Biomass and Sequestered Carbon of *Eucalyptus gomphocephala* as a Boundary Plantations in New Reclamation Lands

Maha, F. Ismail; M. I. Bahnasy and Mona, M. Abbaas

Forestry and Timber Trees Research Department, Horticulture Research Institute, Agricultural Research Center, Egypt.

ABSTRACT

This study was carried out on *Eucalyptus gomphocephala* trees at age of 22 years, that planted as a boundary plantations in Aly Mubarak research farm belong to South of El-tahrir Research Station- Agriculture Research Center. This aimed to determine biomass, CO2 sequestrated and carbon credit certificates. The total number of trees (344 trees) which in this study was divided into three classes according to dbh measurement. The dbh of class (1) ranged from 31 to 42 cm, class (2) ranged from 22 to 30 cm and class (3) ranged from 18 to 21cm. The average of dry weight of AGB (Above ground biomass) in class (1), (2) and (3) were 851.67 ± 101.35, 440.66 ± 73.29 and 106.6 ±26.5 Kg/tree, respectively. These biomass classes sequestered CO_2 of 70.97 ± 8.45, 36.72 ± 6.11 and 8.88 ± 2.21 Kg/tree/y in class (1), (2) and (3), respectively. Total CO_2 sequestered for 344 trees of *E. gomphocephala* as a boundary plantation in the new reclaimed lands was 17.58 ton/year that equal Certified Emission Reduction (CERs).

Keywords: *Eucalyptus gomphocephala*- Above ground biomass- Carbon sequestration.

INTRODUCTION

Global warming and it accelerate impact on the life on Earth a direct threat to human life, biodiversity, and the global economy. Global climate change is not under control. While the full implementation of Paris Agreement's NDCs should limit total annual global emissions in 2030 to 53–56 Gt (gigatons) CO_2e, keeping warming below 2˚C requires reducing emissions to 40 Gt CO_2e on average; to limit warming to 1.5˚C, emissions would need to fall to 24 Gt CO_2e per year. Forests and oceans form a natural buffer against climate change. Forests play a role in mitigating climate change by absorbing carbon dioxide emitted into the atmosphere from human activities, chiefly the burning of fossil fuels for energy and other purposes, into the terrestrial carbon sink. The amount of carbon emissions that have been naturally sequestered from the atmosphere since 1750 has been estimated to be around half due to forests (and other plants, but mostly forests); the remainder has been absorbed by the oceans. Nonetheless, the impact of forests on atmospheric concentrations of carbon dioxide will be the net outcome of the carbon absorbed by forest growth (the carbon sink) and the carbon emitted from deforestation and forest degradation (emissions), UNFF (2019).

Natural forests around the world are rapidly being destroyed as a result of human activities including deforestation, industrialization, urbanization, etc. The result was a global temperature of 0.74 ºC and atmospheric CO_2 levels of 379 parts per million at the end of the previous century, (UNFCCC, 2007and IPCC, 2013). The rate will be doubled by 2050 and raised to 2–4 ºC by 2100, responsible for a 28–98 cm sea-level rise due to the melting of polar ice (IPCC, 2013).

Trees on farms help to increase crop yields, mainly because the microclimate is improved, Kort (1988). Windspeed and evapotranspiration are reduced while temperature extremes are moderated, Alemu (2016). Therefore, agroforestry, especially in arid or semi-arid regions, contributes to climate change adaptation as well. In particular, tree windbreak systems do reduce wind speed, which substantially reduces evapotranspiration and water consumption of agriculture in drylands (Alemu ,2016 and Thevs et al. (2019).

The tree species composition, tree age, location, local climate, and management practices all affect an agroforestry system's potential as a carbon sink. In comparison to treeless agricultural systems, agroforestry systems may also boost SOC (soil organic carbon) and store significant amounts of above- and below-ground carbon (Rizvi et al., 2011and Kumar, 2011). Agroforestry and tree plantings have enormous potential for sequestering the carbon generated by major industries (Ajit et al., 2014).

Biomass has an essential role in the energy sector of the world due to applications in bioenergy. In worldwide, the biomass has become important and presently, is an important tool in implementation of emerging carbon credit mechanism (Mugasha et al. 2013). Numerous advantages will result from properly managed carbon sequestration projects, as well as the supply of sustainably produced energy, fiber, and timber. These advantages include support for indigenous communities, opportunities for conservation and other environmental services, and extra revenue for rural development, (Canadell and Raupach, 2008). Quantification of biomass and C-stocks has grown in importance globally and is currently a key instrument in the application of the new carbon credit market mechanism, (Mugasha et al., 2013).

In the declared regions, pasture and forest formation were predominant. The reservoirs with the biggest increases in carbon tons were Aboveground Biomass (AGB) and Belowground Biomass (BGB), yielding a 2% overall gain over the current situation. This emphasizes how crucial command and control instruments and incentives are for restoring forests, Soares et al. (2023).

Forest ecosystems have been determined to be the largest carbon sinks among all terrestrial ecosystems, depending on their capacity, Paladini et al. (2009).

The tree will store carbon if its intake of carbon dioxide during photosynthesis is greater than its annual release of carbon dioxide through respiration (carbon sequestration). Therefore, a tree that has a net accumulation of carbon during a year (tree growth) also has a net production of oxygen, Abhijit et al. (2017).

Eucalyptus gomphocephala, Myrtaceae family, is known for its height growth (up to 40 meters) and dense wood, making it a significant contributor to AGB. *E. gomphocephala* is fast growing tree and it have produced superior wood yields with good properties of wood. That can be used to produce solid wood which use in many industries, including furniture, poxes, poles, Wooden moldings, pallets, scaffolds, glued laminated wood, doors, windows, flooring and rotative veneers to make plywood. Its green, dry weight of total biomass and total volume of stem were 594.384 ±96.040 and 429.240 ±69.408 (ton/feddan) and 585.928 ±80.023 (m3/ feddan), Ismail et al. (2024).

This study aims to quantify Biomass, carbon storage and CO_2 sequestrate according to main tree components of *E. gomphocephala* as a linear plantations in new reclaimed land.

MATERIALS AND METHODS

This study was carried out on ***Eucalyptus gomphocephala*** Dehn (tuart) trees, belong Fam. Myrtaceae. That planted as a boundary plantations at Aly Mubarak Experimental farm - South El-Tahrir, Horticulture Research Station, located in the El-Bustan area, El- Behiera Governorate, Egypt. The farm is located at a latitude of 33°30′1.4’’N, a longitude of 30°19′ 10.9’’E, and an altitude of 21 m above sea level. The soil belongs to the textural sand class with 91% sand, 5% silt and 4% clay. The trees were planted during April 1999. The trees planted in a 400-meter-long line. 400 trees were planted with a distance of one meter between the trees. The aims of this study assess of the biomass, carbon content, carbon sequestration and oxygen release of trees at age 22 years.

Trees samples:

The total number planted was 400 trees. The number of trees was counted, which was 344 in the year 2021, In addition to 33 trees that were previously cut down. The diameter at breast height (dbh) determined of all trees by measuring tape (cm). The total number of trees was divided into three classes according to the dbh measurement. The dbh ranged from 31 to 42 cm in the first class, that has 165 trees, from 22 to 30 cm in the second class, that has 154 trees and from 18 to 21 cm in the third class, that has 25 trees, the difference in tree growth is attributed to genetic isolation resulting from seed propagation. The price of wood was estimated as Egyptian pounds according to the local market price for the site in 2021. Three sample trees belonging to etch class were selected according to the average of diameter, and cut dawned during May 2021, **(Table 1)** Then the growth parameter and biomass were estimated.

Table (1). Classes and mean price of *Eucalyptus gomphocephala* trees planted as a linear plantation of 400 m, at age 22 years.

Parameters / Class of trees	Average dbh (cm)	Number of trees	Average price of tree wood (EGP)
Class 1	**36.50**	**165**	**2000**
Class 2	**26.00**	**154**	**1600**
Class 3	**19.50**	**25**	**900**
Mean price	**1500**		

Class (1): Av. dbh= 40.07 ± 1.90 cm, Class (2): Av. dbh=29.00 ± 1.00 cm, Class (3): Av. dbh=19.34 ± 1.25 cm

Tree height:

Total tree height (m) was determined by measuring tape from 20 cm above the soil surface to the top of tree. Merchantable height (M) was determined from 20 cm above soil surface to 4cm diameter.

Tree biomass:

The tree is divided into main stem, branches (up to 0.5 cm in diameter) and foliage (leaves, branches less than 0.5 cm, and fruits). The main trunk (outside bark) was divided to successive logs of 2.5 m, by a chain saw. In the field, the green weights (Kg/tree) of each part tree were weighted by a digital scale (with an accuracy of ± 0.1 kg). Dry biomass (Kg/tree) was determined. A 5 cm disk was taken from each part of the main trunk, and 1 Kg from branches and foliage was taken. The foliage oven dried at 70˚C and the stem and branches at 103± 2˚C until constant t weights. The dry biomass of each part of the tree and the total dry and green above ground biomass were calculated using the fresh weight: dry weight ratios for each tree part. Above ground biomass had assessed by sum total of main stem, branches and foliage (Kg/tree).

Stem wood volume calculation:

The diameter and length of all parts of the main bole were measured to estimate the total size of the trunk (m^3), using Samilian's formula (De Gier, 2003).

Basal area: Basal area (m^2/tree) at dbh was calculated for each tree.

Carbon content (C):

Carbon contents of proportions of tree and total above ground biomass (ABG) were calculated from the sum of dry biomass fractions and the commonly accepted generic conversion factor of 0.5 (Chave et al., 2005). The carbon content percentages of stem, branches and foliage of the tree were calculated relative to C content of above ground biomass.

Carbon dioxide sequestered (CO_2/tree/y):

Carbon dioxide sequestered by the tree had determined by multiply the weight of carbon storage in the tree by 3.6663 (Based on the atomic weight of C has 12, and CO_2 has an atomic weight of 44, therefore to convert C to carbon-di-oxide equivalence (CO_2e), the ratio of 44/12 was used, or 3.6663 t of CO_2 for every 1 t of C (Romm, 2008). Divided CO_2e by the age of the tree to get the carbon dioxide that the tree sequesters per year. 1 ton (Mg) carbon-di-oxide equivalence (CO_2e) is equal to 1 Certified Emission Reduction (CERs), UNFCCC (2020).

Statistical Analysis:

The average and standard deviation of the parameters were calculated by The SPSS software program.

RESULTS AND DISCUSSIONS

Growth parameters of *Eucalyptus gomphocephala* trees:

Plantation of *Eucalyptus gomphocephala* trees as an intensive boundary, hence the distance between trees 1 m. Resulted in a great variation in tree growth due to genetic isolation according to seed propagation. They were divided into three classes (1, 2 and 3) according to diameter at breast height (dbh) measurement. The largest number of trees was in class (1) has average dbh of 40.07±1.90 cm, followed by class (2) has dbh of 29.00± 1.00 cm, then class (3) has dbh of 19.34 ± 1.25 cm, **Table (2).** The average of total height and Merchantable height of tree in classes (1), (2) and (3) were (32.33 ± 2.51, 24.00 ± 1.00 and 20.0 ± 0.82 m) and (28.33 ± 1.53, 20.33 ± 1.53 and 17.00 ± 0.82 m), respectively. Basal area and merchantable volume in classes (1), (2) and (3) were (1256.67± 120.21, 656.0 ± 45.09 and 290.0 ± 45.83 cm2) and (0.9627 ± 0.0025, 0.4433 ± 0.0055 and 0.156 ± 0.0036 m3/tree), respectively.

Table (2). The average of growth parameters and standard deviation of three classes of *Eucalyptus gomphocephala* trees at age of 22 years.

Classes & No. trees / Parameters	Class (1) 165 trees	Class (2) 154 trees	Class (3) 25 trees
Total height of tree (m)	32.33 ± 2.51	24.00 ± 1.00	20.00 ± 0.82
Merchantable height of tree (m)	28.33 ± 1.53	20.33 ± 1.53	17.00 ± 0.82
dbh (cm)	40.07 ± 1.90	29.00 ± 1.00	19.34 ± 1.25
Basal area (cm^2)	1256.67± 120.21	656.0 ± 45.09	290.0 ± 45.83
Merchantable volume (m^3/tree)	0.9627 ± 0.0025	0.4433 ± 0.0055	0.156 ± 0.0036

dbh = Diameter at breast height, Mean values ± standard deviation.
Class (1): Av. dbh= 40.07 ± 1.90 cm, Class (2): Av. dbh=29.00 ± 1.00 cm,
Class (3): Av. dbh=19.34 ± 1.25 cm

Biomass, carbon content, CO_2 sequestered of *Eucalyptus gomphocephala* trees:

As the tree biomass increases, the distribution of biomass becomes more similar between branches and foliage, and tends to increase in branches than in foliage**, Table (3).** In class (1) of *E. gomphocephala* trees, green and dry weight of stem were (963.33 ±179.19 and 612.67 ± 93.62 Kg/tree) > foliage (255.0 ± 9.17 and 118.33 ± 3.40 Kg/tree) > branches (152.33 ± 7.50 and 120.67 ± 4.92 Kg/tree), respectively. carbon content and CO_2 sequestered of stem were (306.34 ± 46.81 Kg/tree and 51.05 ± 7.80 Kg/tree/y) > branches (60.34 ± 2.46 Kg/tree and 10.06 ± 0.41 Kg/tree/y) > foliage (59.17±1.70 and 9.86 ± 0.28 Kg/tree/y), respectively. Carbon content % of stem was 71.94 >branches 14.17 > foliage 13.89 %. The average of above ground biomass (AGB) in class (1) of *E. gomphocephala* trees were 851.67 ± 101.35 Kg/tree of dry weight, that sequester CO_2 70.97 ± 8.45Kg/tree/y.

Table (3). Biomass, carbon content, CO_2 sequestrate in the class (1) of *Eucalyptus gomphocephala* tree.

Proportion of tree / Parameters	Stem	Branches	Foliage	AGB
Green weight (Kg/tree)	963.33 ±179.19	152.33 ± 7.50	255.0 ± 9.17	1370.67 ±158.65
Dry weight (Kg/tree)	612.67 ± 93.62	120.67 ± 4.92	118.33 ± 3.40	851.67 ± 101.35
Carbon content (Kg/tree)	306.34 ±46.81	±2.46 60.34	59.17±1.70	425.84 ± 50.68
C content (%)	71.94 %	14.17 %	13.89 %	100.00 %
CO_2 sequestered (Kg/ tree/y)	51.05 ± 7.80	10.06 ± 0.41	± 0.28 9.86	70.97 ± 8.45

AGB = Above ground biomass, Mean values ± standard deviation.

Green and dry weight of stem of class (2) of *E. gomphocephala* trees (**Table 4)** were (576.67 ± 78.47 and 367.33±47.68 Kg/tree) > foliage (92.33 ± 24.21 and 44.0 ± 12.29 Kg/tree) > Branches (40.00 ± 18.03 and 44.0 ± 12.29). Carbon content and CO_2 sequestered were descending order from stem (183.67±23.84 Kg/tree and 30.61 ± 3.97 Kg/tree/y) to foliage (22.00 ±6.15 Kg/tree and 3.67 ± 1.02 Kg/tree/y) then branches (14.67± 6.66 Kg/tree and 2.44 ± 1.11 Kg/tree/y). The carbon content percentage was descending order from stem (83.36%) followed by foliage (9.98 %) then branches (6.66%). The average of Carbon content and CO_2 sequestered of Above ground biomass (AGB) in class (2) of *E. gomphocephala* trees were (220.33 ± 36.65 Kg/tree and 36.72 ± 6.11 Kg/tree/y).

Table (4). Biomass, carbon content, carbon sequestration in the class (2) of *Eucalyptus gomphocephala* trees.

Proportion of tree / Parameters	Stem	Branches	Foliage	AGB
Green weight (Kg/tree)	576.67 ± 78.47	40.00 ± 18.03	92.33 ± 24.21	709.0 ± 120.62
Dry weight (Kg/tree)	367.33±47.68	29.33 ± 13.32	44.0 ± 12.29	440.66 ± 73.29
Carbon content (Kg/tree)	183.67±23.84	14.67± 6.66	22.00 ±6.15	220.33 ± 36.65
C content (%)	83.36 %	6.66 %	9.98 %	100.00 %
CO_2 sequestered (Kg/ tree/y)	30.61 ± 3.97	2.44 ± 1.11	3.67 ± 1.02	36.72 ± 6.11

AGB = Above ground biomass, Mean values ± standard deviation.

The trees in class (3) were the least numerous (25 trees) and the least of biomass, carbon content and carbon sequestered as compared to the class (1) and (2), **(Table 5).** Green and dry weight in class (3) of *E. gomphocephala* trees were descending order from stem were (123.33 ±15.29 and 78.67 ± 10.21 Kg/tree) to foliage were (33.33 ± 15.29 and 15.33 ±7.09 Kg/tree) then branches were (16.0 ± 12.17 and 12.60 ± 9.46 Kg/tree). Carbon content and CO_2 sequestered were descending order from stem were (39.34 ± 5.11 Kg/tree and 6.56 ±0.85 Kg/tree/y) to foliage were (7.67± 3.55 Kg/tree and 1.28 ± 0.59 Kg/tree/y) then branches were (6.30 ± 4.73 Kg/tree and 1.05 ± 0.79 Kg/tree/y).

Table (5). Biomass, carbon content, CO_2 sequestrate in the class (3) of *Eucalyptus gomphocephala* trees.

Proportion of tree / Parameters	Stem	Branches	Foliage	AGB
Green weight (Kg/tree)	123.33 ±15.29	16.0 ± 12.17	33.33 ± 15.29	172.67± 42.44
Dry weight (Kg/tree)	78.67 ± 10.21	12.60 ± 9.46	15.33 ±7.09	106.6 ±26.5
Carbon content (Kg/tree)	39.34 ± 5.11	6.30 ± 4.73	± 3.55 7.67	53.30 ± 13.25
C content (%)	73.80 %	11.81 %	14.39 %	100.00 %
CO_2 sequestered (Kg/tree/y)	6.56 ±0.85	1.05 ± 0.79	1.28 ± 0.59	8.88 ± 2.21

AGB = Above ground biomass, Mean values ± standard deviation.

Most species of eucalypts are superior in growth and production of biomass to other tree species, as they adapted to varying environmental conditions and deepen their roots, which allows them to obtain their nutritional needs even in poor soil. Abhijit et al. (2017) indicated that *Eucalyptus globus* superior over 28 tree species as AGB (above ground biomass) and AGC (Carbon content of AGB). Biomass will affect the size of stem diameter. Similarly, the specific wood density will affect density of plant cells. The increase in carbon stock will be followed by the size of the stem diameter, Lubis et al. (2013).

The results are consistent with what many authors have found. Biomass estimation and the sequestered carbon according to components of living trees are in accordance with the fact that the largest portion of aboveground part of tree volume represents the stem, Paladini et al. (2009). the estimated total dry biomass of *Eucalyptus tereticornis* was 225 Mg/ha (ton/ha) with biomass accumulation in decreasing order of bole>roots>twigs and leaves>fuelwood (branches). Mean C-concentration in different tree components varied from 43-46%. C-stocks ranged from 2.30 in fuel wood to 69.8 Mg/ha in bole, (Kumar et al., 2019). *Eucalyptus* plantations have sequestered significant amount of carbon in different components of trees. stem wood sequestered 50 per cent carbon to the above ground biomass carbon, since it contributes more biomass production, Divya et al.(2022).

Total carbon content and CO_2 sequestered (Ton) of AGB for 344 trees in linear plantation (400 m) of *Eucalyptus gomphocephala* trees at age of 22 years:

The average of Carbon content (ton) and CERs = CO_2 sequestered (ton/ year), hence calculate to above ground biomass (AGB) for the total tees (344 trees), that boundary plantation of *E. gomphocephala* **(Table 6).** Total trees in class (1) had the greatest contribution to CO_2 sequestrated annually (11.71 ton/year), followed by total trees in class (2), 5.65 ton/year then in class (3) 0.22 ton/year. According to above ground biomass only, we can have 17.58 CERs (Certified Emission Reduction), from 344 *E. gomphocephala* trees as a linear plantation in the new reclamation lands. However, the CERs will be higher as it includes carbon stored in below ground biomass and carbon stored in the soil. Estimating the amount of carbon in forest woody biomass is crucial for mitigating the greenhouse effect and for nations who ratified the Kyoto Protocol to be required to report on their carbon dioxide (CO_2) emissions and removals from the forestry sector, Paladini et al. (2009). From the research results, it became clear that, the greater biomass of the tree, the greater the amount of CO_2 sequestered to tree per year. While providing raw material for many wood industries and non-forestry products. While sustainable forest management and forest products lead to improved lifestyles and a reduced carbon footprint, trees increase the amount of carbon removed from the atmosphere (FAO, 2016).

Table (6). Total carbon content and CO_2 sequestered (Ton) of AGB for 344 trees in linear plantation (400 m) of *Eucalyptus gomphocephala* trees at age of 22 years.

Classes / Parameters	Class (1)	Class (2)	Class (3)	Total
Carbon content (ton)	**70.26**	**33.93**	**1.33**	**105.52**
CO_2 sequestered (Ton) = CERs	**11.71**	**5.65**	**0.22**	**17.58**
CO2e %	**66.61**	**32.14**	**1.25**	**100**

CERs = Certified Emission Reduction = CO_2 sequestered (ton/ year)
Class (1): Av. dbh= 40.07 ± 1.90 cm, Class (2): Av. dbh=29.00 ± 1.00 cm,
Class (3): Av. dbh=19.34 ± 1.25 cm

Conclusion: This research focus on the economic and environmental value of *Eucalyptus gomphocephala* trees plantation as a boundary in new reclaimed lands. The Forestry and Timber Trees Research Department has recommended this species in more than one study for inclusion in afforestation plans, windbreaks, and shelterbelts in new reclaimed lands, due to its tolerance to harsh desert conditions, while providing superior biomass and sequestering large amounts of carbon annually. The average of carbon content and CO_2 sequestrated of Above ground biomass (AGB) of *E. gomphocephala* trees that had average dbh of 40.07 ± 1.90 cm were (425.84 ± 50.68 Kg/tree and 70.97 ± 8.45 Kg/tree/y). Planting trees in a 400 m line at a planting distance of 1m at the age of 22 years can achieve carbon credits of approximately 17.58 CERs according to (AGB) only. This research provides applied information on a tree species that grow well in newly reclaimed lands conditions, both in terms of biomass and carbon content, making it a valuable component of windbreaks and shelterbelts, with economical values.

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الملخص العربى

الكتلة الحيوية والكربون الذي تختزنه سنويا أشجار (*Eucalyptus gomphocephala*) المزروعة كحدود للمزارع في أراضي الاستصلاح الجديدة.

مها فاروق محمد إسماعيل – مجدي إسماعيل بهنسي – مني مصطفي عباس
قسم بحوث الغابات والأشجار الخشبية – معهد بحوث البساتين – مركز البحوث الزراعية

أجريت هذه الدراسة على أشجار الكافور (*Eucalyptus gomphocephala*) المزروعة في خط طولي (400 متر) على حدود مزرعة علي مبارك بمحطة بحوث جنوب التحرير التابعة لمركز البحوث الزراعية. وكان الهدف من الدراسة تقدير الكتلة الحيوية، وثاني أكسيد الكربون المخزن، وشهادات ائتمان الكربون. وقد قُسّم إجمالي عدد الأشجار (344 شجرة) إلى ثلاث فئات وفقًا لقياس dbh. تراوحت أبعاد dbh للفئة (1) بين 31 و42 سم، والفئة (2) بين 22 و30 سم، والفئة (3) بين 18 و21 سم. بلغ متوسط الوزن الجاف للكتلة الحيوية فوق الأرض (AGB) في الفئات (1) و(2) و(3) 851.67 ± 101.35، و440.66 ± 73.29، و106.6 ± 26.5 كجم/شجرة، على التوالي. وقـد خزّنت هذه الفئات من الكتلة الحـيوية ثاني أكـسيد الكربون بمقدار 70.97 ± 8.45، و36.72 ± 6.11، و8.88 ± 2.21 كجم/ شجرة/سنة في الفئات (1) و(2) و(3) على التوالي. بلـغ إجمالي ثانـي أكسيد الكربون المخزن لـ 344 شجرة من نوع *E. gomphocephala* كمزرعة حدودية في أراضي الاستصلاح الجديدة 17.58 طنًا سنويًا وهو ما يعادل وحدات خفض الانبعاثات المعتمدة (CERs).