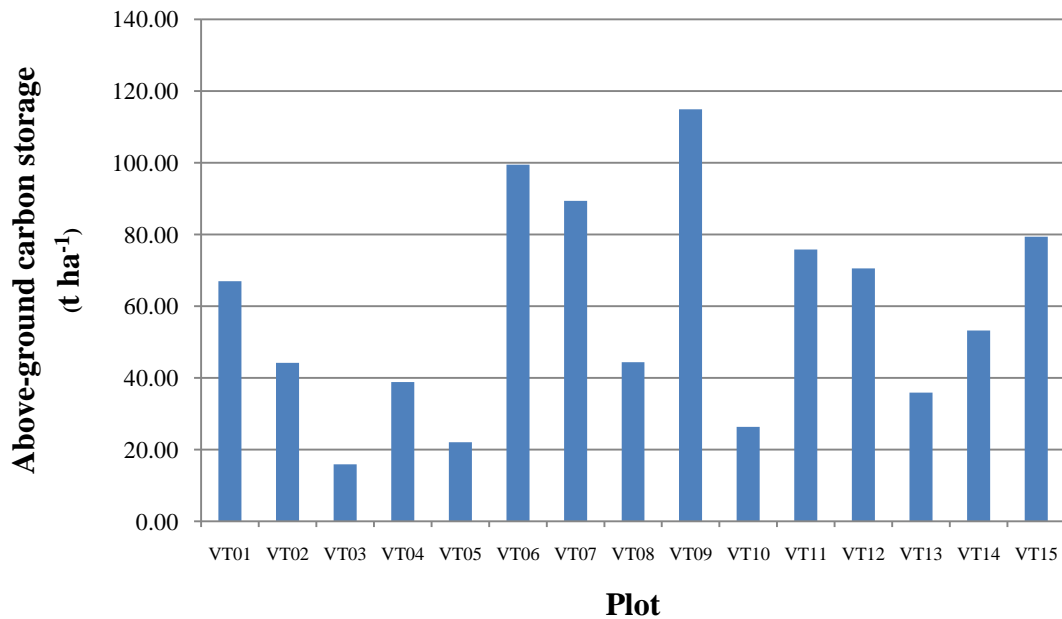


Figure 4.15 Above-ground carbon storage in each plot in Vachirabenjatas park

2) Carbon storage in litter

The results of litter fall biomass were found that VT08 (*Samanea saman*) had the highest litter fall biomass, followed by VT12 (*Peltophorum pterocarpum*), VT13 (*Acacia auriculiformis*) and VT09 (*Acacia auriculiformis*) had the lowest litter fall biomass were 6.39, 4.51, 4.12 and 0.54 t ha⁻¹, respectively (Table 4.17).

Similar to carbon storage of litter fall, VT08 (*Samanea saman*) had the highest litter fall carbon storage, followed by VT12 (*Peltophorum pterocarpum*), VT13 (*Acacia auriculiformis*) and VT09 (*Acacia auriculiformis*) had the lowest litter fall carbon storage were 3.00, 2.12, 1.94 and 0.26 t ha⁻¹, respectively (Table 4.17 and Figure 4.16).

Table 4.17 Litter fall biomass and carbon storage in Vachirabenjatas park

Plot	Biomass		Carbon storage	
	(g m ⁻²)	(t ha ⁻¹)	(g m ⁻²)	(t ha ⁻¹)
VT01	191.23±36.64	1.91±0.37	89.88±17.22	0.90±0.17
VT02	71.78±25.20	0.72±0.25	33.73±11.84	0.34±0.12
VT03	68.05±23.76	0.68±0.24	31.98±11.17	0.32±0.11
VT04	196.15±168.76	1.96±1.69	92.19±79.32	0.92±0.79
VT05	107.35±12.24	1.07±0.12	50.45±5.75	0.50±0.06
VT06	164.58±106.48	1.64±1.06	77.35±50.05	0.77±0.50
VT07	116.18±34.53	1.16±0.34	54.60±16.23	0.54±0.16
VT08	639.10±345.02	6.39±3.45	300.38±162.16	3.00±1.62
VT09	544.18±106.72	5.44±1.06	255.76±50.16	2.56±0.50
VT10	79.63±9.93	0.80±0.09	37.42±4.57	0.37±0.04
VT11	121.89±48.32	1.22±0.48	57.29±22.71	0.57±0.23
VT12	450.68±164.57	4.51±1.64	211.82±77.35	2.12±0.77
VT13	411.93±144.66	4.12±1.45	193.60±67.99	1.94±0.68
VT14	213.50±180.89	2.14±1.81	100.35±85.02	1.00±0.85
VT15	124.09±46.63	1.24±0.47	58.32±21.92	0.58±0.22
Average	-	2.33±1.85	-	0.94±0.79

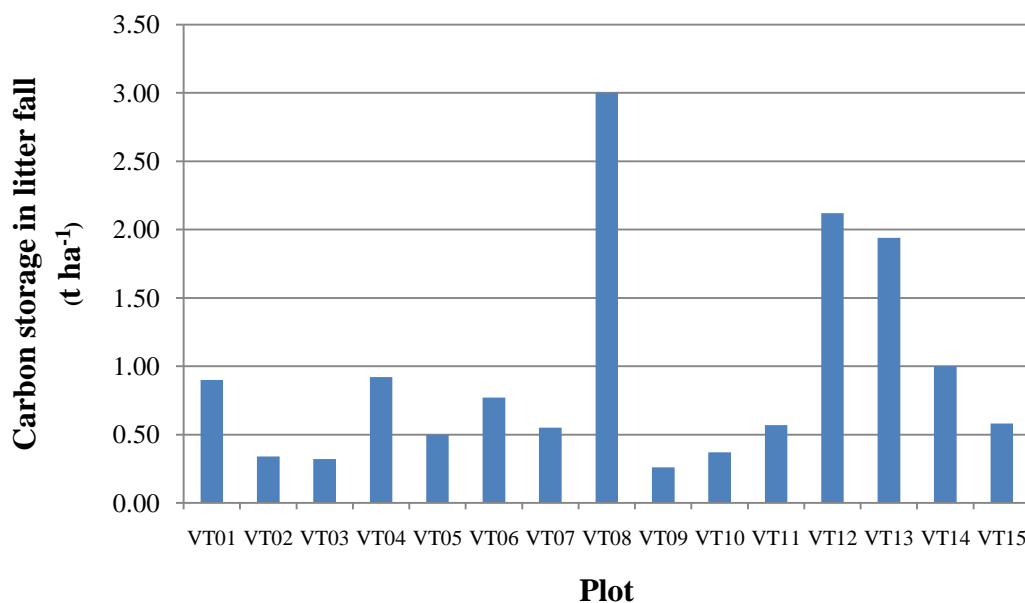


Figure 4.16 Carbon storage in litter fall in each plot in Vachirabenjatas park

The results of grass litter biomass were found that *Zoysia japonica* had the highest grass litter biomass, followed by *Cynodon dactylon*, *Axonopus compuuressus* and *Zoysia matrella* had the lowest grass litter biomass were 1.27, 0.81, 0.56 and 0.53 t ha⁻¹, respectively (Table 4.18). Similar to carbon storage in litter, *Zoysia japonica* had the highest carbon storage, followed by *Cynodon dactylon*, *Axonopus compuuressus* and *Zoysia matrella* had the lowest carbon storage were 0.60, 0.38, 0.26 and 0.25 t ha⁻¹, respectively (Table 4.18).

Table 4.18 Grass litter biomass and carbon storage in Vachirabenjatas park

species	Biomass		Carbon storage	
	(g m ⁻²)	(t ha ⁻¹)	(g m ⁻²)	(t ha ⁻¹)
<i>Zoysia japonica</i>	126.64±24.37	1.27±0.24	50.65±9.75	0.51±0.10
<i>Cynodon dactylon</i>	80.87±31.37	0.81±0.31	32.35±12.55	0.32±0.13
<i>Axonopus compuuressus</i>	56.33±6.13	0.56±0.06	22.53±2.45	0.22±0.02
<i>Zoysia matrella</i>	52.62±12.60	0.53±0.13	21.05±5.04	0.21±0.05
Average	79.11±35.82	0.79±0.36	31.65±14.33	0.32±0.14

3) Carbon storage in soil

The results of soil organic carbon (SOC) storage showed that VT14 (*Tabebuia rosea* and *Acacia auriculiformis*) had the highest SOC storage, followed by VT13 (*Acacia auriculiformis*), VT09 (*Acacia auriculiformis*) and VT01 (*Syzygium cumini*) had the lowest SOC storage were 36.09, 29.69, 26.48 and 6.27 t ha⁻¹, respectively (Table 4.19 and Figure 4.17).

Table 4.19 Soil organic carbon storage in each plot in Vachirabenjatas park

Plot	Carbon content	Carbon storage
	(g kg ⁻¹)	(t ha ⁻¹)
VT01	3.12±1.22	6.27±2.16
VT02	5.45±1.74	11.71±4.17
VT03	8.12±2.76	16.18±5.93
VT04	8.49±1.33	13.90±1.88
VT05	8.93±1.53	15.94±0.49
VT06	7.73±3.04	15.54±6.15
VT07	8.45±3.17	17.30±6.65
VT08	12.55±1.96	25.50±7.75
VT09	13.56±7.83	26.48±14.40
VT10	12.40±3.94	23.13±8.60
VT11	7.93±3.34	15.02±5.76
VT12	11.60±5.48	23.31±12.29
VT13	16.11±2.03	29.69±5.28
VT14	20.90±5.94	36.09±10.70
VT15	8.98±7.00	18.61±15.72
Average	10.17±5.65	19.44±10.39

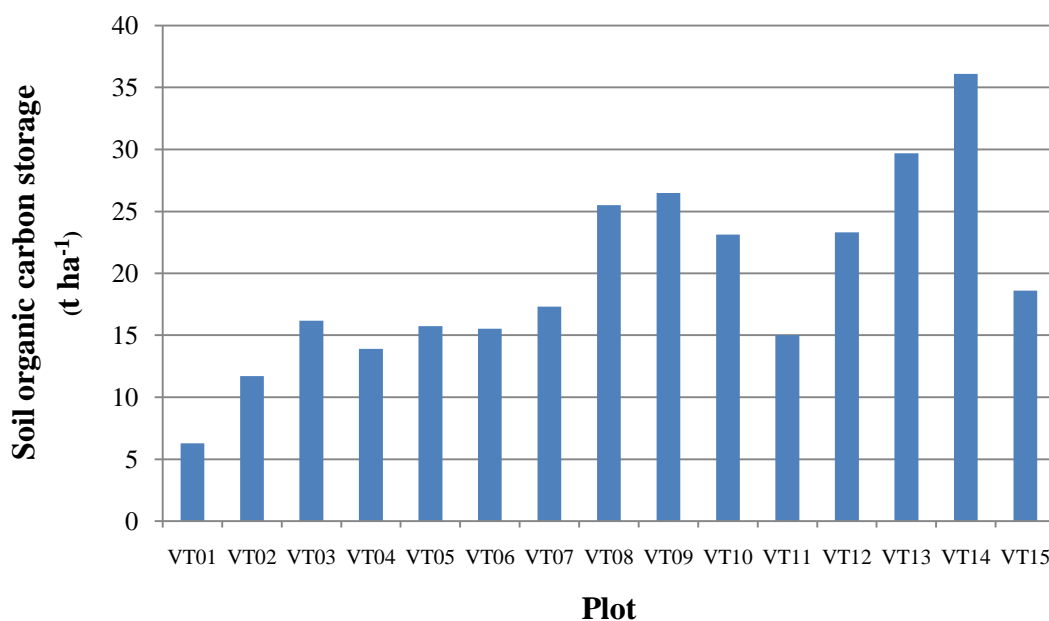


Figure 4.17 Soil organic carbon storage in each plot in Vachirabenjatas park

The results of carbon storage in soil in turf were found that *Cynodon dactylon* had the highest SOC storage, followed by *Axonopus compuuressus*, *Zoysia japonica* and *Zoysia matrella* had the lowest SOC storage were 21.85, 20.96, 16.96 and 15.54 t ha⁻¹, respectively (Table 4.20).

Table 4.20 Soil organic carbon storage in turf in Vachirabenjatas park

Species	Carbon storage	
	(g kg ⁻¹)	(t ha ⁻¹)
<i>Zoysia japonica</i>	9.87±5.09	16.96±7.58
<i>Cynodon dactylon</i>	12.81±3.94	21.85±6.36
<i>Axonopus compuuressus</i>	11.62±3.88	20.96±9.00
<i>Zoysia matrella</i>	8.06±3.47	15.54±8.75
Average	10.96±4.53	19.12±7.62

4) Total carbon storage

The results of total carbon storage in each plot found that VT09 (*Acacia auriculiformis*) had the highest total carbon storage, followed by VT06 (*Peltophorum pterocarpum*), VT07 (*Peltophorum pterocarpum*) and VT03 (*Pterocarpus indicus*) had the lowest total carbon storage were 141.67, 115.74, 107.24 and 32.43 t ha⁻¹, respectively (Table 4.21 and Figure 4.18).

Table 4.21 Total carbon storage in each plot in Vachirabenjatas park

Plot	carbon storage (t ha ⁻¹)				
	AGB	Litter fall	Soil	Total	Total (+GL)
VT01	66.94	0.90	6.27	74.11	74.11
VT02	44.22	0.34	11.71	56.27	56.27
VT03	15.93	0.32	16.18	32.43	32.65
VT04	38.80	0.92	13.90	53.62	53.62
VT05	22.01	0.50	15.73	38.24	38.46
VT06	99.43	0.77	15.54	115.74	115.74
VT07	89.39	0.55	17.30	107.24	107.24
VT08	44.38	3.00	25.50	72.88	72.88
VT09	114.93	0.26	26.48	141.67	141.67
VT10	26.36	0.37	23.13	49.86	50.08
VT11	75.79	0.57	15.02	91.38	91.60
VT12	70.53	2.12	23.31	95.96	96.18
VT13	35.91	1.94	29.69	67.54	67.54
VT14	53.21	1.00	36.09	90.30	90.52
VT15	79.39	0.58	18.61	98.58	98.58
Average	58.48±29.61	0.94±0.79	19.44±10.39	78.86±30.54	79.14±30.50

Note: above-ground biomass (AGB), grass litter (GL)

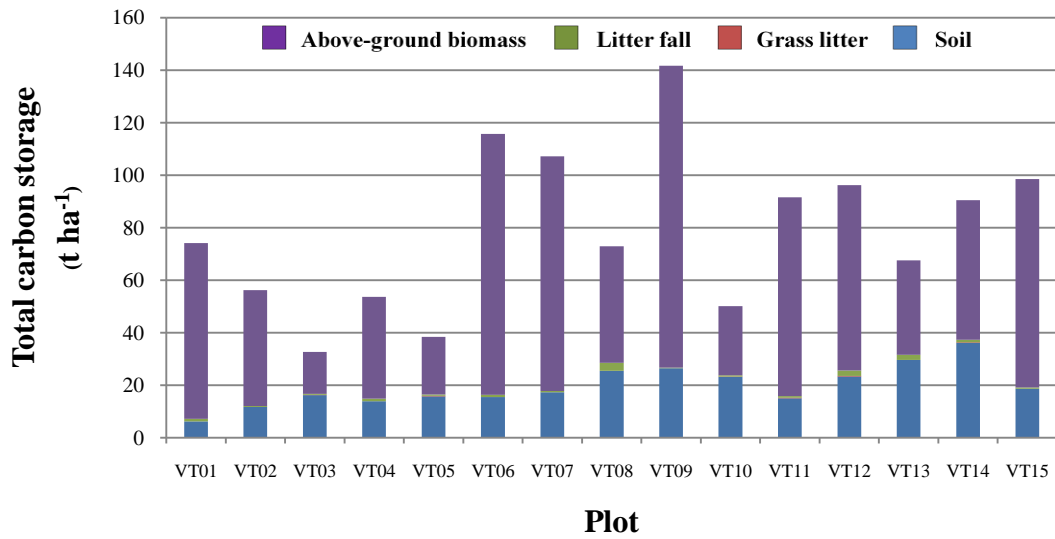


Figure 4.18 Total carbon storage in each plot in Vachirabenjatas park

The average total carbon storage in tree-planting area in Vachirabenjatas park was 79.14 t ha⁻¹, which was separated into carbon storage in above-ground biomass, litter fall, grass litter and soil were 58.48, 0.94, 0.22 and 19.44 t ha⁻¹, respectively. The average total carbon storage in turf was 19.44 t ha⁻¹, which was separated into carbon storage in grass litter and soil were 0.32 and 19.12 t ha⁻¹, respectively (Table 4.22).

Table 4.22 Total carbon storage in Vachirabenjatas park

Land cover	Carbon storage (t ha ⁻¹)				Total
	AGB	LF	GL	Soil	
Tree-planting area	58.48	0.94	0.22	19.44	79.14
Turf	-	-	0.32	19.12	19.44

Note: above-ground biomass (AGB), litter fall (LF), grass litter (GL)

The results of this study showed that the average total carbon storage in tree-planting area in the public park was 72.62 t ha⁻¹, which was separated into carbon storage in above-ground biomass, litter fall, grass litter and soil were 48.48, 1.49, 0.20 and 23.53 t ha⁻¹, respectively. The average total carbon storage in turf was 20.18 t ha⁻¹, which was separated into carbon storage in grass litter and soil were 0.35 and 19.70 t ha⁻¹, respectively (Table 4.23).

Table 4.23 Carbon storage in the public parks

Park	Carbon Storage (t ha ⁻¹)							
	Tree-planting area					Turf		
	AGB	LF	GL	Soil	Total	GL	Soil	Total
LN	34.85±24.57	2.24±1.44	0.17±0.00	26.90±9.38	63.99	0.31±0.14	20.67±7.16	20.98
VT	58.48±29.61	0.94±0.79	0.22±0.02	19.44±10.39	78.86	0.37±0.17	19.12±7.62	19.49
Average	48.48±29.56	1.49±1.27	0.20±0.04	23.53±7.97	73.50	0.35±0.16	19.70±7.43	20.05

Note: Lumpini park (LN), Vachirabenjatas park (VT), above-ground biomass (AGB), litter fall (LF), grass litter (GL)

The study shows that vegetation and soil play the important roles as a major carbon sink in tree-planting area. The carbon sequestration in above-ground biomass more than soil to two times. While soil is the important carbon sink in turf. Compared the total carbon sequestration between tree-planting area in urban park and the plantation in Thailand, it was found that tree-planting area is capable in carbon sequestration (72.63 t ha^{-1}) over the rubber plantation in Thepa district, Songkhla province, at the ages of 2 and 5 years old but less than 12, 16 and 26 years old were 45.43, 89.88, 107.71, 135.27 and 201.56 t ha^{-1} , respectively [69]. It is less than teak plantation, in Thai plywood in Lan Sak District, Uthai Thani province, at the ages of 10, 14, 18, 27 and 28 years old were 169.37, 83.72, 99.11, 170.13 and 149.66 t ha^{-1} , respectively [70]. Our result is also higher than the carbon sequestration of the 1-4 years old eucalyptus plantation in Manchakhiri plantation, Khon Kaen were 48.48, 54.55, 64.70 and 60.41 t ha^{-1} , respectively [71].

To compare to carbon sequestration in above-ground biomass, above-ground carbon storage (48.48 t ha^{-1}) was found to be more than that of 1, 2, 3, 4 and 5 years old *Eucalyptus urophylla* plantation in Sakaerat Environmental Research Station, Nakhon Ratchasima were 5.70, 12.56, 24.78, 37.18 and 43.55 t ha^{-1} , respectively [72]. It is in the same range as the teak plantations of 36.62 to 72.69 t ha^{-1} (5.86 to 11.63 t Rai^{-1}) in Kraeng Kra Wia plantation, Thong Pha Phum district, Kanchanaburi province [73]. The result is higher than the 22 years old teaks and 23 years old *Eucalyptus camaldulensis* plantations but less than 23 years old rubber, PuParn Royal Development Study Centre, Sakon Nakhon province were 9.00, 39.34 and 55.62 t ha^{-1} , respectively [74]. The carbon sequestration in Santiphap park in Bangkok, Thailand (22.13 t ha^{-1}) [75], homegarden in Kerala, India ($16\text{-}36 \text{ t ha}^{-1}$) [76] and 13 years old homegarden in Lampung, Indonesia (35.50 t ha^{-1}) [77] were found less than our result.

The litter fall (1.49 t ha^{-1}) give less sequestered carbon than 2, 5, 12, 16 and 26 years old rubber plantation in Thepha District of Songkhla province were 1.52, 4.84, 6.38, 5.90 and 5.63 t ha^{-1} , respectively [69]. Nevertheless, our carbon sequestration is more than the 14-34 years old *Pinus kesiya* plantation in Boakaew highland watershed, Chiangmai province ($1.67\text{-}3.15 \text{ t ha}^{-1}$) [78] and the 10, 14, 18, 27 and 28 years old teak plantation in Lan Sak District, Uthai Thani were 0.65, 0.72, 0.54, 0.72 and 0.76 t ha^{-1} , respectively [70].

The soil organic carbon storage (23.53 t ha^{-1}) was found less than the 5 and 26 years old rubber plantation in Thepa district, Songkhla province were 58.77 and 55.81 t ha^{-1} at the depth 0-50 cm, respectively [69] and the 10, 14, 18, 27 and 28 years old teak plantation, in Thai plywood in Lan Sak District, Uthai Thani province were 157.03 , 61.72 , 78.78 , 105.67 and 66.83 t ha^{-1} at the dept 0-100 cm, respectively [70]. Compared with urban park and homegarden in other country was found higher than that of Bonobitan central park in Kolkata (7.99 t ha^{-1}) and the botanical garden in Howrah province in West Bengal, state of India (14.57 t ha^{-1}) at the depth of 0-100 cm [79]. It is however less than the value from the homegarden in Kerala, India (101.50 to 127.40 t ha^{-1}) at the depth of 0-100 cm [32].

To Compare the carbon sequestration in turf with other studies, it was found that carbon storage in the grass litter (0.30 t ha^{-1}) is less than carbon storage in above-ground biomass of grass in the urban lawn in Hong Kong (0.50 - 2.10 t ha^{-1}) and soil organic carbon storage (19.70 t ha^{-1}) which is in the same range of 12.60 to 48.90 t ha^{-1} from the depth of 0-15 cm [68]. It is less than carbon storage in above-ground biomass of grass in the urban lawn in Singapore (0.68 t ha^{-1}) and soil organic carbon storage (22 t ha^{-1}) at the depth of 0-10 cm [80]. Comparing to the natural grassland, the carbon in above-ground biomass of grass is less than tropical alpine tussock grassland in the south-eastern Peruvian Andes ($3.35 \pm 0.10 \text{ t ha}^{-1}$) [81]. The carbon sequestration in the soil of the humid grasslands in Brazil at a depth of 0-60 cm ($244.17 \text{ mg ha}^{-1}$) is less than soil organic carbon sequestration in our result [82].

4.2 Factors effecting on carbon sequestration of the parks

4.2.1 Lumpini park

4.2.1.1 Factors of vegetation effecting on total carbon storage in tree-planting area

The relationship between vegetation and total carbon storage in tree-planting area was analyzed. The calculated multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) were 0.990 and 0.980, respectively (Table 4.24).

Table 4.24 The multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) showed the relationship between vegetation and total carbon storage in tree-planting area

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistic			
					R Square	F Change	df1	df2
1	0.990 ^a	0.981	0.980	3.11384	0.981	1212.281	3	71

a. Predictors: (Constant), Number of species, Tree density, Total basal area

b. Dependent Variable: Total carbon storage

The standardized regression coefficient (Beta) showed the relationship between each factor of vegetation and total carbon storage in tree-planting area. From the analysis was found that total basal area was the most related to total carbon storage, followed by tree density and number of species were 0.918, 0.326 and 0.197, respectively (Table 4.25).

Table 4.25 The standardized regression coefficient (Beta) showed the relationship between each factor of vegetation and total carbon storage in tree-planting area

Model	Unstandardized		Standardized	t	Sig.
	Coefficients		Coefficients		
	B	Std. Error	Beta		
1 (Constant)	45.249	1.607		28.149	0.000
Number of species	-1.278	0.136	-0.197	-9.410	0.000
Tree density	-0.092	0.005	-0.326	-17.738	0.000
Total basal area	2.865	0.060	0.918	47.817	0.000

4.2.1.2 Factors of soil properties effecting on total carbon storage in tree-planting area

The relationship between soil properties and total carbon storage in tree-planting area was analyzed. The calculated multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) were 0.480 and 0.166, respectively (Table 4.26).

Table 4.26 The multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) showed the relationship between soil properties and total carbon storage in tree-planting area

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistic			
					R Square	F Change	df1	df2
1	0.483 ^a	0.233	0.166	20.13216	0.233	3.450	6	68

a. Predictors: (Constant), Texture, BD, pH, %OM, %TN, C:N ratios
 b. Dependent Variable: Total carbon storage

The standardized regression coefficient (Beta) showed the relationship between each factor of soil properties and total carbon storage in tree-planting area. From the analysis was found that total nitrogen was the most related to total carbon storage, followed by organic matter, soil buk density and soil reaction was the least related to were 0.885, 0.605, 0.446 and 0.081, respectively (Table 4.27).

Table 4.27 The standardized regression coefficient (Beta) showed the relationship between each factor of soil properties and total carbon storage in tree-planting area

Model	Unstandardized		Standardized	t	Sig.
	Coefficients		Coefficients		
	B	Std. Error	Beta		
1 (Constant)	-95.618	57.759		-1.655	0.102
Texture	1.300	1.178	0.127	1.104	0.274
BD	73.270	19.021	0.446	3.852	0.000
pH	-1.316	2.229	-0.081	-0.590	0.557
%OM	-11.986	14.549	-0.605	-0.824	0.413
%TN	342.786	293.748	0.885	1.167	0.247
C:N ratios	4.546	3.702	0.330	1.228	0.224

4.2.1.3 Factors of soil properties effecting on total carbon storage in turf

The relationship between soil properties and total carbon storage in turf was analyzed. The calculated multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) were 0.773 and 0.455, respectively (Table 4.28).

Table 4.28 The multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) showed the relationship between soil properties and total carbon storage in turf

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistic			
					R Square	F Change	df1	df2
1	0.773 ^a	0.597	0.455	0.05277	0.597	4.205	6	17

a. Predictors: (Constant), Texture, BD, pH, %OM, %N, C:N ratios

b. Dependent Variable: Total carbon storage

The standardized regression coefficient (Beta) showed the relationship between each factor of soil properties and total carbon storage in turf was found that C:N ratios was the most related to total carbon storage, followed by soil bulk density, soil reaction and texture was the least related to were 0.944, 0.490, 0.378 and 0.189, respectively (Table 4.29).

Table 4.29 The standardized regression coefficient (Beta) showed the relationship between each factor of soil properties and total carbon storage in turf

Model	Unstandardized		Standardized	t	Sig.
	Coefficients		Coefficients		
	B	Std. Error	Beta		
1 (Constant)	21.396	0.197		108.506	0.000
Texture	-0.006	0.007	-0.189	-0.845	0.410
BD	-0.201	0.107	-0.490	-1.884	0.077
pH	0.024	0.012	0.378	1.964	0.066
%OM	0.129	0.080	2.234	1.624	0.123
%N	-2.688	1.596	-2.630	-1.684	0.110
C:N ratios	-0.026	0.012	-0.944	-2.277	0.036

4.2.2 Vachirabenjatas park

4.2.2.1 Factors of vegetation effecting on total carbon storage in tree-planting area

The relationship between vegetation and total carbon storage in tree-planting area was analyzed. The calculated multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) were 0.877 and 0.757, respectively (Table 4.30).

Table 4.30 The multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) showed the relationship between vegetation and total carbon storage in tree-planting area

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistic			
					R Square	F Change	df1	df2
1	0.877 ^a	0.770	0.757	15.29839	0.770	58.007	3	52

a. Predictors: (Constant), Number of species, Tree density, Total basal area

b. Dependent Variable: Total carbon storage

The standardized regression coefficient (Beta) showed the relationship between each factor of vegetation and total carbon storage in tree-planting area was found that total basal area was the most related to total carbon storage, followed by tree density and number of species were 0.911, 0.164 and 0.007, respectively (Table 4.31).

Table 4.31 The standardized regression coefficient (Beta) showed the relationship between each factor of vegetation and total carbon storage in tree-planting area

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
	1 (Constant)	25.604	9.046		
Number of species	0.529	5.542	0.007	0.095	0.924
Tree density	-0.050	0.022	-0.164	-2.273	0.027
Total basal area	3.591	0.278	0.911	12.908	0.000

4.2.2.2 Factors of soil properties effecting on total carbon storage in tree-planting area

The relationship between soil properties and total carbon storage in tree-planting area was analyzed. The calculated multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) were 0.407 and 0.064, respectively (Table 4.32).

Table 4.32 The multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) showed the relationship between soil properties and total carbon storage in tree-planting area

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistic			
					R Square	F Change	df1	df2
1	0.407 ^a	0.166	0.064	30.01111	0.166	1.622	6	49

a. Predictors: (Constant), Texture, BD, pH, %OM, %TN, C:N ratios

b. Dependent Variable: Total carbon storage

The standardized regression coefficient (Beta) showed the relationship between each factor of soil properties and total carbon storage in tree-planting area was found that total nitrogen was the most related to total carbon storage, followed by organic matter, soil bulk density and soil reaction was the least related to were 0.885, 0.605, 0.446 and 0.081, respectively (Table 4.33).

Table 4.33 The standardized regression coefficient (Beta) showed the relationship between each factor of soil properties and total carbon storage in tree-planting area

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	-145.129	87.072		-1.667	0.102
Texture	2.617	2.234	0.195	1.171	0.247
BD	71.818	34.067	0.290	2.108	0.040
pH	10.063	7.432	0.257	1.354	0.182
%OM	-10.567	18.659	-0.402	-0.566	0.574
%TN	439.404	407.764	0.792	1.078	0.286
C:N ratios	2.533	3.460	0.197	0.732	0.468

4.2.2.3 Factors of soil properties effecting on total carbon storage in turf

The relationship between soil properties and total carbon storage in turf was analyzed. The calculated multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) were 0.451 and 0.059, respectively (Table 4.34).

Table 4.34 The multiple correlation coefficient (R) and the multiple adjusted correlation of determination (R_a^2) showed the relationship between soil properties and total carbon storage in turf

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistic			
					R Square	F Change	df1	df2
1	0.451 ^a	0.204	0.059	2.46472	0.204	1.407	6	33

a. Predictors: (Constant), Texture, BD, pH, %OM, %TN, C:N ratios

b. Dependent Variable: Total carbon storage

The standardized regression coefficient (Beta) showed the relationship between each factor of soil properties and total carbon storage in turf was found that total nitrogen was the most related to total carbon storage, followed by organic matter, soil reaction and texture was the least related to were 0.788, 0.633, 0.322 and 0.016, respectively (Table 4.35).

Table 4.35 The standardized regression coefficient (Beta) showed the relationship between each factor of soil properties and total carbon storage in turf

Model	Unstandardized		Standardized	t	Sig.
	Coefficients		Coefficients		
	B	Std. Error	Beta		
1 (Constant)	26.547	8.571		3.097	0.004
Texture	0.027	0.307	0.016	0.089	0.930
BD	-0.884	2.710	-0.056	-0.326	0.746
pH	-1.170	0.766	-0.322	-1.527	0.136
%OM	-1.442	3.150	-0.633	-0.458	0.650
%N	41.908	73.035	0.788	0.574	0.570
C:N ratios	0.103	0.417	0.095	0.248	0.806

Considering the coefficient of determination (R_a^2) showing the relationship between vegetation, soil properties and total carbon storage in tree-planting area, it was revealed that vegetation serve as a more dominant factor in the carbon sequestration than the soil properties. We found this in both parks with the coefficient of determination of 0.980 and 0.757, respectively. The total basal area was found the most effective factor on the carbon sequestration in the park. The larger total basal area in the plot, the more amount carbon was sequestered. The total basal area is also involved with the number and size of trees.

From the study in comparing the plot LN09 (*Peltophorum pterocarpum* and *Samanea saman*) to the plot LN03 (mixed 8 species) whose tree densities are similar (60 and 61 trees ha⁻¹, respectively) in Lumpini Park, it was shown the plot of *Peltophorum pterocarpum* and *Samanea saman* has a larger total basal area than the mixed plot (27.15 and 2.95 m² ha⁻¹, respectively). Because the average diameter at breast height (DBH) of *Peltophorum pterocarpum* and *Samanea saman* is higher than the mixed plot (71.76 and 26.26 cm respectively), the plot of *Peltophorum pterocarpum* and *Samanea saman* has more above-ground carbon and total carbon storage.

Similarly, *Acacia auriculiformis* plot ($33.84 \text{ m}^2 \text{ ha}^{-1}$) in Vachirabenjatas park has larger total basal area than *Pterocarpus indicus* plot ($6.79 \text{ m}^2 \text{ ha}^{-1}$) when comparing the plot VT09 (*Acacia auriculiformis*) whose tree density was 130 trees ha^{-1} to the plot VT03 (*Pterocarpus indicus*) whose density was 132 trees ha^{-1} . It was due to the greater average DBH of *Acacia auriculiformis* (53.11 cm) than *Pterocarpus indicus* (24.98 cm). As the result, *Acacia auriculiformis* plot has more above-ground carbon and total carbon storage.

This is consistent with the study of Salunkhe and colleagues on the above-ground biomass and carbon storage in tropical deciduous forests, in the State of Madhya Pradesh, India. It was found that the above-ground biomass is positively correlated with the total basal area. In the plot of mature trees, the diameter of the tree trunks is larger and giving more above-ground biomass than the plot with higher tree density. The total basal area and above-ground biomass are highly correlated with tree architecture [40]. It is in accordance with Borah and his team's work in which the above-ground biomass and carbon storage of plant species were studied in tropical forest in Cachar district of Assam, Northeast India. The above-ground biomass is related to the total basal area with statistically significance [83]. Slik and colleagues also found that the above-ground biomass associated significantly and positively with basal area [84].

Considering the coefficient of determination (R_a^2) showing the relationship between the soil properties and total carbon storage in turf, it can be seen that the soil properties affect low to moderately on carbon sequestration in Lumpini park but not in Vachirabenjatas park. The coefficients of determination were 0.455 and 0.059, respectively.

4.3 Management approach to enhance in the carbon sequestration in the parks

From the result, proposed management approaches to enhance in the carbon sequestration in the urban park are listed below.

4.3.1 Increasing of tree-planting area

Total carbon storage in tree-planting area is higher than the turf's capacity, the focus on carbon sequestration is more likely in biomass or in the trees with the increase in more trees-planting area within the park. The estimated area proportion of tree-planting area and turf in Lumpini park and Vachirabenjatas park are 75 and 25 percent, and 60 and 40 percent, respectively. It can be seen that the turf in Vachirabenjatas park is quite large because it used to be a golf course before. Therefore, there are possible area to plant more trees.

4.3.2 Selection of plants species

The study shows that the plot of *Peltophorum pterocarpum* (common names: Copper pod, Yellow flame, Yellow Flameboyant, Yellow Poinciana, Golden Flamboyant, Radhachura), *Samaneas aman* (common name: Rain tree, East indian walnut) and *Acacia auriculiformis* (Common names: Auri, Black wattle, Wattle, Tan wattle, Papuan wattle, Northern black wattle, Earpod wattle, Earleaf acasia) are found more carbon storage because they are medium to large size trees in their mature state, long-lived with high growth rate. Moreover they are also high wood density and high pollution resistance. Therefore, these species can help increase carbon sequestration in the urban park well. Since the parks were created for leisure, *Peltophorum pterocarpum* and *Samanea saman* are suitable species for shading in urban park. In addition, *Acacia auriculiformis* gives colorful fragrant flowers creating a beautiful relaxing scented environment in the park.