Estimation of Carbon Stock for some Tree Species and Soil in Serabioum Plantation

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ABSTRACT

Field experiment was carried out at Serapium plantation that irrigated with treated sewage water, to study the productivity and carbon stock of three of the most wide planted tree species in Egypt, *Corymbia citriodora, Khaya senegalensis* and *Casuarina equisetifolia* aged 5,11 and 7 years old, within a close range of total height and dbh in 2013. Results showed that one feddan of *Khaya senegalensis* or *Casuarina equisetifolia* gave the same amount of total stored carbon (tree biomass, litter layer and soil organic carbon) 34.7 and 34.4 Ton C/feddan. While, one feddan of *Corymbia citriodora* gave 15.8 ton C. the highest annual increment of growing volume, biomass and stored carbon were recorded in *Casuarina equisetifolia* followed by *Corymbia citriodora* While, *Khaya senegalensis* had the lowest value. Main stem volume can be used to predict stored carbon in tree biomass with a high correlation coefficient (R^2). Also, both of root/shoot ratio (R) and biomass expansion factor (BEF) were calculated to estimate standing trees biomass.

Key words: Carbon stock, BEF, Root/ Shoot ratio, Biomass, *Corymbia citriodora, Khayasenegalensis* and *Casuarinaequisetifolia*.

INTRODUCTION

Forests play an important role in global carbon cycle, because of their large pools of carbon. So, accurate estimation of forest biomass is required for greenhouse gas inventories and soil carbon accounting. Therefore, reporting carbon stocks and stock changes based on accurate surveying methods for the Kyoto Protocol is needed. (IPCC, 2003; Krankina*et al.*, 2004; Patenaude*et al.*, 2005; UNFCCC, 1997).

Carbon credits on the United Nation's programs for Global Reforestation and Reducing Emissions from Deforestation and Forest Degradation

Depends on the accuracy of carbon stock estimates (Gibbs *et al.*, 2007; Canadell and Raupach, 2008).That for forests have the majority of the global vegetation biomass (Klein Goldewijk, 2001).The global forests cover 3870 million ha according to FRA 2000 ,contains 386 billion cubic meters of wood of a total standing volume. While, woody vegetation stock estimated by 422 billion tons dry matter above-ground biomass of stems, branches, tops and foliage (FAO 2001).

Carbon stock changes in the forest areas according to annual variation in net primary production and soil respiration, that resulting from climatic variation (Ciais *et al.* 2005). Therefore, in the last few years the interest of the quantification of the forest ecosystems biomass and its potential carbon fixation were increased (Chave *et al.*, 2005; Fearnside, 1996; Schulp *et al.*, 2008; Sierra *et al.*, 2007). Where, total global carbon in soils ranged between 1500 and 2000 Gtons; as forest biomass stored the majority of it (Janzen, 2004; Smith, 2004).

For calculating biomass, carbon stock, stem volume converted to biomass components (foliage, branches, stem and roots of different sizes) with biomass expansion factor (BEF) , (Lehtonen *et al.* 2004). Tree biomass is the main component of the carbon stock of vegetation, but the understory vegetation especially litter may play an important role (Muukkonen *et al.* 2006).

Biomass expansion factor is the ratio of the dry weight of the aboveground biomass (stem, foliages, branches and twigs) to main stem volume, (Lehtonen *et al*, 2004).that used to convert merchantable stem wood volumes (m^3/ ha) to total biomass carbon values (Mg C/ ha) which can be used to estimate carbon budgets (Fukuda *et al.* 2003; Kilbride *et al.* 1999).While, root : shoot ratio (*R*) is commonly used to convert standing volumes of timber into total carbon stocks, for the purpose of national inventories of greenhouse gas emissions and sequestration (Levy*et al.* 2013).

Using a carbon fraction of 0.50 is problematic because carbon values that have been directly measured range from about 0.45 to 0.55 (Lamlom and Savidge 2003). Tree biomass is multiplied by a carbon fraction to estimate the mass of carbon contained in that tree. Species-specific values of carbon fraction are not widely available and therefore a generalized value of 0.50 is typically used (Brown 2002; Goodale*, et al.*, 2002; Harmon *et al.* 1990; Pacala *et al.* 2001; Van Deusen and Roesch 2011).

At the local level, Egypt is one of the countries with the lowest forest cover (70,000 ha). Except a few natural forests in Egypt like mangroves that can be found along the Red Sea, almost all of the planted forests have been established on marginal lands and irrigated with treated

waste water. These forest plantations are an important means to store carbon in the soil and plant tissue and combat desertification trends (FAO, 2012).

Corymbia citriodora, Khaya senegalensis and *Casuarina equisetifolia* are fast growing trees in Egypt, planted in large area at different plantations. Serapium plantation is an example of successful plantation and the growth rate of these species were 31.6 (m³/ha), 102.5 (m³/ha) and 25.0 (m³/ha), respectively (FAO, 2012).

A little is known about trees growth, biomass and stored carbon at established plantations in Egypt .where, woody trees have the ability to store a large amount of atmospheric Co^2. So, this study aims to build a database including trees productivity of biomass and carbon stock of above & underground tree components, annual growing stock, Biomass expansion factor (BEF) and root/shoot ratio (R) of each tree species and Organic carbon content of litter layer and soil under the studied species.

MATERIALS AND METHODS

1-Study area and tree species:

This study was carried out in November 2013 in Serapium plantation that located in northeastern Egypt 30°, 29', 15.55" N, and 32°,14',25.43" E , within the governorate of Ismailia, roughly 16 km. south of Ismailia town and next to the Suez Canal and Serapium village .Plantation area is 373.3 feddan, planted with 10 tree species (FAO, 2012) .

In this study, three tree species that planted at large area and showed fast and good growth rate were selected to calculate their component biomass and carbon stock (Table 1).

Table 1. Tree species and planted area

Tree species	Age (years)	Planting Area (feddan)	Planting Space (m)
Crombya citriodora	5	12	3*3
Khaya senegalensis	11	13.44	3*3
Casuarina equisetifolia	7	3.84	3*3

2 - Experimental design:

A sample of 9, 8 and 7 trees were selected randomly of *Corymbia citriodora, Khaya senegalensis*, and *Casuarina equisetifolia*, respectively. Then trees were cut down, and extract their root system. Main stem of each tree was cut into logs at 10%, 30%, 50%, 70%, 90% of tree's total height for volume and biomass calculation. Tree crowns and roots were separated. Stem logs, crown and root system fresh weight was taken,

then they dried at 70C°and weighted when reached a constant weight.

3- Above& below ground biomass and carbon calculation:

-Biomass

Main stems were cut into logs then their fresh and dry weight were taken. Also, crown branches were separated, dried and weighted. Both of coarse and fine roots were collected, cut, dried and weighted.

1-Above ground biomass = crown dry weight (kg) + stem dry weight (kg).

2-Below ground biomass = root system dry weight (kg).

3-Total tree biomass (kg) = above ground biomass + below ground biomass.

4-Biomass of total area = main of total tree biomass (kg) * trees number / feddan*planted area (feddan) +litter layer biomass.

- Carbon:

1.Stored carbon (kg) = Biomass of total area (kg)*0.5 (Brown and Lugo, 1984).

2.Stored Co_2 (kg) = stored C (kg) *3.67

3.Stored Co_2 metric tons= stored Co_2 (kg) * 0.001 (Nowak, 1994)

4- Tree volume measurements & equations:

For each felling tree total and commercial height, diameter over bark at dbh and at 0, 10, 20, 30, 50, 70, 90 % of tree total height, diameter at eight directions of crown (m) and crown length (m), depth and diameter of root system zone were measured.

-Volume of each log (V) was calculated with Smalian equation according to this formula:

$$V = \frac{g_1 + g_2}{2}\, h$$

Where: g_1, g_2 is bottom and top log basal area (m²), h is log height (m) (Gray, 1956).

-Upper part of stem was calculated as a cone according to next equation: $V = (1/3)\, \pi\, r^2\, h$

Where: h is a log height (m), r is a log base radius.

5 –Trees density:

Number of living trees with dbh ≥ 5cm were counted at feddan.

6- Litter layer

For each tree species three ground samples of (1m²) area were measured then all fall litters (dead leaves and twigs) within this area were collected, dried at 70C°and weighted when reached a constant weight.

7- Root/Shoot ratio (R)

Root/Shoot ratio was calculated using the following equation.

R = BGB/AGB (Sanquetta *et al.*, 2011)

Where: R is root/shoot ratio,

BGB: oven dry weight of root (kg)

AGB: oven dry weight of above ground components of tree (kg).

8- Biomass Expansion Factor (BEF)

Biomass expansion factor calculated by divide dry weight of the above ground biomass (stem, foliages, branches and twigs) to main stem volume, as following equation.

BEF = W / V (Lehtonen *et al*, 2004).

Where: W is the dry weight of above ground biomass (kg)

: V is the volume of main stem (m^3).

9 - Soil organic carbon

Three replicates of soil samples were taken at different depth 0-10, 10-60 and 60-120 cm from each tree species stand, to calculate soil bulk density, organic matter % and organic carbon according to this equation: The carbon stock of soil organic carbon (Soc) calculated as (Pearson et. al 2007):

$$Soc = \rho * d * C \%$$

where,

Soc = soil organic carbon stock per unit area,

ρ = soil bulk density [g cm^{-3}],

d = the total depth at which the sample was taken [cm], and

C = carbon concentration [%].

10 - Wood density

Samples along tree stems were cut into regular geometric forms to calculate their volume, then oven dried at 103 ±2 c^0 to a constant weight .Wood density calculated according to this formula:

$$Wood\ density = \frac{dried\ weight}{volume}$$

11- Statistical analysis

Mean, standard divisions, coefficient of variation (C.V) were calculated for results. Also, a simple linear regression analysis was used to test the significantly between tree volume, biomass and carbon content of tree components according to (Snedecor and Cochran, 1974).

RERSULTS AND DISCUSSION

Khaya senegalensis and *Casuarina equisetifolia* with the same dbh and total height rang 10- 23 cm, 8.4-15 m and 10.5- 22cm, 8.5-16 m. with mean dbh 15.4cm, 12.53 cm and mean total height 12.1, 15.5 m, respectively. While, *Crombya citriodora* with dbh rang 8.8-16 cm and 16.46 cm mean, total height rang 10.5-19.3m and 11.97 m mean were studied to calculate their biomass productivity and stored carbon per feddan. Means of tree characteristics were summarized in (Table 2).

1-Tree components biomass

Above ground biomass of *Crombya citriodora*, *Khaya senegalensis* and *Casuarina equisetifolia* species were calculated using both stem and crown dry weight (kg) while, fine and coarse roots dry weight were used as below ground biomass .Results indicated that mean values of above ground biomass were 73.03± 13.9, 131.87± 17.5 and 117±24.6 kg. while, the mean values of below ground biomass were 20.4±4, 40.75 ± 5.5 and 35.34± 6.7 kg, for the three species respectively. Total tree biomass calculated using sum of above and below ground biomass and recorded 94 ±16.16, 173.2 ± 32 and 153.3 ±25.23 kg. for the three species, respectively (Table3). Results showed that *Khaya senegalensis* had the highest means of above, below and total biomass followed by *Casuarina equisetifolia*. while, *Crombya citriodora* had the lowest value. Result was agreeable with Warnasooriya and Sivananthawerl (2016) where, total biomass of *Khaya senegalensis*11-12 years old was (170.18 kg). Also, Faming *et al.* (2013) mentioned that above, below and total biomass increased markedly with stand age on *C. equisetifolia* plantations.

2- Stored carbon:

Biomass of total tree, tree components above and below ground (kg) were converted to C content (kg) by multiplied to 0.5 factor. Results presented in table (3) showed that stored carbon in above and below ground and in total biomass of *Crombya citriodora* were 36.47 ± 7.6, 11.8 ± 1.9 and 48.4 ± 6.13 kg, respectively, while *Khaya senegalensis* were 65.96 ±12.7, 20.48 ± 3.1 and 86.4 ±15.36 kg. when, *Casuarina equisetifolia* recorded 58.8 ±10.4, 17.9 ±3.5 and 76.66 ± 13.8Kg , in order, (Table 3). De Costa and Suranga (2012) found that the mean C stock (t /ha) for *Eucalyptus citriodora* 86.81, however, it was 27.38 for *Casuarina* spp. Swamy *et al.*(2011) explain The variation in carbon stock values due to variation in the biomass production capacity of species related to growth habit of the species. Generally high C stock and productivity, depends on higher above ground biomass (AGB) in long rotation forests compared to short one. Accurate quantification of carbon stocks of the forests required local information

Table 2. Means of Above ground and below ground measurements for the three species

Tree Species	Above ground measurements				Root measurements			
	Stem measurements (m)		Crown measurements (m)					
	Total height (m)	Dbh (cm)	Crown length (m)	Mean crown diameter at (8 directions) (m)	Depth of the root crown (cm)	Width of the root crown (cm)	Length of the primary root (cm)	Diameter of the primary root (cm)
Crombya citriodora	15.54	12.53	8.43	2.26	95.70	196.50	143.83	14.13
Khaya senegalensis	11.97	16.46	7.63	2.64	86.11	275.56	130.75	15.41
Casuarina equisetifolia	12.11	15.4	10.25	2.16	90.86	340.71	196.67	9.18

Table 3.   Means and statistical analysis of trees growth parameters and product

Analysis	Mean	M.S	S D	C V
Corymbia citriodora				
volume (m^3)	0.12	0.0004	± 0.02	15%
Stem biomass (kg)	58.15	109.6	± 10.5	18 %
Crown biomass (kg)	14.85	10.17	± 3	20 %
Above ground biomass (kg)	73.03	194.4	± 13.9	19 %
Below ground biomass (kg)	20.4	16.4	± 4	19.6%
Total tree biomass (kg)	94	261.2	±16.16	17 %
Root/ shoot ratio (R)	0.26	0.001	±0.03	11.5%
Biomass Expansion Factor (BEF)	0.73	0.01	±0.1	13.4%
Wood density (g/cm^3)	0.60	0.001	± 0.03	5%
Stored Carbon in above ground tree (Kg)	36.47	50.84	± 7.6	20.8%
Stored Carbon in Below ground tree (Kg)	11.8	3.46	± 1.9	16 %
Stored Carbon in total tree (Kg)	48.4	37.6	± 6.13	12.65%
Dry weight of litter layer g/m2	56	36	±6	11%
Carbon content of litter layer kg/ area feddan	1411	10000	±100	7%
Khaya senegalensis				
volume (m^3)	0.16	0.001	±0.03	19 %
Stem biomass (kg)	71.23	184.2	±13.6	19 %
Crown biomass (kg)	60.29	201.8	± 14	23 %
Above ground biomass (kg)	131.87	317.7	± 17.5	13.3 %
Below ground biomass (kg)	40.75	30.8	± 5.5	13.5 %
Total tree biomass (kg)	173.2	1023	± 32	18.5 %
Root/ shoot ratio (R)	0.32	0.004	± 0.06	18.6 %
Biomass Expansion Factor (BEF)	0.92	0.03	± 0.17	18.6%
Wood density (g/cm^3)	0.51	0.002	± 0.04	7.8%
Stored Carbon in above ground tree (Kg)	65.96	161	± 12.7	19 %
Stored Carbon in Below ground tree (Kg)	20.48	9.6	± 3.1	15 %
Stored Carbon in total tree (Kg)	86.4	236.01	±15.36	17.8 %
Dry weight of litter layer g/m2	122	126	±11	9%
Carbon content of litter layer kg/ area feddan	3443	146689	± 383	11%
Casuarina equisetifolia				
volume (m^3)	0.13	0.0004	± 0.02	15 %
Stem biomass (kg)	75.19	183.5	±13.5	18 %
Crown biomass (kg)	43.4	57.8	± 7.6	17.5 %
Above ground biomass (kg)	117.4	605	± 24.6	21%
Below ground biomass (kg)	35.34	44.33	± 6.7	19 %
Total tree biomass (kg)	153.3	636.5	±25.23	16.5 %
Root/ shoot ratio (R)	0.29	0.01	± 0.06	20.7 %
Biomass Expansion Factor (BEF)	1.03	0.03	±0.16	15.5%
Wood density (g/cm^3)	0.59	0.001	± 0.03	5%
Stored Carbon in above ground tree (Kg)	58.8	108.8	±10.4	17.7%
Stored Carbon in Below ground tree (Kg)	17.9	13.1	± 3.5	19.7 %
Stored Carbon in total tree (Kg)	76.66	191.25	± 13.8	18 %
Dry weight of litter layer g/m2	61	42	± 6.5	11%
Carbon content of litter layer kg/ area feddan	492	10000	± 100	20 %

on tree allometry, wood density and species composition, (Brigitte *et al.*2016).Where, trees act as CO_2 absorber from the atmosphere and store it in the form of wood (Chaturvedi and Khanna, 1984). Thus, absorbing CO_2 from air and locking it in the forest biomass is one of the important method to remove large volume of CO_2 from the atmosphere.

3-Tree volume (V),root/ shoot ratio (R) ,biomass expansion factor (BEF) and wood density (d) g/cm³:

For calculating biomass of standing trees without cutting them down, main stem volume, wood density and other relations such as R and BEF are used. As presented in table (3) means of tree volume and (R) increased by increasing trees age . Mean values were $0.12 \pm 0.02, 0.13 \pm 0.02$ and $0.16 \pm 0.03 m^3$; 26% ±0.03, 29 % ± 0.06 and 32% ± 0.06, for *Crombya citriodora*, *Casuarina equisetifolia* and *Khaya senegalensis* ,respectively. While, BEF recorded the highest value by *Casuarina equisetifolia* (1.03 ± 0.16), then *Khaya senegalensis* (0.92 ±0.17) and finally *Crombya citriodora* (0.73± 0.1). while, wood density values were 0.6 ±0.03, 0.51 ±0.04 and 0.59 ± 0.03 for *Crombya citriodora*, *Khaya senegalensis* and *Casuarina equisetifolia* , respectively. Both of wood density value of *Khaya senegalensis* and *Casuarina equisetifolia* recorded low values according to Orwa *et al.*(2009) and FAO (1997) wood density range (0.6 to 0.85) for *Khaya senegalensis* and wood density of *Casuarina equisetifolia* 0.83 according to FAO (1997) and Swamy *et al.*(2011) while*, Crombya citriodora* wood density was agreeable with FAO (1997) 0.64 g/cm³.On other hand, values of volume and wood density of *Khaya senegalensis* was within range (0.01 to 1.04 m³/tree) and (0.27 to 0.76 g cm⁻³) respectively, according to Daniel (2011) on his study on *Khaya* species. aged 12 years.

Results showed that BEF and V of *Casuarina equisetifolia* and *Khaya senegalensis* recorded high results, while, *Crombya citriodora* showed opposite trend (Brown and Schroeder 1999) ,also they referred to the significant relation of BEF and the growing volume for most forest types ,where, generally BEF starting high at low volumes and then it decrease to rich a constant low value at high volumes. Also, Yunjian Luo et *al.* (2013) agreed with this trend, they found that BEF of Casuarina was 1.58±0.32 and for Eucalypts was 1.50±0.20 in China forests. Thus, that BEF decreased with increasing stand age and size (e.g., dbh, tree height, and standing volume). Also, this result matched with FAO (2012) for Khaya trees during a study at

spreamium. Although, *Khaya senegalensis* recorded the highest volume per hectare (102.5 m³/ha), it didn't match with annual increment while, *Crombya citriodora* was the opposite. In case of *Casuarina equisetifolia* it recorded the highest growth value because it considers one of the superior fast-growing tree species in biomass production. Pongsak- Sahunalu and Wiratana- Tanpibal (1985) found high growth of 12-years old Casuarina trees 16.2 cm dbh and 20.3 m height , also, Swamy *et al.* (2011) observed superior performance for *Casuarina equisetifolia*, due to its ability on nitrogen-fixation, so it can grow well on poor and salty soils (CABI 2012).While , (R) increased as dbh increased this trend match with , Sohial *et al.*(2014). So, BEF and R are initial information should be calculated to estimate biomass of stand.

4-Annual growing biomass and carbon stock.

Table (4) presented mean values of annual increment of growth parameters and biomass productivity. Results showed that *Crombya citriodora* has the highest annual increment in total height and dbh (3m &2.6cm) then *Casuarina equisetifolia* (1.6m &2.1 cm), however, *Khaya senegalensis* had the lowest values (1.1m & 1.6 cm). where, the highest values of Tree total biomass, carbon stock and growing volume /feddan were recorded by   *Casuarina equisetifolia, Crombya citriodora* and *Khaya senegalensis,* respectivly**.** Faming *et al.* (2013) found That annual accumulation of Carbon in plant biomass of *C. equisetifolia* aged 3–6, 6–13 years old were 8.2 and 4.2 Mg C ha−1 yr−1, respectively also they mentioned that biomass and carbon accumulation increased markedly with stand age. Also, FAO (2012) found that the best volume increment showed by *Eucalyptus citriodora* and *Khaya senegalensis*

5-Soil organic carbon and litter layer:

Table (5) presented mean values of soil bulk density, organic matter % and organic carbon under each tree species at different depths. Results showed that the highest values of OM% and OC% were at the soil upper layer 10cm depth. The highest mean of total organic carbon kg/ feddan was observed at soil under *Casuarina equisetifolia* (1071.4kg), then followed by *Crombya citriodora* (815.3 kg) while, *Khaya senegalensis* recorded the lowest value 305.8kg.Where, litter layers of 7, 10 and 15 cm thickness under species *Casuarina equisetifolia, Crombya citriodora* and *Khaya senegalensis*, contained 492, 1411 and 3443Kg C / feddan, respectively (Table 3).

Table 4. Annual increment means of the three species growth parameters and production

Measurement Tree Species	Age (years)	Total height (m)	dbh (cm)	Crown Biomass (kg)	Stem Biomass (kg)	Above ground Biomass (kg)	Root Biomass (kg)	Total Biomass (kg)	Growing Volume (m³/ feddan)	Trees carbon stock /feddan (kg)	Total carbon Stock (tonne)
Crombya citriodora	5	3	2.6	3	11.6	14.6	4.1	18.8	6.5	9.7	3.17
Khaya senegalensis	11	1.1	1.6	5.5	6.5	10.67	3.7	15.7	4.0	7.9	3.16
Casuarina equisetifolia	7	1.6	2.1	6.2	10.7	10.7	5.1	21.9	9	11	4.9

Table 5. Means and statistical analysis of soil characteristics under the tree species

Soil depth	Bulk density g/cm³	Organic matter OM %	Organic Carbon OC%	Total Organic Carbon Kg/ feddan	Total Organic Carbon Ton/ all area
Species			*Crombya citriodora*		
0-10cm	1.51	0.88	0.51	324.42	3.89
10-60 cm	1.29	0.34	0.31	849.02	10.19
60-120 cm	1.50	0.58	0.34	1272.33	15.27
Mean	1.43	0.67	0.39	815.3	9.78
MS	0.016	0.02	0.011	225489	32.47
SD	± 0.13	± 0.14	± 0.1	± 474.9	± 5.7
C.v.	9%	21%	25.8%	58%	%58
			Khaya senegalensis		
0-10cm	1.47	0.27	0.16	97.10	1.31
10-60 cm	1.52	0.19	0.11	352.28	4.73
60-120 cm	1.68	0.19	0.11	468.03	6.29
Mean	1.56	0.2	0.13	305.8	4.11
MS	0.012	0.002	0.0007	36016	6.5
SD	± 0.1	± 0.04	± 0.03	± 189.8	± 2.5
C.V.	7%	18.5%	20.6%	62%	60%
			Casuarina equisetifolia		
0-10cm	1.45	0.9	0.52	317.85	1.21
10-60 cm	1.50	0.7	0.41	1282.31	4.87
60-120 cm	1.57	0.7	0.41	1613.95	6.13
Mean	1.5	0.77	0.45	1071.4	4.1
MS	0.004	0.013	0.005	453337.8	6.5
SD	± 0.06	± 0.1	± 0.07	± 673	± 2.5
C.V.	4%	14%	15.7%	62.8%	%61

These results were at the same line with Swamy *et al.* (2011) in their study on six different tree species included *Casuarina equisetifolia,* they found a highly significant variation of soil organic carbon may be attributed to amount of litter fall, decomposition, nutrient release to the soil. Also, carbon sequestration potential in soils can be strongly affected by root production and soil microbial activity proportional to inputs of soil organic carbon at the top layers. Accordingly, as the depth increases, the organic carbon was decreased due to low decomposition of organic matter.

6- Predicted trees stored carbon using main stem volume:

A simple linear regression analysis were used to test the significance between main stem volume and above ground, below ground and total tree biomass stored carbon for *Crombya citriodora* , *Khaya senegalensis* and *Casuarina equisetifolia*. Results showed a highly significant correlation coefficient (R^2) between the main stem volume and stored carbon in above ground, below ground and total tree biomass as shown in Table (6) and Fig (1). Also, stored carbon can be predicted using stem volume according to equations summarized in Ttable (7). This is agreeable with Timothy *et al*. (2007). Also, Houghton *et al.* (1999).Where, to get an accurate measurement of carbon pool and fluxes it is necessary to know about the volume of tree and total biomass. Moreover, Peter *et al*. (2002) described that tree dbh and volume are more time-consuming and accurate approach can be used to predict wood mass using regression model.

CONCLUSION

Results showed that *Crombya citriodora* tree aged 5 years old had 0.12 m³ volume and 126.87 kg biomass that stored 63.44kg carbon and stored 15.8 tone C/ feddan ,with annual increment 6.5 m³of volume and 3.17 tone C/feddan. when, *Khaya senegalensis* tree aged 11 years gave 0.16m³ volume , 173.2 kg biomass and stored 86.4 kg Carbon. while, it stores 34.7 tone total C / feddan, with 8.11 m³ annual volume increment and 3.16 tone annual stored carbon increment .where's *Casuarina equisetifolia* tree aged 7 years gave 0.13 m³ volume , 153.3 kg biomass and stored 76.66 kg carbon. We can obtain 34.4 tone stored C/ feddan , 9 m³ annual volume increment and 4.9 tone annual stored carbon increment, for *Casuarina equisetifolia*.
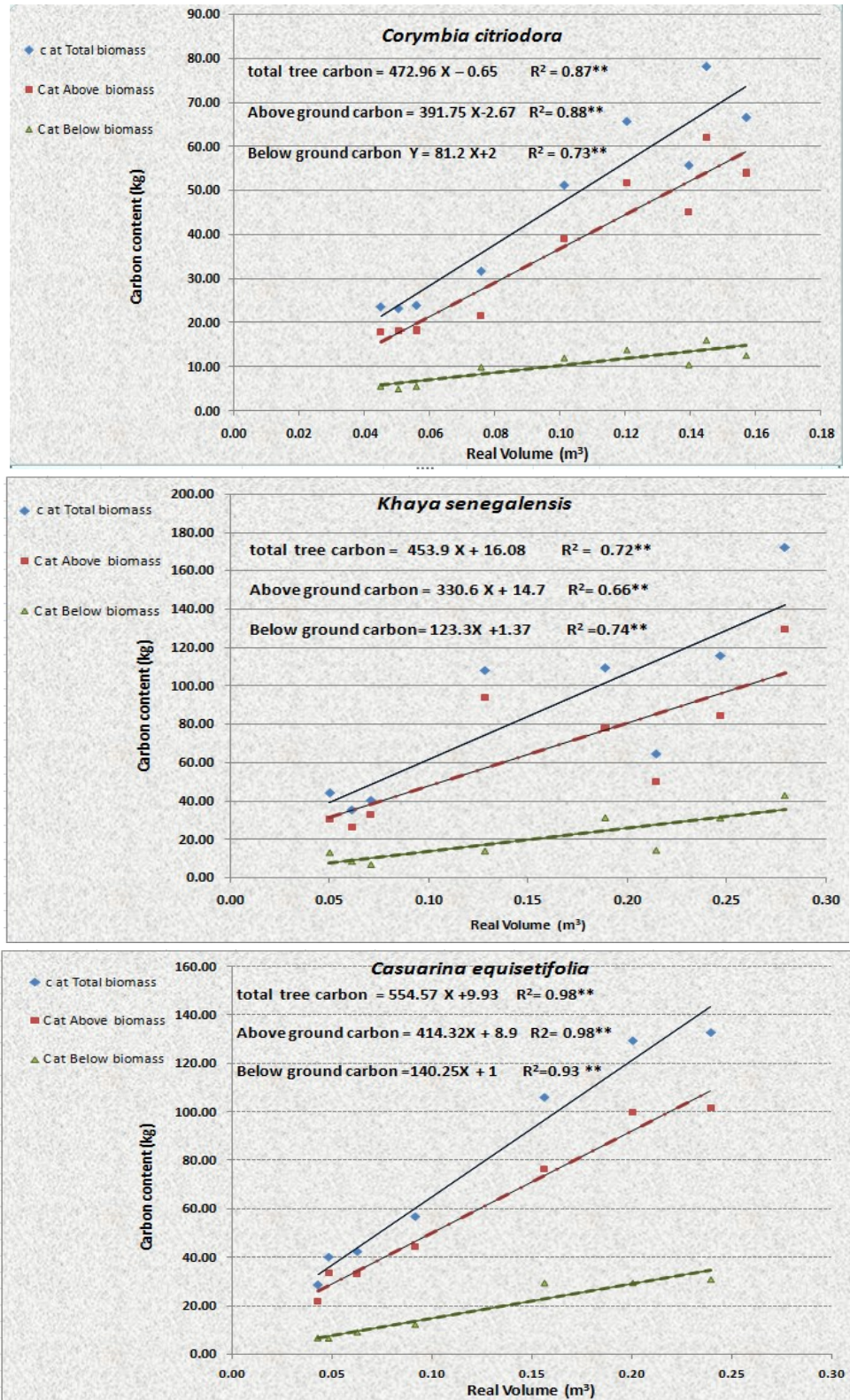
Corymbia citriodora

total tree carbon = 472.96 X – 0.65 $R^2 = 0.87**$

Above ground carbon = 391.75 X-2.67 $R^2 = 0.88**$

Below ground carbon Y = 81.2 X+2 $R^2 = 0.73**$

Khaya senegalensis

total tree carbon = 453.9 X + 16.08 $R^2 = 0.72**$

Above ground carbon = 330.6 X + 14.7 $R^2 = 0.66**$

Below ground carbon= 123.3X +1.37 $R^2 = 0.74**$

Casuarina equisetifolia

total tree carbon = 554.57 X +9.93 $R^2 = 0.98**$

Above ground carbon = 414.32X + 8.9 $R^2 = 0.98**$

Below ground carbon =140.25X + 1 $R^2 = 0.93**$

Fig. 1.Regression analysis of the tree stem volume (m3) and carbon stock (kg)

Table 6. Simple regression analysis of real and different form factors for the three species

species variables				*Crombya citriodora*		
	d.f.	S.S.	M.S.	F value	pr	R^2
C at aboveground biomass kg	8	299.3	42.75	50.97	0.0002	0.88**
C at belowground biomass kg	8	35.4	5.06	18.5	0.004	0.73**
C at total tree's biomass kg	8	482.6	68.9	46.1	0.0003	0.87**
species variable				*Khaya senegalensis*		
	d.f.	S.S.	M.S.	F value	pr	R2
C at aboveground biomass kg	7	3211.5	535.25	11.60	0.01	0.66**
C at belowground biomass kg	7	307	51.2	16.88	0.006	0.74**
C at total tree's biomass kg	7	4519.8	753.3	15.54	0.008	0.72**
species variable				*Casuarina equisetifolia*		
	d.f.	S.S.	M.S.	F value	pr	R2
C at aboveground biomass kg	6	140.9	28.2	232.7	0.0001	0.98**
C at belowground biomass kg	6	55.16	11	68	0.0004	0.93**
C at total tree's biomass kg	6	260.75	52.2	225.3	0.0001	0.98**

Table 7. Prediction equations of tree biomass carbon content (kg) using stem volume m³

Species	Stored C of above ground biomass (kg)	R^2	Stored C of below ground biomass (kg)	R^2	Stored C of total tree biomass (kg)	R^2
Crombya citriodora	Y = 391.75X-2.67	0.88**	Y = 81.2X+2	0.73**	Y = 472.96 X – 0.65	0.87**
Khaya senegalensis	Y= 330.6 X + 14.7	0.66**	Y= 123.3X +1.37	0.74**	Y= 453.9 X + 16.08	0.72**
Casuarina equisetifolia	Y= 414.32X + 8.9	0.98**	Y =140.25X + 1	0.93 **	Y= 554.57X +9.93	0.98**

According to the results ,it was expected that older trees give the highest volume and biomass. but, *Crombya citriodora* had the highest annual increment of total high, dbh and above biomass even it's the youngest .that's because young trees growing faster in height. While, *Casuarina equisetifolia* had the highest annual increment of volume, total biomass and carbon stock.

Finally, trees act an important role to store carbon in their tissues and soil, decreasing atmosphere warm and give wood as a main commercial product. Moreover, planting trees using treated sewage water is consider a save way to reuse this water. So, we need to expand planted area of fast growing trees especially, *Casuarina equisetifolia* and *Crombya citriodora*.

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الملخص العربي

تقدير المخزون الكربونى لبعض أنواع الأشجار والتربة فى مزرعة سيرابيوم

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اقيمت تجربة حقلية فى غابة سيرابيوم التى تروى بمياه الصرف الصحى المعالج، لدراسة الأنتاجيـــة والمخــزون الكربونى لثلاثة أنواع من الأشجار الخشبية الاكثر انتــشارا فى مصر وهم الكافور الليمونى والكايا والكازوارينا ذيــل الحصان وأعمارهم ٥ و١١ و٧ سنوات، ولهم مدى متقارب من الارتفاع الكلى والقطر عند ارتفاع الصدر وذلك فى عام ٢٠١٣. اظهرت النتائج ان انتاجية فدان من أشجار الكايـــا والكازوارينا من الكربون الكلى المخزون(الكتلـــة الحيويـــة للشجرة+ طبقة المتساقطات + الكربون العضوى بالتربة) كانت تقريبا متساوية ٣٤,٧ و٣٤,٤ طن كربون/ فدان.بينما فدان من الكافور الليمونى اعطى ١٥,٨ طن كربون/ فدان. سجلت أعلى زيادة نمو سنوى فى الحجم والكتلـــة الحيويـــة

والكربون المخزون فى أشجار الكازوارينا يليها الكـــافور ،بينما الكايا كانت الاقل قيمة. وقد اظهر التحليل الاحصائى باستخدام معادلات الارتداد البسيط انه يمكن التنبـــؤ بكميـة الكربون المخزون فى الكتلة الحيوية للشجرة بمعامل ارتباط عالى المعنوية. كذلك تم تقدير نسبة الجـــذر/للأفـــرع (R) ومعامل تمدد الكتلة الحيوية (BEF)لاستخدامهم فـــى تقـــدير الكتلة الحيوية للشجر القائم.

الكلمات الكاشفة: المخزون الكربونى،معامل زيـادة الكتلـــة الحيوية، نسبة الجذور للأفرع، الكتلـــة الحيويـــة، الكـــافور الليمونى وكازوارينا ذيل الحصان.