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Investigation of Biomass Efficiency Assessment Methods of Open Green Areas for Sustainable Cities

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Abstract
One of the most important environmental problems in today's world is climate change caused by greenhouse gases. Due to the increase in CO2 emissions from greenhouse gases, climate change is increasing and moving towards the point of no return. In this process, many ideas have been developed to combat climate change. One of these ideas is that cities should be sustainable. In order for cities to be sustainable, activities such as expanding the use of renewable energy resources in cities, increasing green and environmentally friendly transportation, improving air quality, and minimizing carbon emissions should be carried out. In this context, open green areas have important effects in terms of improving air quality, reducing the heat island effect in cities and especially keeping carbon emissions to a minimum. Thus, the efficiency and productivity of carbon capture and storage of green areas come to the fore. There are several methods to measure the carbon capture and storage efficiency of green areas and to evaluate their efficiency. In this study, the methods used in determining open green areas in cities and evaluating biomass productivity in these areas will be examined.
Keywords: Sustainable Urban Development; Climate Change; Green Areas; Biomass Efficiency.

1. Introduction

Humankind lived as hunter-gatherers in the early days of their existence on earth. In this process, its relations with nature have been within the framework of gathering and prey-hunter relationship. This relationship, which continues throughout certain processes and formations, has completely changed with the discovery of agriculture and settled life, and it has turned into a lifestyle in which humankind has become a hunter. With this new lifestyle, for the first time in the world, radical changes related to human activities have begun to occur. One of these changes is the urbanization phenomenon that started with the settled life that meets almost all the needs of human beings, especially the basic needs. With urbanization, the natural landscape elements of the earth were changed and reformed, and cultural landscape elements were started to be formed by arranging them to respond to human use. Thus, destruction started on natural resources and all the elements that constitute the ecosystem as a whole, and natural processes-formations and changes in climatic conditions began. In times when the phenomenon of urbanization was not develop and became dominant as it is today, climatic events were changing with natural processes. However, due to reasons such as industrialization, artificial surfaces, increased carbon gas emissions, transportation, increased population, consumption frenzy, deterioration of habitats and rapid consumption of natural resources, rapid and unnatural changes in the climate have begun to occur. Thus, we come across the phenomenon of climate change, which seems like a new phenomenon, but has continued its existence since the first moments of life.

Increased use of fossil fuels with urbanization, change in land use, reduction of forest areas, acceleration of greenhouse gas accumulation due to high human activities such as the spread of industrialization and the disruption of the ecological balance due to the natural greenhouse effect increases the effect of climate change, with the surface temperatures of the earth rising above the average (İğci et.al., 2019). The way to prevent climate change and warming effect is to slow down the greenhouse gases and especially the carbon dioxide emission, which is the main cause of climate change, and at the same time to be recovered. This approach suggests that there should be entities that capture and store carbon from cities. In this context, the closest answer that can come to mind is vegetative masses. When we think about what the biomass resources could be in a city, a single tree can be a biomass resource, as well as urban green areas with plant communities that come together naturally or artificially. Urban green spaces are also highly functional areas, especially in ecological dimensions, in the fight against climate change in sustainable cities. In this approach, in this study, the methods by which efficiency is calculated in terms of carbon storage and retention of urban green spaces in sustainable cities will be examined.

2. Material and Methods

The quality of life in a city is directly proportional to the amount of urban green spaces in that city. Urban green spaces are a very important urban element in terms of the climate of the world as well as the quality of urban life and urban health. In this study, urban green areas, which are indispensable for sustainable cities, form the material of the study, as they are biomass resources and have the characteristics of carbon capture. The method of the study, on the other hand, consists of examining and evaluating the studies conducted on both regional and global scales on urban green areas, biomass concepts, biomass resources and biomass calculations.

3. Biomass Concept and Biomass Resources in Cities

Biomass corresponds to the amount of mass formed by the trunk, branch, leaf, bark and roots of trees. (Işık, 2013). On the other hand, Alemdağ (2008) and Saraçoğlu (1998; 2000) defined the vegetative mass (biomass) as the total mass of organisms consisting of a population or a community in a given time (Sakıcı et.al.,2004). Thus, plants found alone or as a community constitute biomass resources. In addition, IPCC biomass resources Asan et.al. (2005), by opening a big title to forest ecosystems, he defined the places where carbon accumulates from forest areas as "carbon pools". In addition, he grouped carbon pools under three main headings as living biomass, dead organic matter and soil, and divided them into five sub-categories as aboveground biomass, underground biomass, dead wood, litter and soil organic matter (Değermenci, 2016). According to the categorization made by the IPCC, plants are both above-ground and underground biomass resources, being a living biomass resource. Plant parts regarding the evaluation of plants as living biomass resources are as in Figure 1.

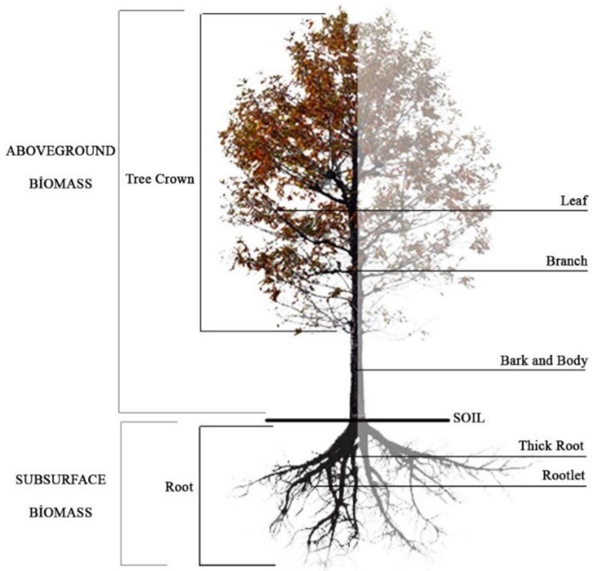

Figure 1. Biomass elements on a tree (arranged according to Gülsunar, 2011).

Plants perform photosynthesis in order to maintain their vital activities. Plants meet the carbon they need in the photosynthesis process from CO2 molecules released into the nature. Thus, with the return of CO2 to the nature as oxygen, both nature and cities form the basis of biomass resources due to the activities of plants in carbon capture. Bolund. et.al. (1999), in addition to the benefits of carbon retention, trees in cities provide a variety of ecosystem services including protection of biodiversity, removal of atmospheric pollutants, noise reduction / prevention, reduction of urban heat island, microclimate regulation, soil regulation, groundwater feeding, soil erosion prevention (Singh et.al., 2010). In addition, ecosystem services provided by trees in cities differ according to Forman (2014) according to the species of plants, their ages and the characteristics of the environment in which they are found. In this approach, a comparison between a tree in a park and a road tree will show that a tree in the park collects more atmospheric pollutants. Likewise, a tree in a park will hold more carbon than a road tree (Hepcan, 2017). Due to the fact that the efficiency of plants in terms of carbon capture in cities varies according to their environment, the types of urban areas where trees are located gain importance. In addition, it is possible to say that the plant density in the area will also have an important effect. In this context, Nowak et.al. (2002) and Nowak et.al (2008) and Nowak et.al. (2013), although the density of vegetation in urban green areas is smaller than the vegetation in a forest, urban green areas also have a significant carbon storage capacity (Ovantari et.al.;2018). For this reason, urban green areas, which have a very important role at this level where the effects of climate change are approaching to the point of irreversibility; can be classified as Children's playgrounds, sports and recreation areas, neighborhood parks, pocket parks, city parks, botanical gardens, hobby gardens, zoos, urban agricultural areas, rivers, wetlands, urban forests, public buildings gardens, university campuses. In addition, urban green areas are highly efficient areas in terms of carbon since they have permeable surfaces covered with soil and / or plants. In order to increase the effectiveness of these areas on carbon emission, carbon measurements should be made and studies should be carried out to increase efficiency according to the results obtained. Thus, today, according to Nowak (2000) and Brack (2002), scientific studies have gained importance in calculating the values of carbon and other ecosystem services stored in urban green areas and Ahern et al (2014), it is the calculation of both the amount of carbon stored and the ecosystem services using measurable mathematical methods (Hepcan, 2017).

4. Biomass Carbon Calculation Methods

Before carbon calculation methods, it is necessary to examine the methods suggested by the researchers in the literature in order to obtain data about biomass types. The data obtained in this way is important in the creation of data or materials to be used in other methods.

4.1. Sampling of Biomass Types

4.1.1. Calculating the Aboveground Biomass of a Tree

In order to calculate the above-ground biomass of a tree, it is necessary to measure the diameter and height of the tree. For this, an area of 5m x 40m is first created around the tree and every tree species with a diameter between 5cm and 30cm is marked in this area. After this stage, for the diameter measurement of each tree species, a point measurement is made at a height of 1.3 m from the soil surface. However, any wounds etc. on the tree trunk at this height the measurement is made at a greater height and the body diameter is determined (Hairiah, 2001). The method of how the measurement should be made is as in Figure 2.

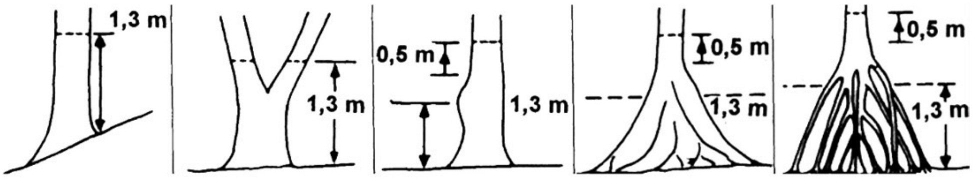

Figure 2. Measurement of tree diameter at a height of 1.3 meters (Hairiah, 2001).

The next step after measuring the diameter of the tree is to measure the tree height. The method used for this measurement is the hypotenuse rule formed by the two short sides of the triangle we use in geometry. For this measurement, the person who will measure the height of the tree holds on his arm a stick stretched at the same length to the distance between his hand and his eye. Then it moves back and forth until the tip of the tree and the top of the stick become a row (Hairiah, 2001). The method of how this measurement should be made is as in Figure 3.

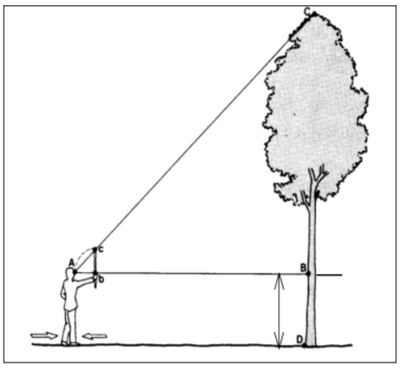

Figure 3. Measurement of tree height (Weyerhauser et.al., 2000; Hairiah, 2001).

There are a number of tools that should be used during these measurements; bands, ropes, etc. to determine boundaries, lasermeters to measure lengths and distances, cutting tools such as knives and saws, a map showing the area and plant species in the area, Google Maps with a location to determine tree locations. digital maps and several different types of tools are required.

Hairiah (2001) revealed in his study that a measurement can be made with samples taken from the measurements given in his study in order to estimate the biomass of the plant. They derived two types of formulas for these measurements. The first formula is based on length and diameter measurement.

Biomass: πr^2 cm^2 L cm x Wood Density g cm^{-3}

Hairiah (2001) proposed another formula for unbranched tree species that can be calculated using the cylinder volume of the trees.

Biomass: π $D^2hp/40$

In this formula, the component h is the length in m; The D component represents the tree diameter in cm and the p component represents the specific wood weight in g cm^{-3}

4.1.2. Calculating Subsurface Biomass of a Tree

To calculate the underground biomass, samples are taken from tree roots. Roots are classified as capillary root, fine root and coarse root. Fine roots are taken away from the cut trees, using a steel pipe of 6.4 cm in diameter and 30 cm in length at 4 points, which are naturally intact and randomly located. For the coarse root, first the tree from which the root sample will be taken is determined, then root pits of 60x180 cm are dug around this tree. The depth of the pits is dug to the depth reached by roots of 5 mm diameter. (Mısır, 2011).

4.1.3. Calculation of Dead-Living Cover and Dead Wood Biomass

In the area where herbaceous and woody species are located, 1 or 2 sampling quadrats of 1x1 m dimensions are formed randomly. The coverage degrees of the living cover remaining in these areas are determined and these living covers are removed from the soil surface and weighed. In order to determine the litter on the soil surface, litter organic matter is collected up to the mineral soil in sampling areas of 25x25 cm at 4 random locations. In addition to these steps, dead wood samples in these randomly generated areas are collected and weighed (Mısır, 2011).

4.2. Carbon Calculation Methods Based on Biomass

4.2.1. Regression Analysis Method

This method is a classical method and is widely used. The principle of the method is to calculate the obtained data using various allometric equations by passing the biomass samples obtained as mentioned above through certain processes in the laboratory environment.

According to the measurements made with the sample trees, it is the method in which all biomass components, dead-alive, dead wood and underground biomass are used, and the carbon retained in the soil is estimated with easily measurable parameters such as tree chest diameter and height.

4.2.2. Biomass Carbon Calculation with Biomass Expansion Factor

The Biomass Expansion Factor is used in biomass calculation as an important influence of a mathematical equation. Biomass expansion factor (BEF) according to Dewar et.al., (1992), Porte et.al, (2002), Fukuda et.al, (2003), Tobin et.al., (2007), is a method of determining biomass based on tree wealth value from national forest inventory data. This method is the ratio of wood density value to above-ground biomass value as a result of multiplying tree wealth by the BEF coefficient (Kocaman, et.al, (2020). Then, the subsoil biomass value is calculated by using the ratio of aboveground biomass to root. Finally, the biomass carbon stock is determined by multiplying both above-ground biomass and subsurface biomass by carbon factor (CF) (Değermenci, 2018). A few equations and mathematical values needed for the method should be known. The required equations and values have been prepared in the Global Forest Resources Assesment 2010 Country Report (FRA 2010) (Işık, 2013). The equations needed for carbon calculation are as follows (Işık, 2013).

Stage 1: Calculation of above-ground biomass

$$AGB = DGH \times FKA \times CF$$

Step 2: Calculation of subsurface biomass

$$SSB = AGB \times CF$$

Stage 3: Calculation of Live and Litter Biomass

$$AGB_{\text{(Alive and Dead Cover)}} = (AGB + SSB) \times LC$$

Stage 4: $ACTB = AGB + SSB + AGB_{\text{(Alive and Dead Cover)}}$

Stage 5: $ACTB \times C_1$ (The amount of carbon in the total biomass)

$(ACTB \times C_1) \times C_2$ (The amount of carbon in the soil)

Thus, the total amount of carbon is found by adding the carbon in the total biomass and the carbon in the soil.

In the equation;

AGB: Above-ground biomass (tonne)
PTV: Planted trunk volume (m^3)
ODW: Oven dry weight
CF: Variable used to convert planted stem volume to above-ground biomass
LC: Latitude coefficient
ACTB: The amount of carbon in the total biomass
C_1 , C_2 : Carbon value depending on forest latitude

4.2.3. Biomass Carbon Calculation with Geographic Information Systems (GIS)

Methods based on geographic information systems are widely used in scientific studies today. These systems, which do not have a limit to their area of use, can be used in numerous fields such as education, engineering, economics, sociology, architecture and health, especially in geography. Starting from the word geography, it is possible to use geographic information systems in every situation where time, space, people and other living things exist. With the 21st century, great steps have been taken, especially in spatial planning. With this understanding of planning, geographical information systems have started to be used today to plan urban green areas as a space and to make carbon calculations based on biomass in urban green areas.

In order to be able to calculate biomass with geographic information systems, various digitized and ready-to-use data in GIS environment are needed. It is possible to produce an idea about what these data will be as a result of the literature research. According to literature research, "Biomass Map should be produced" in order to calculate biomass with GIS. In this context, what the GIS and biomass calculation method can be has been exemplified by the studies of various researchers.

In a study in the literature, GIS was used to estimate carbon storage capacity at forest level. According to the method, the first stage is the data collection stage and it is the digitization of the information obtained by collecting the information about the forest biomass related to the study area. The second step is to analyze the data sets prepared in vector format according to the classical biomass estimation method. The third stage is the determination of the soil organic carbon amount calculated in raster format and the format conversions of the biomass and soil organic carbon data. The fourth and final stage is to integrate these data with ArcGIS. In addition, various allometric equations are used in GIS methods as well as other method this study, the research used two different equations in both the production of the biomass map and the calculation of the soil organic carbon amount. (Ersoy et al., 2015). Another researcher using the GIS method made a case study on forest ecosystems. The researcher divided his method into four stages. The first step is to determine the work area and all the data values and items of the work area are entered to the system. The second phase is data collection and database development. This stage forms the basis of evaluation and spatial analysis. The third stage is the determination of vegetation sinks, vegetation carbon stocks and soil carbon amounts in the study area. The fourth and final stage is the mapping and evaluation of the biomass of the forest ecosystem. The researcher made use of various materials including forest inventory data, vegetation map, satellite images, digital elevation model and soil data. The researcher reached carbon stock values by using allometric equations in his study. (Deng et al., 2011). Considering the researches in the literature, the methods and materials used in biomass or biomass carbon storage calculations with the GIS method varies.

4.2.4. Biomass Carbon Calculation with I-Tree Method

It is a model used by the US Department of Agriculture Forest Service to measure the ecosystem services provided by trees in the city and has been accepted by many international countries, Nowak et al. (1998) and Hirabayashi et al., (2012), Pace et al., (2018); Thus, it has been used in research studies in many countries around the world. Regarding the working principles of the model, USDA (2008) and Marcus (2015) I-Tree have similar tools but for different purposes. These tools, i-Tree Design, ecosystem services for trees around structures; i-Tree Canopy, ecosystem services of forest-level areas; i-Tree Streets, financial benefits of street / road trees including ecosystem services; i-Tree Storm, damage detection of trees on the street after a storm; i-Tree Vue, evaluation of tree and land cover; i-Tree Eco is the number, diameter, species etc. for any tree population. ecosystem services, especially features; i-Tree Hydro provides evaluations such as measuring changes and quality status on water basins and water surfaces (Nowak et al., 2011). In particular, the i-Tree ECO tool works based on the character data of plant species and calculates ecosystem services using parameters such as plant leaf area, leaf biomass, allometric equations. If the type information in the study area is not included in the database of the model, it will calculate according to the plant species characteristics in the model database. Therefore, using the model in regions outside the United States may pose a problem, especially for native species (Pace et al., 2018) As a result of their studies, the researchers stated that when i-Tree is used in countries other than the USA, there are differences according to various restrictions and other calculation methods / programs.

Researchers in Turkey, who used ArcGIS and i-Tree Eco model to calculate biomass, stated that the two programs produced different results. In a study, the total leaf biomass of the trees in the study area was calculated as 23,461 kg; In the calculations made with ArcGIS, it was calculated as 14.802.69 kg. Considering the trees individually, it is seen that both calculations are very close to each other. However, they stated that the difference between the overall biomass total is greater than it appears. At this point, the researchers made a second calculation by selecting one species. In this study, the biomass of Pinus nigra Arnold Subsp tree species in the calculation method made with ArcGIS was 17.35 kg; In the calculation made in the i-Tree model, it was calculated to be 15.22 kg. They mentioned that the difference between these values is tolerable for a single tree, but the researchers said that there were 306 of these plant species in the study area, stated that they created greater differences in the total amount of biomass. As a result of the researches, they predicted that the reason for these differences may be due to the use of coefficients valid in the USA in the biomass calculation of the UFORE model (Tuğluer et al., 2018)

5. Conclusion

Many methods have been reached within the scope of this study and commonly used methods have formed the basis of this study. These methods are Regression Analysis, Biomass Expansion Factor, GIS and I-tree; The methods refer to diameter and height values of plants, which are easily measurable features. The methods are examined under the headings as follows.

- Regression Analysis Method

With this method, the amount of carbon accumulated in all biomass resources (aboveground biomass, underground biomass, dead-alive cover and dead wood biomass and soil biomass) can be calculated. However, it is time-consuming and costly due to the time taken for sample collection in the study area and the evaluation of these samples under laboratory conditions.

- Biomass Expansion Factor (BEF) Method

BEF is the coefficient that converts a variable into another variable in biomass calculation. Many variables (Oven-dry weight, carbon factor) values need to be known for this method. National forest management inventories can be used for the values of these variables. For this method, the value that the researcher should obtain from the sample taken from the plant is the amount of planted stem volume. After reaching this value, it is possible to reach the result by following the steps specified in the method. As in the regression method, soil carbon calculation can be made in the method.

- Geographic Information System (GIS) Methods

This method is a method that has become widespread, especially today, with the increase in technology. As a result of examining the studies of these methods, it has been seen that there is a diverse method pool. Each researcher uses a method specific to his field of study and unique to his own. These methods provide diversity in terms of material and method. Since it is a program that works on the basis of digital mapping, it has been seen that the result product obtained in the biomass calculations to be made with GIS is the Biomass Map. Although there are several successive steps to produce this map, the common point with other methods is the use of various allometric equations. Also, in this method, soil carbon calculation can be made. From the investigations examined, it has been observed that the GIS method is particularly cost-effective and is a method with high time efficiency since it can be performed remotely.

- i-Tree Method

This method, like all other methods, is based on the easily calculable properties of the plant. This model method, which provides an easily accessible and practical use, not only measures and evaluates carbon calculation, but also measures other ecosystem services provided by plants. Although this program, which is prepared in accordance with the local coefficients of the USA, is possible to use internationally, it causes various restrictions in countries outside the USA. The reason for this is that the coefficients belonging to each country are not included in this model. Although there are no coefficients for each country in the model, there are studies in the literature in which the accuracy rates of the values obtained by the i-tree model are high. In this context, creating local plant coefficients suitable for the geographical conditions of each country for the I-tree model and developing the model in this direction will eliminate the concerns about the results to be obtained in the future studies. However, with this model, soil carbon calculation cannot be made.

As a result, the presence of biomass is very important in cities that aim to be a sustainable city. Urban green areas stand out as biomass resources in sustainable cities because they are carbon sinks thanks to the plants they contain. For this reason, biomass calculations in urban green areas should be supported, for protecting and increasing biomass in cities. Especially today, with the development of technology and the practicality of methods, city tree, a city park, an urban forest, etc. Biomass calculations can be made in urban green areas of all sizes. In this sense, it is more appropriate to use GIS in biomass calculation, since data can be used at local scales, but biomass studies will gain momentum with the development of the I-tree model on locality.

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Conflict of Interests

The authors declare no conflict of interest.

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