CHAPTER FOUR

RESULTS

Table 1: Soil carbon stock in different soil fractions at 0 – 10 cm in the Guinea savanna agro-ecological zone of Ghana

Forest reserve	Carbon stock (Mg C/ha) in the different soil fractions			♠Mean
	Small Macroaggregates (250 -2000 µm)	Microaggregates (53 – 250 µm)	Silt + Clay (< 53 µm)	
Kenikeni	5.01	4.80	12.41	7.41
Sinsablegbinni	7.35	8.30	12.11	9.26
Klupene	5.68	4.82	12.61	7.70
♣Mean	6.02	5.98	12.38	
Lsd (5%)	‡1.76 †3.04			
Fpr	‡‡<0.001 ††0.009			
CV (%)	32.20			

♠Mean value for reserve; ♣Mean value of soil fraction, †Lsd for forest reserves; ‡Lsd for different soil fractions; ‡‡Fpr for different soil fractions; ††Fpr for forest reserves

Table 2: Soil carbon stock in different soil fractions with distance from dominant tree in different forest reserves of Guinea savanna zone of Ghana

Forest reserve	Distance from dominant tree	SCS (Mg C/ha) in different soil fractions		
		SM	M	S + C
Kenikeni	Sub-canopy	5.43	4.63	12.48
	Drip line	4.33	2.99	11.37
	§(SC +DL) x 2	5.27	6.78	13.38
Sinsablegbinni	Sub-canopy	6.45	6.22	12.30
	Drip line	8.07	10.37	12.55
	§(SC +DL) x 2	7.55	8.33	11.47
Klupene	Sub-canopy	7.09	5.74	13.32
	Drip line	5.67	4.40	15.89
	§(SC +DL) x 2	4.28	4.31	8.62
Lsd (5%)	5.27			
Fpr	0.85			
CV (%)	32.2			

§(SC +DL) x 2 = Twice the distance from base of tree to the drip line; SM = Small Macroaggregates; M = Microaggregates, S+ C = Silt + Clay

Table 3: Spatial distribution of carbon stock from dominant tree under three forest reserves in the Guinea savanna zone of Ghana

Forest reserve	Distribution of carbon stock (Mg C/ha) with distance from dominant tree species			♠Mean
	Sub-canopy	Drip line	§(SC + DL) x 2	
Kenikeni	7.51	6.23	8.47	7.40
Sinsablegbinni	8.32	10.33	9.11	9.26
Klupene	8.72	8.65	5.74	7.70
♣Mean	8.18	8.40	7.77	
Lsd (5%)	†1.76 ‡1.76			
Fpr	‡‡0.773			
CV (%)	32.20			

♠Mean value for reserve; ♣Mean value for distance from dominant tree, †Lsd for forest reserves; ‡Lsd for sampling spot from the dominant tree; §(SC + DL) x 2 = Twice the distance from base of tree to the drip line; ‡‡Fpr for sampling spot from the dominant tree

Table 4: Soil chemical characteristics of different reserves in the Guinea savanna agro-eological zone of Ghana

Forest Reserve	Depth (cm)	Soil chemical properties		
		SOC (%)	N (%)	P (mg/kg)
	0-10	0.71	0.07	7.92
Kenikeni	10-20	0.74	0.07	5.61
		(0.72)	(0.07)	(6.77)
Sinsablegbinni	0-10	0.80	0.08	5.66
	10-20	0.80	0.08	24.97
		(0.80)	(0.08)	(15.31)
Klupene	0-10	0.72	0.05	7.34
	10-20	0.63	0.05	2.44
		(0.67)	(0.05)	(4.89)
Yakombo	0-10	0.59	0.06	1.96
	10-20	0.80	0.08	3.36
		(0.71)	(0.07)	(2.66)
Gambaga	0-10	0.74	0.06	8.16
	10-20	0.80	0.07	8.64
		(0.77)	(0.07)	(8.40)
Mean (depth)	0-10	0.71	0.07	6.21
	10-20	0.75	0.07	9.01
Lsd (5%)		†0.20	†0.02	†2.03
		‡0.14	‡0.01	‡1.29
		*0.32	*0.03	*2.88
Fpr		††0.791	††0.007	††<0.001
		‡‡0.525	‡‡0.386	‡‡<0.001
		**0.665	**0.871	**<0.001
CV (%)		33.50	33.80	29.50

() = Mean values for forest reserves; †Lsd for forest reserves; ‡Lsd for sampling depth; *Lsd for forest reserves/sampling depth interaction; ††Fpr for forest reserves; ‡‡Fpr for sampling depth; **Fpr for forest reserves/sampling depth interaction

Table 5: Mineral N variations under different forest reserves in the Guinea savanna agro-ecological zone of Ghana

Forest reserve	Soil depth (cm)	NO_3^-	NH_4^+ (mg/kg)	NH_4^+: NO_3
Kenikeni	0-10	15.87	11.59	0.73
	10-20	11.11	0.50	0.05
		(13.49)	(6.04)	(0.39)
Sinsablegbinni	0-10	11.49	3.80	0.33
	10-20	12.59	0.43	0.03
		(12.04)	(2.12)	(0.18)
Klupene	0-10	23.89	6.33	0.27
	10-20	13.46	2.04	0.15
		(18.68)	(4.18)	(0.21)
$^{\Psi}$Mean	0-10	17.08	7.24	0.44
	10-20	12.39	0.99	0.08
		†1.85	†0.89	†0.07
Lsd (5%)		‡1.51	‡0.73	‡0.06
		*2.62	*1.26	*0.10
Fpr		††<0.001	††<0.001	††<0.001
		‡‡<0.001	‡‡<0.001	‡‡<0.001
		**<0.001	**<0.001	**<0.001
CV (%)		47.30	47.40	2.00

() = Mean values for forest reserves; †Lsd for forest reserves; ‡Lsd for sampling depth; *Lsd for forest reserves/sampling depth interaction; ††Fpr for forest reserves; ‡‡Fpr for sampling depth; **Lsd for forest reserves/sampling depth interaction

Table 6: Summary of results on exchangeable bases under different reserves in the Guinea savanna agro-ecological zone of Ghana

Forest Reserve	Depth (cm)	Exchangeable bases (cmol$_{(+)}$ /kg soil)			
		K	**Mg**	**Na**	**Ca**
Kenikeni	0-10	0.17	1.82	0.06	2.86
	10-20	0.20	1.88	0.07	3.13
		(0.18)	(1.85)	(0.07)	(2.99)
Sinsablegbinni	0-10	0.16	1.91	0.06	3.41
	10-20	0.15	2.43	0.06	3.54
		(0.16)	(2.17)	(0.06)	(3.47)
Klupene	0-10	0.12	1.39	0.04	3.31
	10-20	0.12	1.79	0.04	3.71
		(0.12)	(1.59)	(0.04)	(3.51)
Yakombo	0-10	0.07	1.87	0.03	3.74
	10-20	0.08	2.89	0.04	5.23
		(0.07)	(2.38)	(0.04)	(4.49)
Gambaga	0-10	0.28	2.30	0.08	4.49
	10-20	0.24	1.82	0.07	3.52
		(0.24)	(2.06)	(0.07)	(4.01)
Mean (depth)	0-10	0.16	1.86	0.05	3.56
	10-20	0.16	2.16	0.06	3.83
Lsd (5%)		†0.04	†1.01	†0.01	†1.61
		‡0.03	‡0.64	‡0.009	‡1.02
		*0.06	*1.43	*0.02	*2.28
Fpr		††<0.001	††0.569	††<0.001	††0.407
		‡‡0.874	‡‡0.340	‡‡0.574	‡‡0.600
		**0.448	**0.648	**0.830	**0.660
CV (%)		28.30	55.40	26.70	48.10

() = Mean values for forest reserves; †Lsd for forest reserves; ‡Lsd for sampling depth; *Lsd for forest reserves/sampling depth interaction; ††Fpr for forest reserves; ‡‡Fpr for sampling depth; **Lsd for forest reserves/sampling depth interaction

Table 7: Summary of some soil chemical properties under different forest reserves in the Guinea savanna agro-ecological zone of Ghana

Forest reserve	Soil depth (cm)	EA ($cmol_{(c)}/kg$)	ECEC ($cmol_{(c)}/kg$)	BS (%)	TEB	Ph
Kenikeni	0-10	0.12	6.49	97.91	6.37	6.40
	10-20	0.12	6.48	97.52	6.36	6.30
		(0.12)	(6.48)	(97.58)	(6.36)	(6.40)
Sinsablegbinni	0-10	0.14	5.67	97.32	5.53	6.10
	10-20	0.13	6.33	97.15	6.19	6.10
		(0.14)	(6.00)	(97.24)	(5.86)	(6.10)
Klupene	0-10	0.13	5.65	97.52	5.52	6.30
	10-20	0.14	5.80	97.55	5.66	6.20
		(0.14)	(5.73)	(97.53)	(5.59)	(6.20)
Yakomba	0-10	0.23	5.94	95.26	5.71	5.90
	10-20	0.14	8.37	97.04	8.24	6.10
		(0.18)	(7.16)	(96.15)	(6.97)	(6.00)
Gambaga	0-10	0.14	7.28	97.94	7.14	6.00
	10-20	0.14	5.79	97.46	5.65	5.90
		(0.14)	(6.54)	(97.70)	(6.39)	(6.00)
$^{\Psi}$Mean	0-10	0.15	6.21	97.19	6.05	6.10
	10-20	0.13	6.55	97.34	6.42	6.10
Lsd (5%)		†0.06	†2.05	†1.81	†2.77	†0.35
		‡0.04	‡1.74	‡1.14	‡1.75	‡0.22
		*0.09	*3.88	*2.56	*3.91	*0.50
Fpr		††0.287	††0.856	††0.382	††0.872	††0.097
		‡‡0.365	‡‡0.688	‡‡0.788	‡‡0.675	‡‡0.730
		**0.444	**0.703	**0.704	**0.690	**0.757
CV (%)		47.30	47.40	2.00	48.90	6.30

() = Mean values for forest reserves; †Lsd for forest reserves; ‡Lsd for sampling depth; *Lsd for forest reserves/sampling depth interaction; ††Fpr for forest reserves; ‡‡Fpr for sampling depth; **Fpr for forest reserves/sampling depth interaction; $^{\Psi}$Mean = Mean across the soil depth; EA = Exchangeable acidity; BS = Base saturation; TEB = Total exchangeable bases; ECEC = Effective cation exchange capacity

Table 8: Microbial biomass in the different forest reserves at different soil depths

Forest reserve	Soil depth (cm)	Microbial biomass (mg/kg)			Microbial quotient (%)		
		C_{mic}	N_{mic}	P_{mic}	qC_{mic}	qN_{mic}	qP_{mic}
Kenikeni	0-10	100.80	11.99	3.12	1.84	0.22	0.06
	10-20	44.30	2.40	0.71	0.71	0.04	0.02
		(72.50)	(7.20)	(2.07)	(1.27)	(0.13)	(0.04)
Sinsablegbinni	0-10	49.30	2.30	3.54	0.61	0.03	0.05
	10-20	52.80	6.90	3.21	0.72	0.10	0.04
		(51.00)	(4.60)	(3.38)	(0.67)	(0.06)	(0.04)
Klupene	0-10	130.10	19.06	4.58	2.41	0.36	0.08
	10-20	98.40	20.76	2.27	1.93	0.40	0.04
		(114.30)	(19.91)	(3.43)	(2.17)	(0.38)	(0.06)
Mean (Depth)	0-10	93.40	11.12	3.75	1.62	0.20	0.06
	10-20	65.20	10.02	2.17	1.12	0.18	0.03
		†6.16	†1.30	†0.90	†0.56	†0.09	†0.02
Lsd (5%)		‡5.03	‡1.06	‡0.74	‡0.46	‡0.08	‡0.02
		*8.72	*1.84	*1.28	*0.80	*0.13	*0.03
Fpr		††<0.001	††<0.001	††<0.007	††<0.001	††<0.001	††0.095
		‡‡<0.001	‡‡<0.044	‡‡<0.001	‡‡<0.036	‡‡0.534	‡‡0.004
		**<0.001	**<0.001	**0.065	**0.100	**0.026	**0.155
CV (%)		8.30	13.20	32.80	44.30	40.40	50.10

() = Mean values for forest reserves; †Lsd for forest reserves; ‡Lsd for sampling depth; *Lsd for forest reserves/sampling depth interaction; ††Fpr for forest reserves; ‡‡Fpr for sampling depth; **Fpr for forest reserves/sampling depth interaction; C_{mic} = Microbial biomass Carbon; N_{mic} = Microbial biomass Nitrogen; P_{mic} = Microbial biomass Phosphorus; SOC = Soil Organic Carbon; qC_{mic} = Microbial Carbon Quotient (C_{mic}/SOC x 100); qN_{mic} = Microbial Nitrogen Quotient (N_{mic}/N x 100); qP_{mic} = Microbial Phosphorus Quotient (P_{mic}/P x 100)

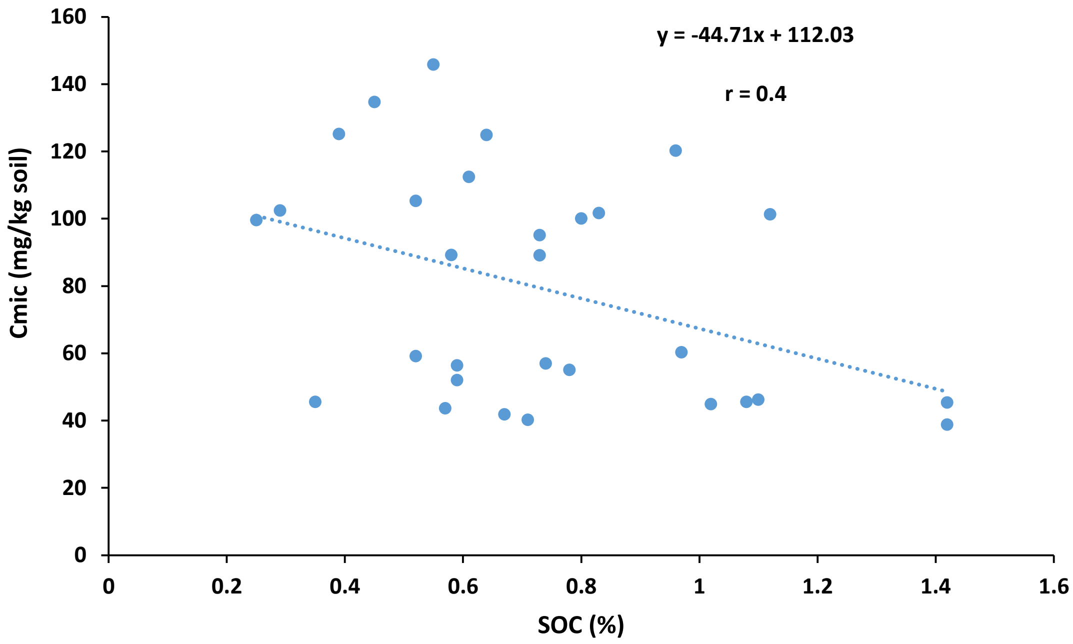


Fig 1: Relationship between soil microbial biomass C and SOC under the forest reserves

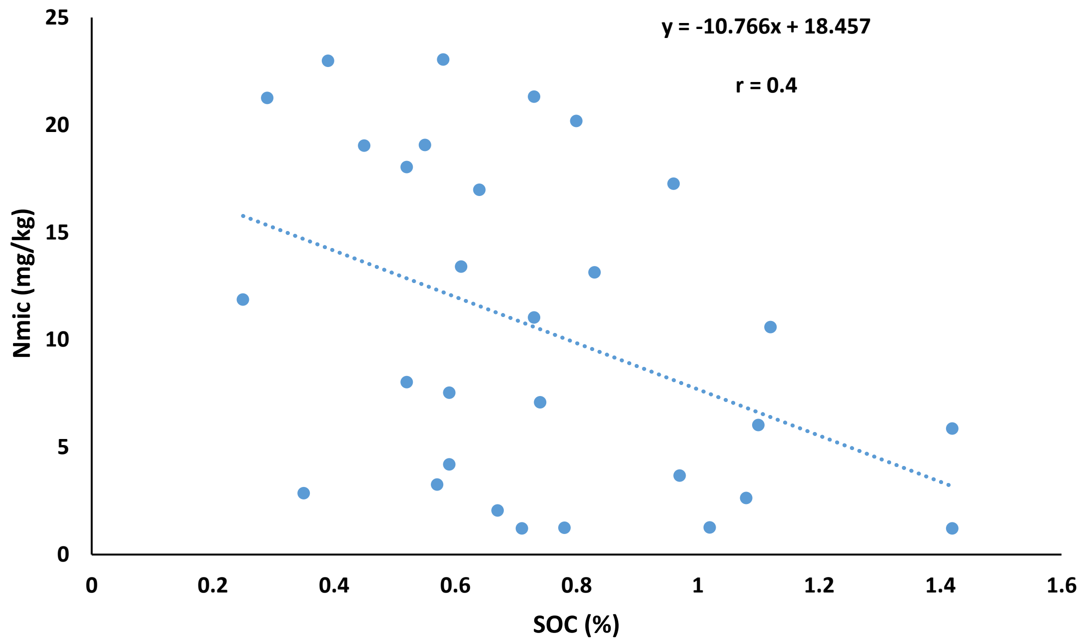


Fig. 2: Relationship between soil microbial biomass N and SOC under the forest reserves

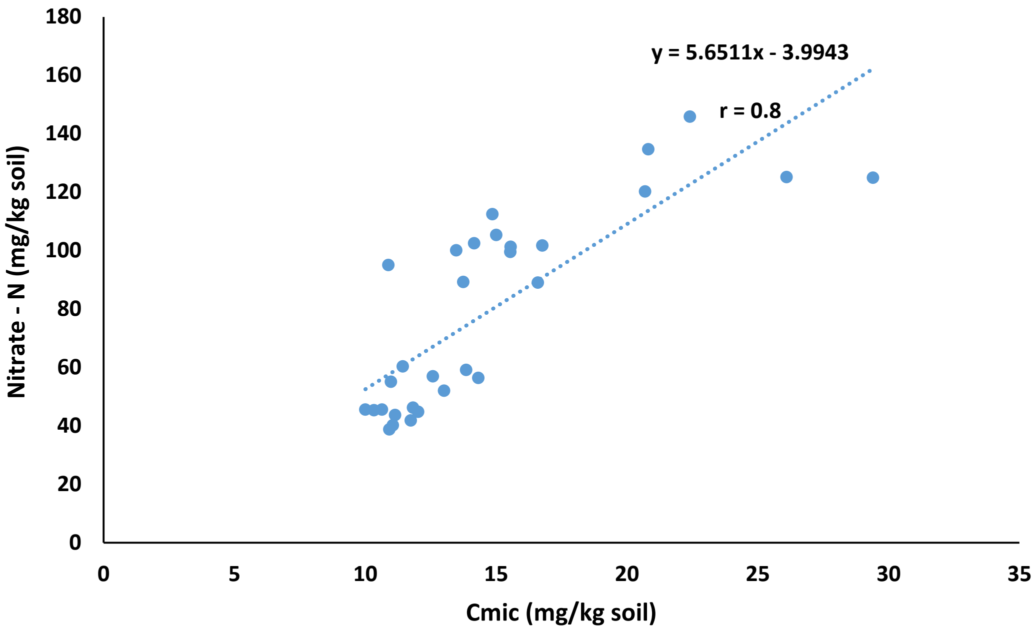


Fig. 3: Relationship between nitrate - N and microbial biomass C

Table 9: Microbial biomass carbon-to-nitrogen/phosphorus ratios

Forest reserve	Soil depth (cm)	Microbial biomass C:N/P ratios			
		C_{mic}/N_{mic}	$C_{mic}/NH_4^+\_N$	$C_{mic}/NO_3^-\_N$	C_{mic}/P_{mic}
Kenikeni	0-10	8.44	8.73	6.38	32.37
	10-20	20.63	90.50	4.01	45.40
		(14.54)	(49.62)	(5.19)	(38.89)
Sinsablegbinni	0-10	27.76	14.31	4.29	14.42
	10-20	7.66	168.65	4.20	17.32
		(17.71)	(91.48)	(4.25)	(15.87)
Klupene	0-10	6.90	20.79	5.56	30.17
	10-20	4.79	64.33	7.38	58.04
		(5.85)	(42.56)	(6.47)	(44.10)
Mean (Depth)	0-10	14.37	14.61	5.41	25.66
	10-20	11.03	107.83	5.20	40.25
Lsd (5%)		†6.06	†33.66	†0.73	†13.65
		‡4.95	‡27.49	‡0.59	‡11.15
		*8.57	*47.61	*1.03	*19.30
Fpr		††0.002	††0.014	††<0.001	††<0.001
		‡‡0.175	‡‡<.001	‡‡0.455	‡‡0.013
		**<0.001	**0.009	**<0.001	**0.184
CV (%)		51.20	58.90	14.70	44.40

() = Mean values for forest reserves; †Lsd for forest reserves; ‡Lsd for sampling depth; *Lsd for forest reserves/sampling depth interaction; ††Fpr for forest reserves; ‡‡Fpr for sampling depth; **Fpr for forest reserves/sampling depth interaction

Table 10: Relationship between microbial carbon quotient (qC_{mic}) and carbon stocks of the different soil fractions

Independent parameter (x)	Dependent parameter (y)	Regression eqn	r^2
C stock of small macroaggregates	qC_{mic}	y = -0.63x+5.42	0.68
C stock of microaggregates	qC_{mic}	y = -0.43x +4.21	0.90
C stock of silt + clay fractions	qC_{mic}	y= 3.64x -43.43	0.99

Eqn: Equation

Table 11: Relationship between microbial N quotient (qN_{mic}) and carbon stocks of the different soil fractions

Independent parameter (x)	Dependent parameter (y)	Regression eqn	r^2
C stock of small macroaggregates	qN_{mic}	y = -0.10x+0.83	0.57
C stock of microaggregates	qN_{mic}	y = -0.07x +0.64	0.82
C stock of silt + clay fractions	qN_{mic}	y= 0.66x -7.94	1.00

Eqn: Equation

Table 12:. Relationship between microbial P quotient (qP_{mic}) and carbon stocks of the different soil fractions

Independent parameter (x)	Dependent parameter (y)	Regression eqn	r^2
C stock of small macroaggregates	qP_{mic}	y = -0.07x+0.10	0.30
C stock of microaggregates	qP_{mic}	y = -0.01x +0.10	0.57
C stock of silt + clay fractions	qP_{mic}	y= 0.06x -0.65	0.91

Eqn: Equation

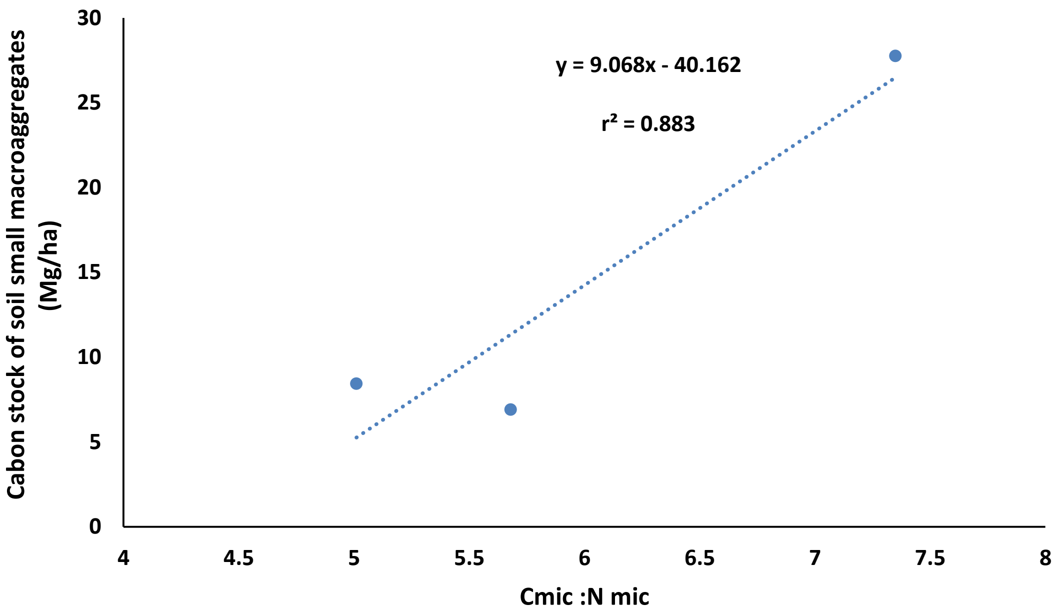


Fig. 4: Pooled relationship between carbon stock of the small macroaggregates and Cmic: ratio under the three forest reserves

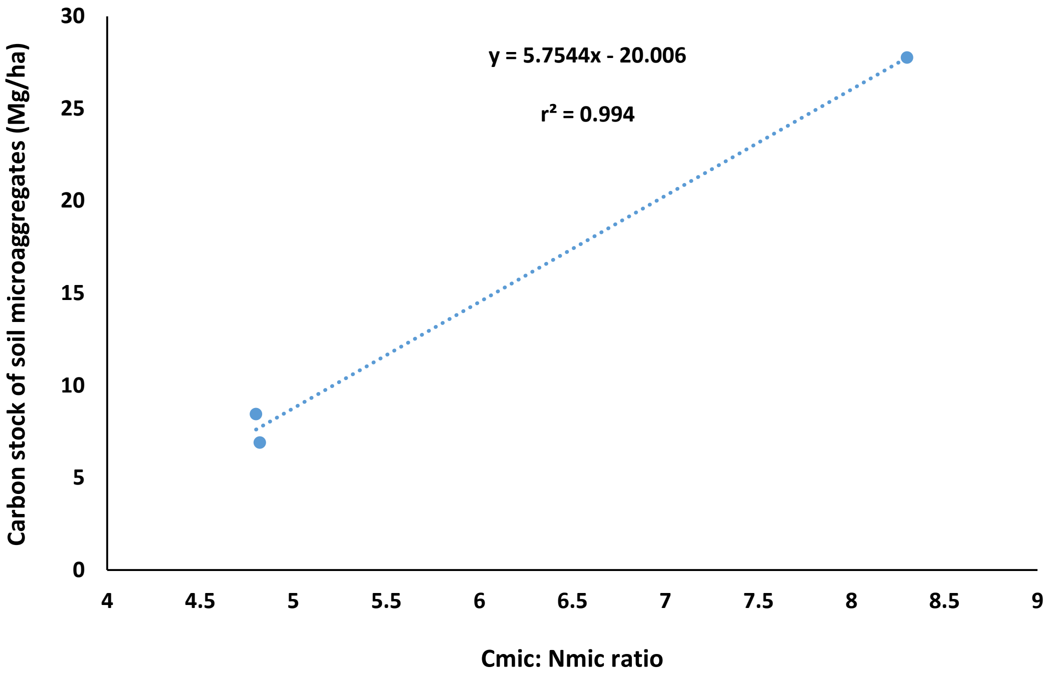


Fig. 5: Pooled relationship between carbon stock of the microaggregate fraction and Cmic: ratio under the three forest reserves

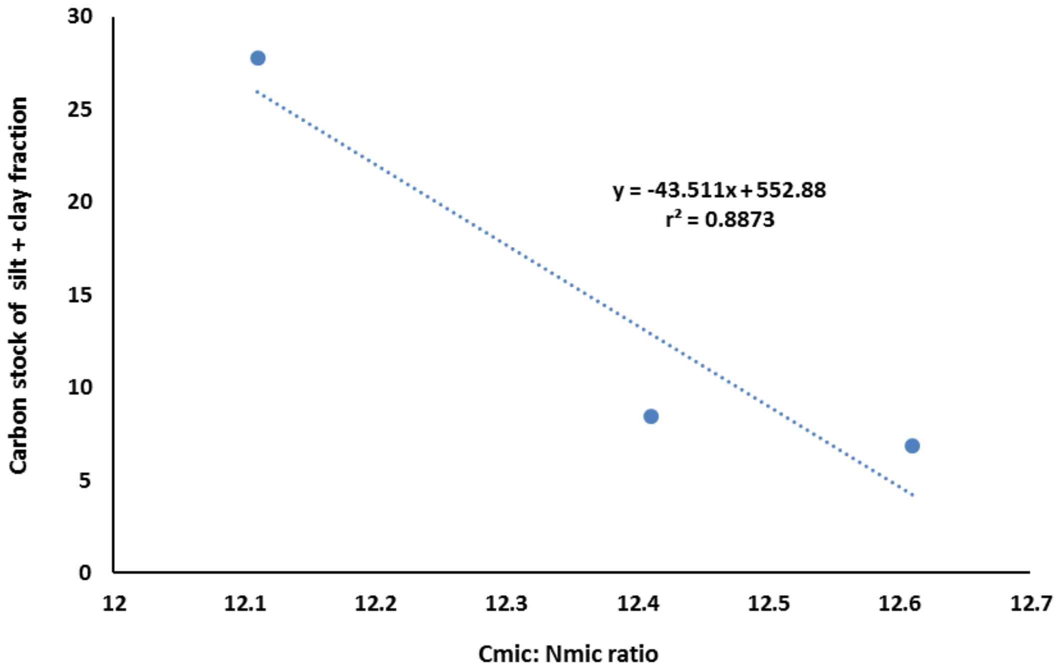


Fig. 6: Pooled relationship between carbon stock of the silt + clay fraction and Cmic: ratio under the three forest reserves

Table 14: Tree stand and carbon stock of various components of three forest reserves in the Guinea savanna zone of Ghana

Forest reserve	Total trees ha^{-1}	Carbon stock (Mg C ha^{-1})			[¶]Total
		Trees	Grass	Necromass	
Kenikeni	178	60.01	0.47	0.09	60.57
Sinsablegbinni	536	26.74	0.11	0.14	26.98
Klupene	169	6.61	0.08	0.29	6.98
Total*	883	93.36	0.66	0.52	94.54

*Total carbon stock for all the three forest reserves; [§]Total carbon stock for all components; [¶]Total carbon stock for each forest reserve

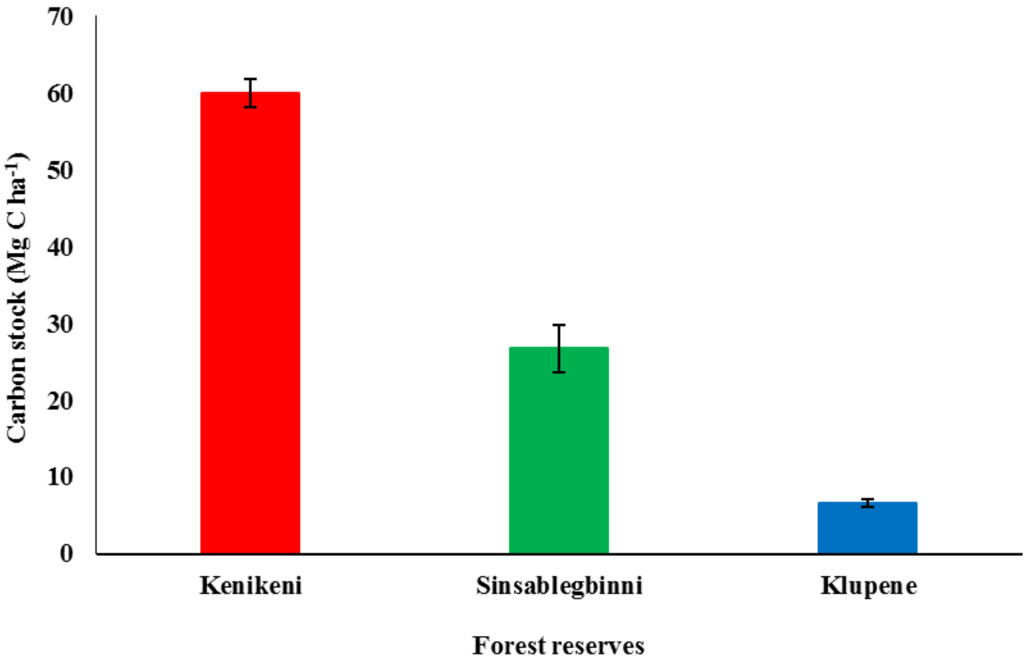


Figure 7: Carbon stock of trees with > 10 cm *dbh* in the three forest reserves

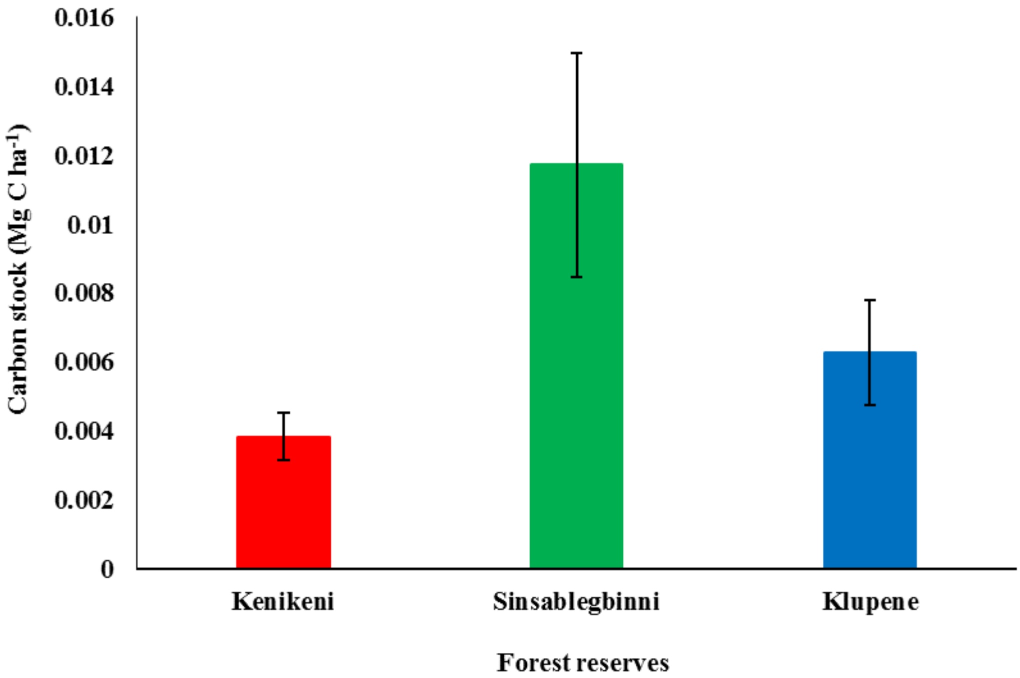
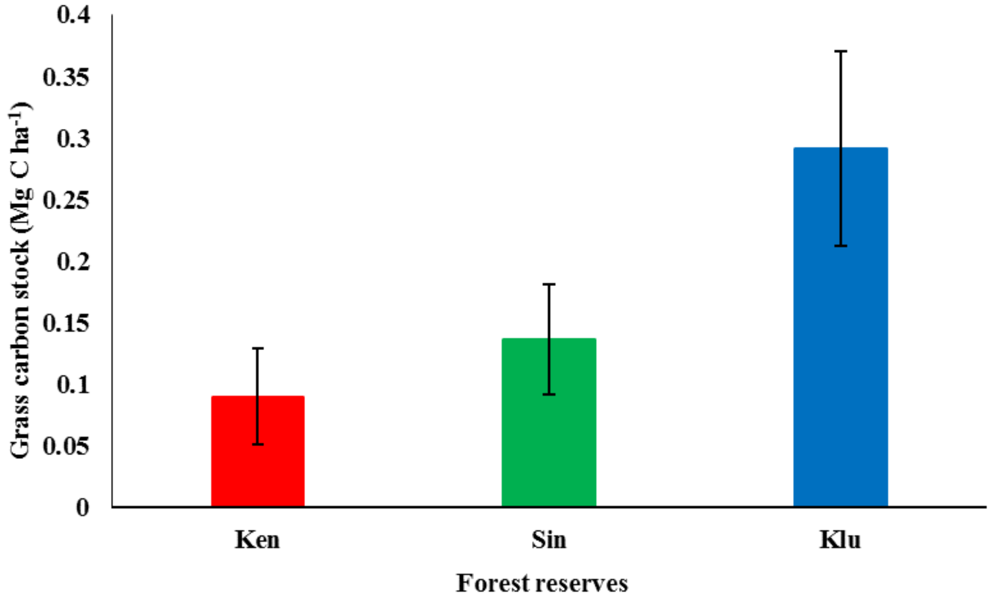
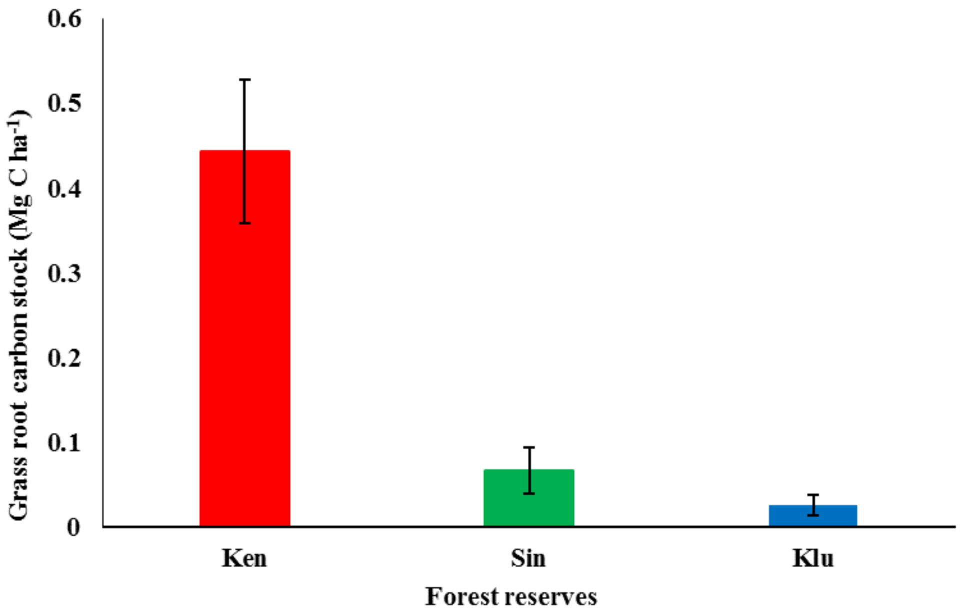


Figure 8: Carbon stock of trees with < 10 cm *dbh* in the three forest reserves



*Ken = Kenikeni forest reserve; Sin = Sinsablegbinni forest reserve; Klu = Klupene forest reserve

Figure 9: Aboveground grass carbon stock (Mg C ha^{-1}) in the three forest reserves



*Ken = Kenikeni forest reserve; Sin = Sinsablegbinni forest reserve; Klu = Klupene forest reserve

Figure 10: Belowground grass carbon stock (Mg C ha^{-1}) in the three forest reserves

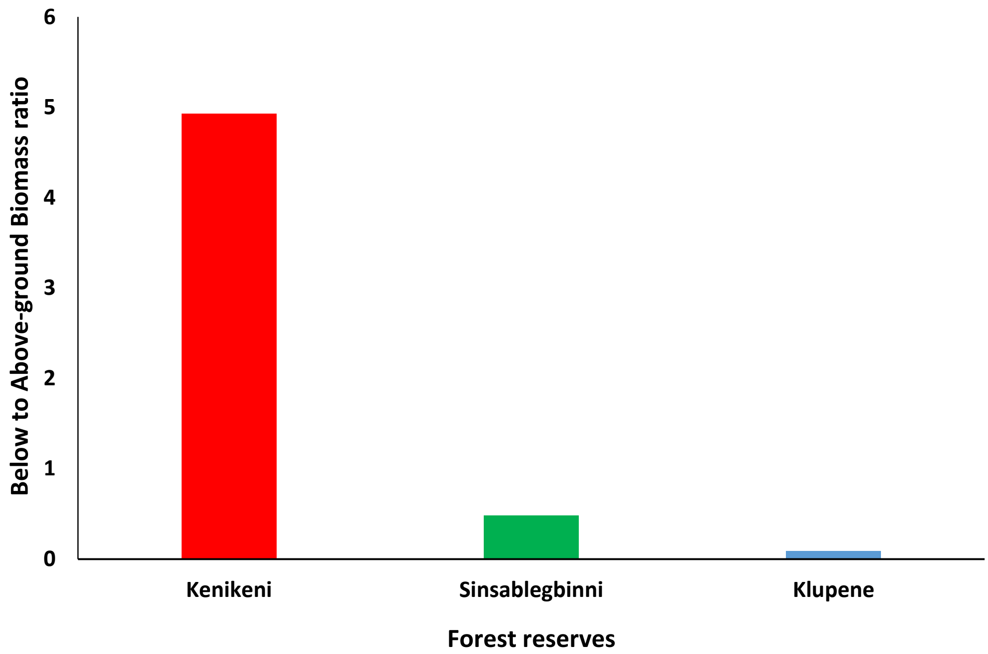


Fig. 11: Numerical representation of the below- to above-ground grass biomass carbon ratio

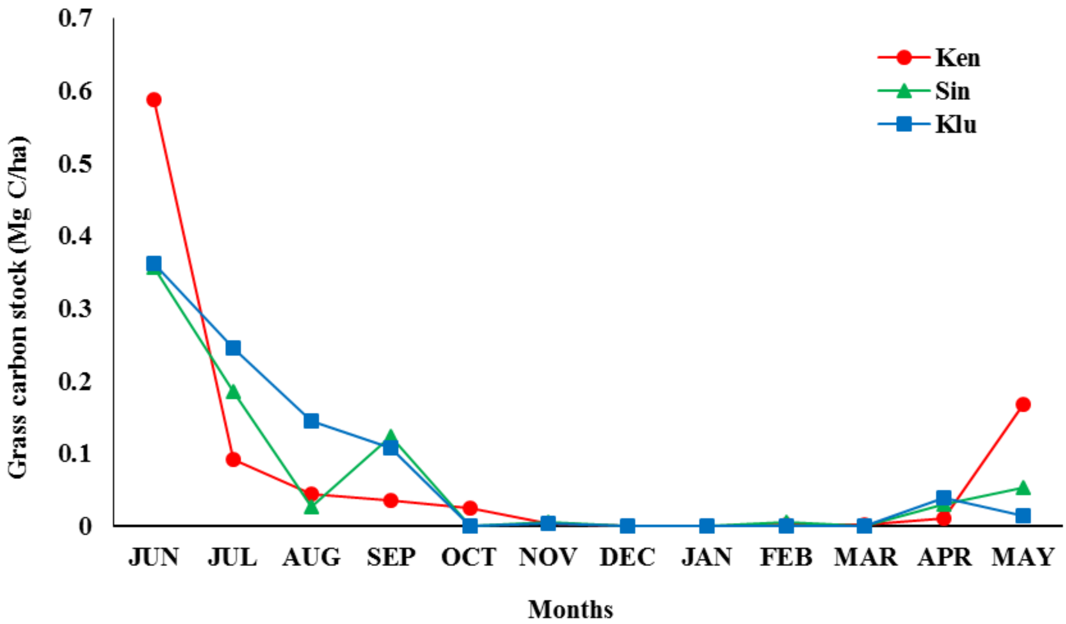


Figure 12: Trend of grass carbon stock in the three forest reserves

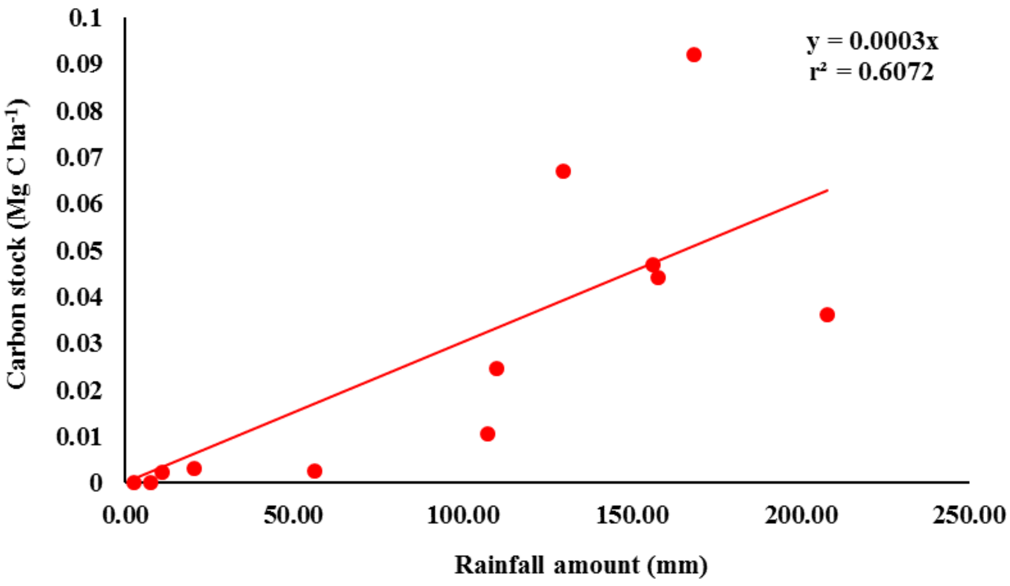


Figure 13: Rainfall amount and grass carbon stock in Kenikeni forest reserve

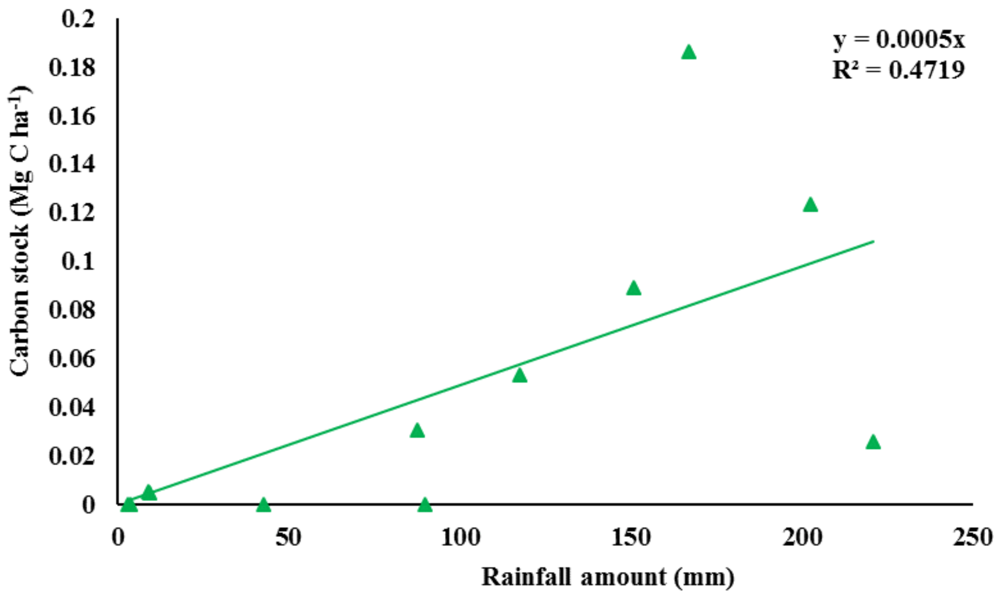


Figure 14: Rainfall amount and grass carbon stock in Sinsablegbinni forest reserve

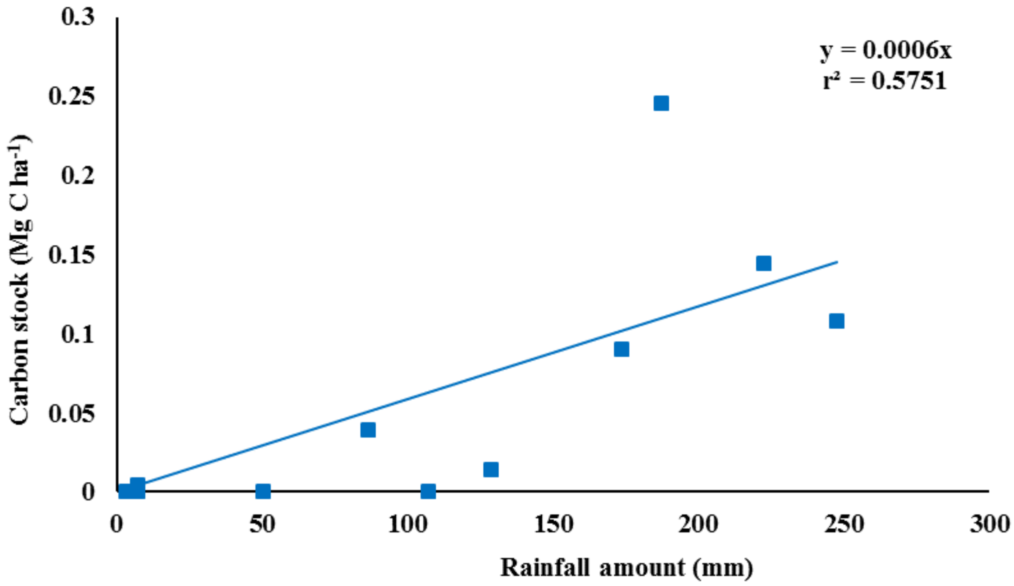


Figure 15: Rainfall amount and grass carbon stock in Klupene forest reserve

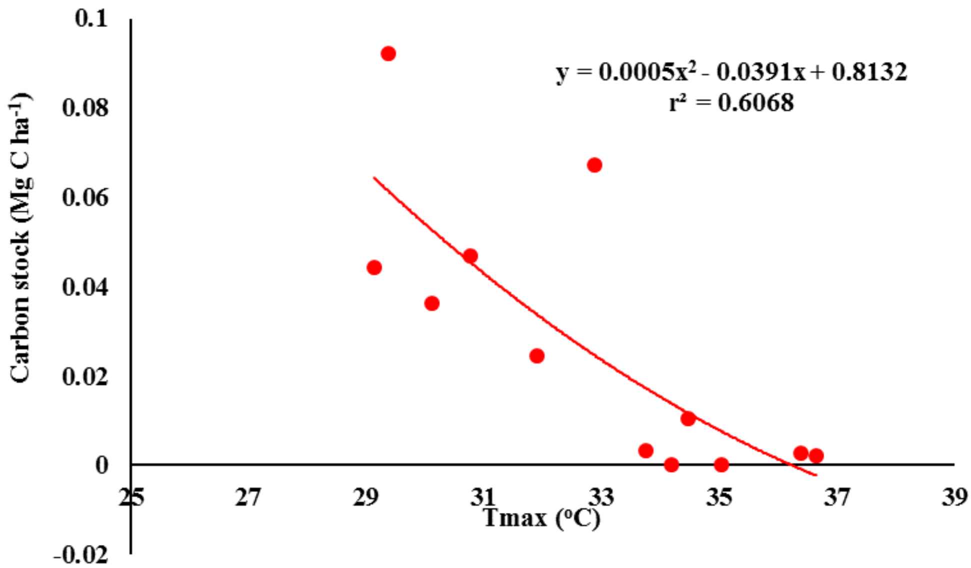


Figure 16: Maximum temperature (Tmax) and grass carbon stock in Kenikeni forest reserve

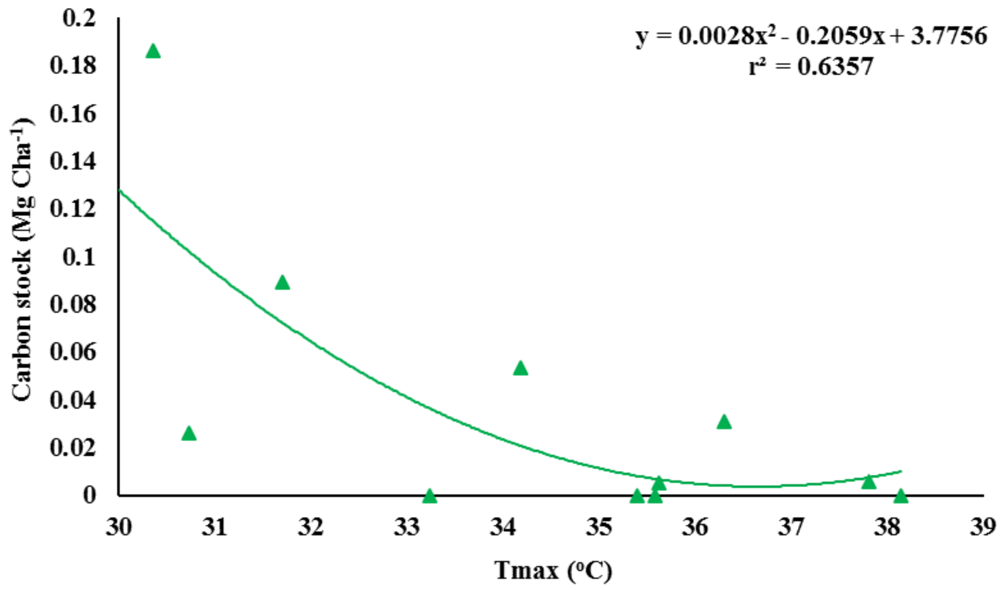


Figure 17: Maximum Temperature (Tmax) and grass carbon stock in Sinsablegbinni forest reserve

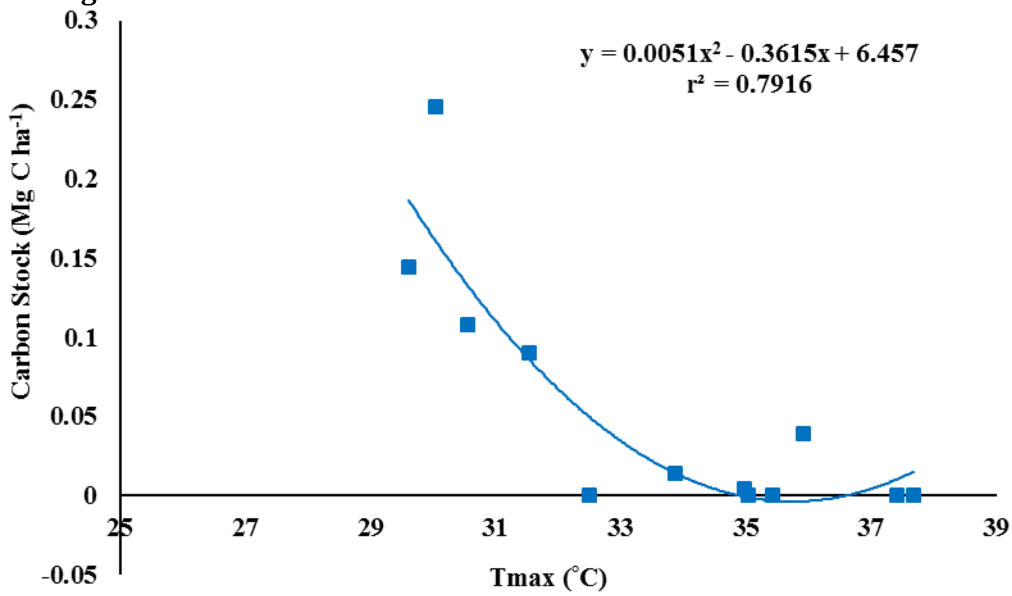


Figure 18: Maximum temperature (Tmax) and grass carbon stock in Klupene forest reserve

Table 15: Summary of grass carbon stock modelling

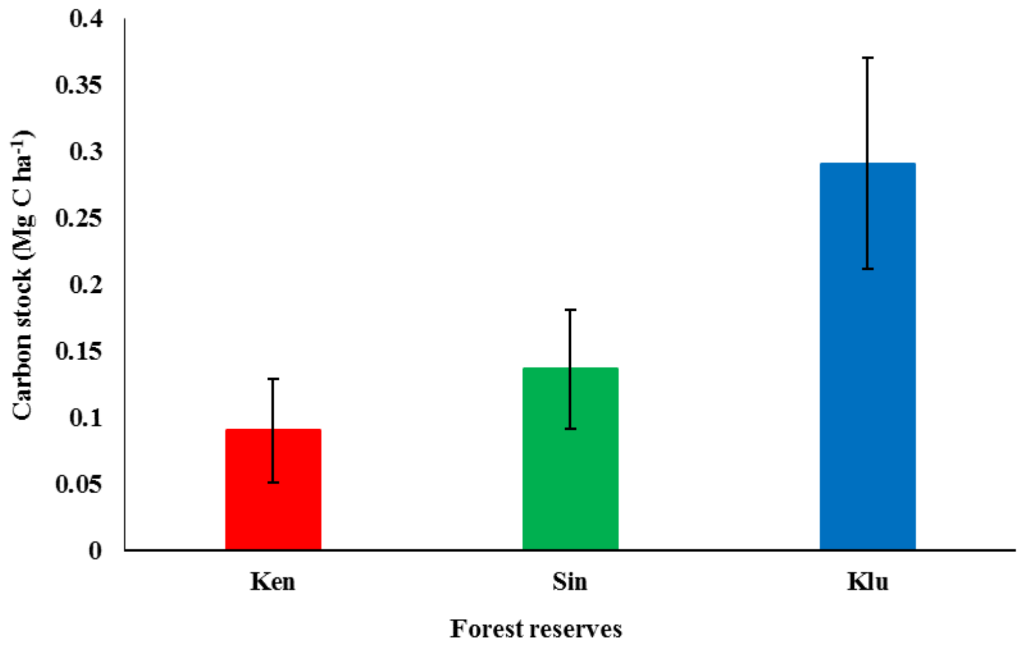
Site	Model	Prediction index	
		R^2	RMSE
Kenikeni	Additive	0.660	0.017
Sinsablegbinni		0.664	0.035
Klupene		0.816	0.034
	Pooled	0.556	0.039
Kenikeni	Multiplicative	0.639	0.017
Sinsablegbinni		0.567	0.040
Klupene		0.770	0.040
	Pooled	0.560	0.039

R^2 = Coefficient of determination; RMSE = Root mean square error

Table 16: Model parameters and predictive indices for grass carbon stock for the different forest reserves

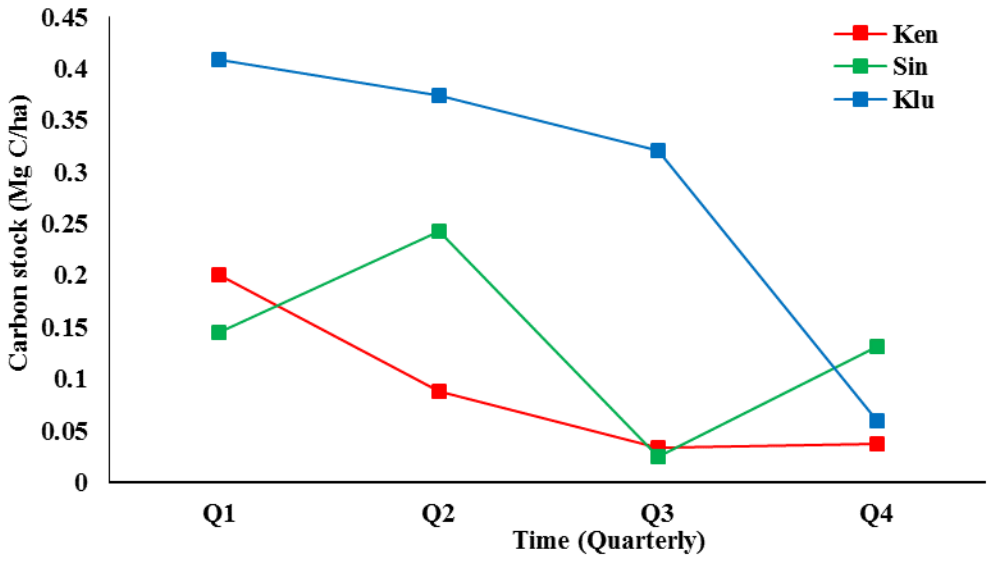
Site	†Model	Model parameters				Predictive index	
		a	b_o	b_1	b_2	R^2	RMSE
Kenikeni	Add	0.00018	0.00027	0.022	0.451	0.660	0.017
Sinsablegbinni		-0.00010	0.0031	0.229	4.214	0.664	0.035
Klupene		-0.00007	0.0053	0.379	6.795	0.816	0.034
	Pooled	0.00028	0.0016	0.112	2.001	0.556	0.039
Kenikeni	Mult	0.00079	-0.0041	-0.233	-2.855	0.639	0.017
Sinsablegbinni		0.0054	0.0029	0.202	3.569	0.567	0.041
Klupene		0.0095	0.0029	0.202	3.529	0.770	0.040
	Pooled	0.0026	0.0027	0.202	3.834	0.560	0.039

†Add = Additive effect; Mult = Multiplicative effect; Pooled = Pooled effect



Ken = Kenikeni forest reserve; Sin = Sinsablegbinni forest reserve; Klu = Klupene forest reserve

Figure 19: Necromass carbon stock in the three forest reserves



Ken = Kenikeni forest reserve; Sin = Sinsablegbinni forest reserve; Klu = Klupene forest reserve; Q1 = First quarter (June – August), Q2 = Second quarter (September – November); Q3 = Third quarter (December – February); Q4 = Fourth quarter (March – May)

Figure 20: Trend of necromass carbon stock in the three forest reserves