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Ecological importance and role in carbon sequestration of urban trees (In case of Isparta Anadolu Neighborhood)

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Abstract: As result of human activities, greenhouse gasses include carbon dioxide, methane, water vapor, nitrous oxides etc. in atmosphere have increased. It is called "Global Warming" that greenhouse gasses cause of artificial increase of heat in atmosphere and on the face of the earth. In nowadays, it probably is perceived that it is dangerous and imperceptible about threat of global warming for life. But this problem is slowly and slyly grows up. However it will be effect negative to all of life and cause to become extinct of human. Most of concentrated of greenhouse gasses are be seen (about between 70% and-80%) in urban areas and environment. In nowadays, urban tress which is still under debate and discussed rehabilitation as concept, first approach to consider in C sequestration and rehabilitation of urban ecosystem. In addition, establishment of new urban trees is also very important for urban planning/management and social/environmental functions. The urban road trees have an important effect on carbon sequestrating a decreasing the amount of CO_2 release at the city center. The rapid growth rates of urban trees compared with rural forest trees and the carbon sequestration relationship can be partly explained by the relatively large proportion of leaf biomass. The purpose of this work is to discuss an approach to the determination of urban tree biomass and carbon sequestration values. In this study; the biomass and carbon sequestration values of the trees were determined and interpreted using the tree inventory data obtained from the project of TUBITAK 110Y301 (Gul, et al., 2015). Isparta city Anadolu neighborhood was selected as the study area and the data of the existing urban trees were analyzed. As a result of the study, it has been determined that the number of trees, tree species, leaf surface area, age and height characteristics may increase or affect the biomass and carbon sequestration values in the area. Determination of biomass and carbon sequestration values of urban trees and calculation of their monetary values will be a strategic parameter especially in the case of operational studies against global warming. In particular, the environmental impacts of trees and forests in urban areas will be scientifically demonstrated and will play an important role in raising public awareness.
Keywords: Urban trees, Biomass, Carbon sequestration, Ecology

1. Introduction

In recent years, intensifying human and nature associations have caused factors such as extreme and unconscious consumption of natural resources, environmental problems and distorted urbanization. As a result, unfortunately, the fact that we directly and indirectly affect our world and our living spaces negatively has become a fact accepted by all. The view that global warming and possible effects are one of the important elements threatening the future of humanity and life is widely accepted. "GLOBAL WARMING" is defined as the increase in the amount of greenhouse gases given to the atmospheric environment, which is the result of human activities, and the resultant increase in greenhouse effect, artificial increase of some atmospheric strata and earth temperature. In particular, about 97% of carbon dioxide in the world is naturally released. As a result of human activities, it contributes to greenhouse gases in the atmosphere by about 3%. Although the human effect of total emission has a small percentage, experts have argued that human-made greenhouse gases are in a position to degrade natural balances. Indeed, scientific evidence proves this. Especially in the 20-30 years, the end result of multifaceted human activities is an accepted approach where the greenhouse gases are constantly increasing in atmospheric concentrations. It is widely accepted that this increase leads to the gradual degradation of natural balances or ecosystems (Gül et al., 2009). Global warming, which has become a serious problem on the world scale, can be perceived as a development that is threatening the life cycle but is far too remote or uncertain to worry. However, it is stated that this problem which develops slowly and insidiously may affect the life cycle negatively in the future and may even lead to the extinction of human generation on earth (UNFCCC, 2005b).

Our planet's reserve areas for CO_2 are known to be the atmosphere, oceans and terrestrial biosphere environments. A significant portion of the terrestrial biosphere is forests and has an important role in global warming and climate change. Forests and other green areas as living organisms that photosynthesize absorb the free CO_2 in the atmosphere, stabilize them in more stable complex compounds and contribute to their long-term storage. For this purpose, one of the most important strategies for global warming and climate change in developed countries is to store CO_2 in the forest ecosystem (plant, dead cover and soil). This strategy is generally described as carbon sequestration. Urban trees and urban forests have an important position in order to sequestration CO_2 in the city centers. (Gül et al., 2009).

Urban trees have a very important function in order to increase people's quality of life in the city centers, to improve the aesthetic of the city in terms of visual and ecological aspects, to reduce carbon dioxide emissions and to carbon sequestration.

The open and green spaces that are important for the discipline of landscape architecture play a major role in the improvement of urban ecosystem such as urban heat island effect, carbon sequestration. In this context, the contribution of the urban green areas to the urban ecosystem, has become a need to be determined by scientific research.

The aim of this study is to demonstrate the importance of ecological functions of urban forests on biomass and carbon sequestration, to examine the inventory results of existing trees in Isparta Anadolu Neighborhood, to calculate and interpret the biomass and carbon sequestration values.

2. Material and method

2.1. Material

An effective inventory study is required for this study to take place. For this study, Anadolu Neighborhood, one of the most important neighbourhood of Isparta City, was chosen. The reason for the selection of Anadolu neighborhood as a study area is its proximity to the city center, its borders with intercity roads, the amount of green space is high and the location of the neighborhood. The neighborhood has very favorable conditions for the application of the working method in terms of the amount of green space, number of trees and tree ages (Figure 2.1., Figure 2.2.).

Figure 0.1. The view of Isparta development plan (Gül et al., 2015)

Figure 0.2. The View of Anadolu Neighborhood Borders (Gül et al., 2015)

2.2. Methods

In the study, the inventory data obtained from TÜBİTAK 110Y301 Project were utilized (Gül, et al., 2015). For this purpose, biomass and carbon sequestration of the trees were calculated with the formulas given below by tree inventory data in the Isparta Anadolu Neighborhood. Through this process, some numerical information about inventory of the trees were obtained and individual ecological effects of the trees were determined.

2.2.1. Obtaining tree inventory information by land practices

The following data were obtained from the inventory studies were carried out on the TÜBİTAK 110Y301 (Urban Trees Information System Model) Project by Gül et al. (2015). For this purpose "Urban Trees Inventory Information Form" has been established for the field studies. Inventory studies for forests and trees are very important in terms of sustainable and ecological design (Gül et al., 2014). It was proposed by Form Gül et al., (2015) and is given in

Table 0.1. The required data in the urban tree data sheet were determined in the field studies and the following formulas were used to calculate the biomass and carbon sequestration capacities. The parameters to be used when making structural measurements of trees were also made according to the standards recommended by Gül et al., (2015).

Table 0.1. Urban Trees Inventory Information Form (Gül et al., 2015)

Urban Trees Inventory Information Form								
Date of registration:……..…./………...…./…………...….								
Tree sequence number	Latin name:	Turkish name:	Age:	Tree Length(m):	Body Height (m):	Body Diameter (cm). (d: 1.30m)	Crown Width (m)	Percent loss of crown covering (%) (%)
1								

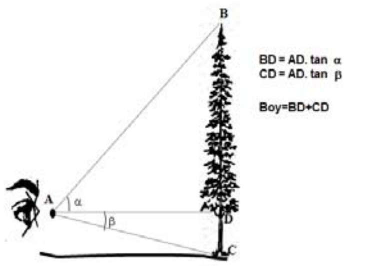

Figure 2.3. Calculation of length according to trigonometric basis

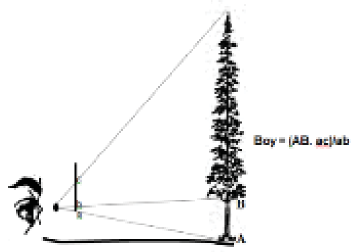

Figure 2.4. Length calculation using ruler

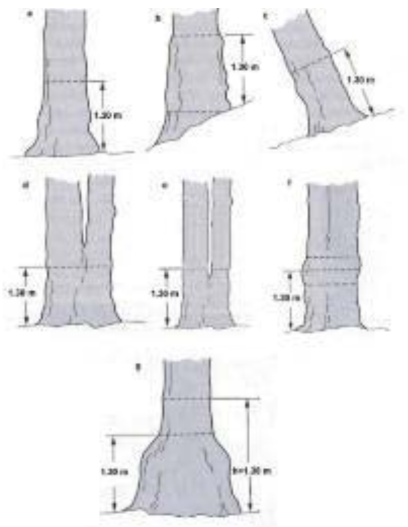

Figure 2.5. Diameter measurement applications in trees (Avery and Burkhart, 1994)

2.2.2. Biomass and carbon sequestration calculations

Leaf surface area and biomass were determined with the help of the following formulas, taking into consideration the tree size, chest diameter, crown top surface area, top diameter, crown height, crown loss ratio and shading factor values of each tree. Calculation of tree leaf surface and leaf biomass were done according to chest diameter. However, sufficient accuracy can not be achieved in the regression equations generated during calculations according to chest diameter. Only 64% of the leaf surface as a function of chest diameter; And 54% of leaf biomass can be explained. However, it has been found that leaf surface and leaf biomass are better explained when some other parameters of the tree participate in the calculation. Accordingly, in calculating leaf area or dry biomass weight, 91% of leaf surface area and 92% of leaf biomass are explained using chest diameter, shading factor, crown top surface area, top diameter and crown length variables. In our study, the equation for the leaf area was used as follows (Nowak, 1996).

$$Y = e^{(-4.3309 + 0.2942H + 0.7312D + 5.7217Sh - 0.0148S)}$$

Since the coefficients of the equation in question are obtained by the linearization of the logarithmic equation, it must be summed with the correction factor. The correction factor for the equation is taken as half of the variance. Thus, the correction term (Correction term=$\sigma^2/2$=0.1159) is obtained. In addition, the equations are used in the following way with the addition of the crown loss ratio.

$$Y = e^{(-4.3309 + 0.2942H + 0.7312D + 5.7217Sh - 0.0148S + 0.1159)} * C$$

- Y: Leaf Area (m^2);
- e: Natural logarithm;
- X: Body diameter (cm);
- Sh: Average shading factor for grown trees. (This value will be taken as 0,83 for broad leaves and 0,91 for needle leaves.)
- S: Outer peak surface area of the tree (π.D(H+D)/2);

- C: Crown loss rate;
- D: Avarege crown diameter (m);
- H: Crown Length (m)

The following equation is used for leaf biomass.

$$Y_b = e^{(1.9375+0.4184*H+0.6218*D+3.0825*Sh-0.0133*S+0.1073)}*C$$

- Yb: Leaf biomass (m2);
- e: Natural logarithm;
- X: Body diameter (cm);
- Sh: Average shading factor for grown trees. (This value will be taken as 0,83 for broad leaves and 0,91 for needle leaves.)
- S: Outer peak surface area of the tree (π.D(H+D)/2);
- C: Crown loss rate;
- D: Avarege crown diameter (m);
- H: Crown Length (m)

For the amount of carbon sequestration; According to Macaroglu (2011), carbon-stock biomass converted to carbon in mass-based carbon determination, Zhang et al. (2009) estimates that the average biomass of single tree is 49.9% 1.3 (mean + se), while carbon stocks vary between 43.7% and 55.6% relative to species. In Lamlom and Savidge (2003) 's study of 41 species, it calculated that it stored between 46.3% and 55.2% carbon. In the annex table 5.2 of the fra-2010 guide, the average coniferous trees were stock 51% carbon and deciduous trees were stock %48 carbon in the geographical climate zone in Turkey. The general acceptance is that the single tree component can be multiplied by the biomass factor of 0.5 to reach the amount of carbon stored (Nowak and Crane, 2002).

In this study, carbon sequestration formulas were used as follows.

- Amount of carbon sequestration for coniferous trees (CSct) = Leaf biomas (Yb) x 0,51
- Amount of carbon sequestration for deciduous trees (CSdt) = Leaf biomas (Yb) x 0,48

3. Results and discussion

3.1. Tree inventory data and analysis in Isparta Anadolu Neighborhood

The Anadolu neighborhood is located in the northeast of Isparta city center. It has an area of 487.798 m^2. At the same time there are 2 small parks in the neighborhood. The population of the Anadolu Neighborhood was 7510 in the year 2016. A total of 1424 trees were planted in 124 neighborhood parks and 1300 roads in Anadolu Neighborhood. When the tree species in the Anadolu Neighborhood are examined; there are *Pinus nigra subsp. Pallasiana (*36,9%)*, Cedrus libani (19,8%*)*, Catalpa bignonioides (9,*3%), *Robinia pseudoacacia 'Umbraculifera* (8,9%) and *Fraxinus excelsior (8,8%)* . When examined in terms of the ages of the trees, 48,88% are in the 6-10 age group and 44,52% are in the 11-20 age group. (Table 3.1., Table 3.2., Table 3.3.).

The total area of the Anadolu Neighborhood is 487.798 m^2, and the crown widths of the trees in the neighborhood are approximately 14.778 m^2. This proportion constitutes approximately 3% of the area (Table 3.4.).

Table 3.1. Anadolu Neighborhood tree types and percentage distribution

Plant name	Number	Percentage (%)
Abies cilicica	1	0,07
Acer platanoides	5	0,35
Ailanthus altissima	50	3,51
Betula alba	4	0,28
Biota orientalis	5	0,35
Betula pendula	2	0,14
Catalpa bignonioides	133	9,34
Cedrus libani	282	19,80
Cupressus arizonica	12	0,84
Cupressus sempervirens	3	0,21
Eleagnus angustifolia	6	0,42
Ficus carica	1	0,07
Fraxinus excelsior	126	8,85
Lagerstroemia indica	1	0,07
Morus alba	32	2,25
Morus nigra	2	0,14
Pinus nigra subsp, pallasiana	526	36,94
Platanus orientalis	29	2,04
Prunus armeniaca	7	0,49
Prunus avium	14	0,98
Prunus domestica	12	0,84
Prunus dulcis	17	1,19
Robinia pseudoacacia 'Umbraculifera'	128	8,99
Salix babylonica	8	0,56
Tilia tomentosa	18	1,26
Total	1424	100,00

Table 3.2. Anadolu Neighborhood tree age and percentage distribution

Tree Age	Number	Percentage (%)
0-10 Years	753	52,88
10 Years and More	671	47,12
Total	1424	100.00

Table 3.3. Anadolu Neighborhood tree length and percentage distribution

Tree length	Number	Percentage (%)
<3 m Small Tree	77	5,41
3 – 6,9 m Medium Tree	1074	75,42
7 – 20 m Big Tree	273	19,17
Total	1424	100,00

Table 3.4. Anadolu Neighborhood tree crown and percentage distribution

Percentage of Tree Crown	Area (m^2)	Percentage (%)
TA= Total Area (m^2)	487.798 m^2	
TACA= Total tree crown width area ($\prod r^2$) (m^2)	14.778 m^2	
(Percentage of total tree crown density in the area)TACP=100x TACA/TA		3,0%

3.2. Examination of biomass and carbon sequestration rates of trees in Anadolu Neighborhood

The total leaf surface area of 1424 trees is 63861.90 m^2 in Anadolu Neighborhood. The leaf biomass value is 3886 kilograms. The amount of carbon sequestration in total leaf biomass was calculated as 1938 kilograms. Based on the total area of the Anadolu Neighborhood, the amount of carbon sequestration per square meter was 3.97 kilograms. The individual, total biomass, leaf surface area and carbon sequestration capacity of the trees in the Anadolu Neighborhood are given in Table 3.5. In addition, the trees over 10 years old in the Anadolu Neighborhood have been identified. The average leaf surface of these trees was 1358,53 m^2, the mean biomass was 97,49 kilograms and the average carbon sequestration was 47,3 kilograms (Table 3.6.).

Table 3.5. Leaf surface area (m^2), leaf biomass value (gr) and carbon sequestration amounts of trees in Anadolu Neighborhood

Plant name	Number	Leaf Surface Area (m^2)	Leaf Biomass Value (gr)	Carbon sequestration Amounts (gr)
Abies cilicica	1	13,81	644,05	328,47
Acer platanoides	5	156,90	15793,85	7581,05
Ailanthus altissima	50	1864,49	133023,82	63851,43
Betula alba	4	169,61	12690,05	6091,22
Betula pendula	2	84,81	6345,03	3045,61
Biota orientalis	5	86,54	4560,70	2325,96
Catalpa bignonioides	133	2950,20	149741,84	71876,08
Cedrus libani	282	19655,45	1238421,70	631595,07
Cupressus arizonica	12	979,42	60964,79	31092,04
Cupressus sempervirens	3	111,95	5581,57	2846,60
Eleagnus angustifolia	6	265,78	15992,13	7676,22
Ficus carica	1	32,39	1783,49	856,08
Fraxinus excelsior	126	2758,85	183493,44	88076,85
Lagerstroemia indica	1	30,50	1613,03	774,25
Morus alba	32	2526,54	184191,13	88411,74
Morus nigra	2	114,81	5861,98	2813,75
Pinus nigra subsp, pallasiana	526	22329,19	1132310,72	577478,47
Platanus orientalis	29	4322,07	360857,07	173211,39
Prunus armeniaca	7	345,58	21404,47	10274,15
Prunus avium	14	317,09	16836,45	8081,50
Prunus domestica	12	418,03	24940,07	11971,23
Prunus dulcis	17	418,46	26303,23	12625,55
Robinia pseudoacacia 'Umbraculifera'	128	1578,71	102934,80	49408,70
Salix babylonica	8	1164,62	93052,94	44665,41
Tilia tomentosa	18	1166,08	87198,25	41855,16
Total	1424	63861,90	3886540,60	1938813,99

Table 3.6. Average leaf surface area (m^2), leaf biomass value (gr) and carbon sequestration amounts of trees/per aged 10 years and over in the Anadolu Neighborhood

Plant name	Avarage Leaf Surface Area (m^2)	Avarage Leaf Biomass Value (gr)	Avarage Carbon Sequestration Value (gr)
Acer platanoides	31,38	3158,77	1516,21
Ailanthus altissima	63,04	4679,70	2246,26
Betula pendula	46,01	3473,66	1667,35
Biota orientalis	16,43	870,61	444,01
Catalpa bignonioides	38,02	2337,56	1122,03
Cedrus libani	81,53	5287,74	2696,75
Cupressus arizonica	120,34	7512,25	3831,25
Eleagnus angustifolia	57,99	3552,85	1705,37
Fraxinus excelsior	60,51	4297,18	2062,65
Lagerstroemia indica	30,50	1613,03	774,26
Morus alba	101,03	7545,14	3621,67
Pinus nigra subsp, pallasiana	59,11	3105,23	1583,67
Platanus orientalis	158,99	13291,44	6379,89
Prunus armeniaca	44,42	2940,28	1411,33
Prunus avium	37,27	2254,60	1082,21
Prunus domestica	51,40	3180,67	1526,72
Prunus dulcis	49,60	3276,47	1572,71
Robinia pseudoacacia 'Umbraculifera'	88,19	7697,24	3694,67
Salix babylonica	145,58	11631,62	5583,18
Tilia tomentosa	77,18	5780,76	2774,76
TOTAL	1358,53	97486,80	47296,94

3.3. Examination of the relationship of urban trees within biomass and carbon sequestration

There are many positive effects of urban trees on the urban ecosystem and the people of the city with the services and contributions they provide. The most contributing factors to urban trees are increasing air quality, reducing soil erosion, reducing carbon dioxide emissions, reducing greenhouse effect, reducing noise levels, enhancing people's social relations and psychology, creating a habitat for wildlife, and increasing recreational opportunities. Urban trees have an important function in order to reduce CO_2 emissions and to carbon sequestration in the city centers.

In this study, it is predicted that in terms of biomass and carbon sequestration, the number of trees in one area, leaf surface area, tree age, play a determining role. In particular, as a strategic target against global warming, the number of trees per person is considered to be 2 trees. As a matter of fact, the number of trees in Anadolu Neighborhood is total 1424 trees and 0.19 trees per person falls. For this reason, the number of trees per capita was found to be inadequate. In this context, the number of trees in the neighborhood dimension should be increased by 10 times.

To this end, strategies have been developed in 48 cities in the United States to reduce emissions of greenhouse gases under the climate protection campaign. For example, Austin hopes to reduce 33,000 tons of CO_2 emissions after 12 years by planting between 4,700 and 15,000 trees per year in residential areas of the city (ICLEI, 1997). The proportion of CO_2 that trees consume during photosynthesis while growing actively may be greater than the release rate of gas during respiration. This will reduce the rate of CO_2 in the atmosphere. Trees around the building reduce the need for warming and weather conditions. Thus, they can reduce the CO_2 emissions that can occur with electricity generation. Trees are an important CO_2 sequestration areas in the conservation of energy for weather conditions and warming areas (Larcher, 1980). Carbon sequestration is related to the tree growth and death process, which depends on the tree species composition, age structure and health. The newly planted trees accumulate CO_2 rapidly within 20-30 years, and then the annual increase in CO_2 retained begins to decrease (Harmon et al., 1990). While Urban forests hold average of 4 to 8 tonnes / ha of CO_2, rural forests hold about 2 times more CO_2 than urban forests due to high tree density (Birdsey 1992). However, because urban trees tend to grow faster than rural trees, they have more CO_2 per tree (Jo and McPherson 1995).

In this study, grown trees were found to store much more carbon than trees growing. After reaching grown up, long-lived trees have been found to be more efficient species for carbon sequestration. Even though fast-growing trees keep more CO_2 than slow-growing trees, this advantage is lost because fast-growing trees die at a younger age.

One of the most important factors that affect the carbon sequestration of trees for a long time is the survival time of urban trees. Other factor in carbon sequestration in urban areas is the selection of the most appropriate tree species for the areas to be established.

In this study, it was seen that the appropriate species were not used according to the location properties of urban trees. For example; Needle-leaved species were used in the middle of paved pavements. This situation prevents the growth of trees in a healthy way with the effect of environmental conditions. Failure to reach the sufficient size of the trees will also cause the amount of biomass to be low. This may lead to a lower carbon capture value.

According to Jo and McPherson, (1995); the trees that do not fit the area, grow slowly, display some signs of different pressures, get sick or die early. If the production and consumption in the natural ecosystem are in a balance and complementary, it is necessary to create 'environmentally friendly' cities that meet their own consumption with their own production in urban ecosystem in the context of imitating nature. In this context, the importance of trees which use in urban areas is very large (Gül and Polat, 2009).

4. Conclusion

Nowadays, planning and managing of urban trees have been becoming increasingly important. At the same time, urban trees have been coming to the fore with using, sharing and evaluating of monetary and non-monetary services and contributions. In particular, city administrators, planners and researchers demand that the current state of urban trees and forests be learned, their values provided to the urban ecosystem be explored and applied.

As a result of this study; Biomass and carbon sequestration values were calculated on a species basis and individually by making detailed inventory of urban trees. According to this; The total number of trees in the Anatolian region of Isparta is 1424. The crown area covered by trees is 3% of the total area. There are 0.19 trees per person compared to the neighborhood population. Accordingly, the number of trees are insufficient. It has been determined that there is a mistake in choosing the tree species and that the " the right plant in the right place" usage principle has not been applied. It is estimated that the existing trees in the area have total 3886.5 kg leaf biomass and 1938.8 kg carbon sequestration. The highest values per tree in terms of biomass and carbon sequestration in tree species were; *Platanus orientalis, Salix babylonica Cupressus arizonica, Robinia pseudoacacia 'Umbraculifera'* and *Morus alba* species.

At the end of the study; the number of trees, tree species, leaf surface area, age and height characteristics may increase or affect the biomass and carbon sequestration value in the vicinity. Determination of biomass and carbon sequestration values of urban trees and calculation of their monetary values will be an important strategic parameter in the urban heat island mitigation and operational studies against global warming. It will especially play an important role in raising public awareness. Thanks to this study approach; The environmental effects of the trees and forests in the cities will be scientifically demonstrated and they will be more effective in planning and management of the city.

As a result, a city tree information system should be established for each city in our country and strategic tree management planning should be done. Gul et al., (2015), "Urban Trees Information System Model" should be prepared for each city and a database with detailed tree inventory should be prepared. With the database to be constructed, it will be possible to calculate the urban trees' services and contributions to the urban ecosystem, particularly biomass and carbon storage, in concrete terms. In order to make the cities sustainable, livable and healthy, urban heat island effect and reduction of carbon emissions should be the priority action. For this, it is possible to increase the number of trees with the principle of "the right plant in the right place" to realize the importance of urban trees and forests, to diversify scientific researches and to transform the strategic decisions of city trees into actions.

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