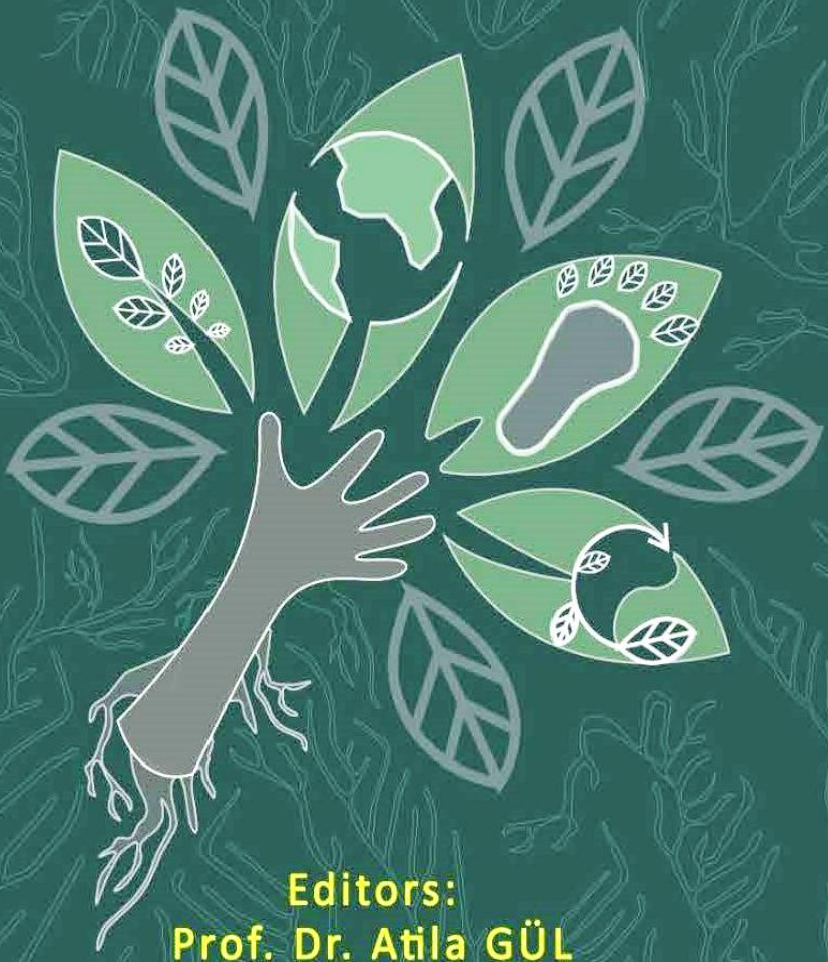
CLIMATIC CHANGE, CARBON MANAGEMENT AND GREEN SPACE SYSTEMS IN ARCHITECTURAL SCIENCES



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PREFACE

In the history of humanity, especially in the last few years, the pressure and intervention of humankind on natural resources has gradually increased. Primarily, due to urbanization, industrialization, and technological and digital developments, the gradual increase and diversification of production and consumption activities focused on economic growth has brought multifaceted problems and negativities. In this context, human beings have exploited, changed, shaped, and destroyed nature as a unilateral commodity in line with their needs and demands. Capitalist approaches in the pursuit of 'maximum profit' in economic production and consumption relations and implementing activities/investments that are incompatible with natural (ecological) systems constitute the basis of the problems.

It was widely accepted that the leading cause of climate change and its adverse effects, which is dictated as a global problem today, is the carbon cycle disruption due to multifaceted and excessive human production and consumption activities.

It is possible to say that sustainability, which is the balance between meeting the needs of humanity today while meeting the needs of future generations, is at the center of the conflict between ecology and economy. Since human beings, as a component of nature, will co-exist with nature, they should be in harmony with nature, have an ecology-centered perspective, and reflect it in their attitudes and behaviors by considering nature as a goal rather than a tool.

To mitigate the negative consequences of climate change on a global scale and for the adaptation process, the protection of natural resources and ensuring sustainability, the transformation of nature/ecological and science-based spatial use decisions and policies into action, and the dissemination of interdisciplinary joint studies in the spatial planning, design, and management process should be the primary goal.

In this context, there is an absolute need for communication and cooperation between the disciplines of Architectural Sciences in solving global problems.

The editors of this book believe that a more livable and sustainable world can be created by carrying out interdisciplinary studies of spatial planning and design disciplines together under the roof of ***Architectural Sciences***.

In this context, '***The Journal of Architectural Sciences and Applications (JASA)***,' which pioneered the collective work of related disciplines, was first published in 2016. Subsequently, JASA Editors have made significant contributions to creating various books containing original studies and bringing the latest developments in the field to the reader. This book, titled Climate Change, Carbon Management and Green Space Systems in Architectural Science, contains 16 chapters and covers precious topics.

The authors of the chapters are solely responsible for the copyrights of the figures, pictures and visuals in the book chapters, their content, the accuracy of references and citations, the proposed ideas and compliance with all the rules of publication ethics.

We want to thank the authors, the referees with their valuable contributions, İKSAD Publishing House, and Professor Atila GÜL, General Coordinator of the Architectural Sciences book series, who contributed to the completion of this book.

We hope that our book '***Climate Change, Carbon Management and Green Space Systems in Architectural Science'*** will be helpful to the readers.

Best regards.

01.10.2024

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Afforestation and Reforestation (AR) Project Design Stages for Carbon Storage, Carbon Calculation Methods and Estimation

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1. Introduction

In the history of humanity, especially since the last 30 years, the pressure and intervention of human beings on natural resources has gradually increased. Especially as a result of urbanization, industrialization, technological and digital developments, economic growth-oriented production and consumption activities have gradually increased and diversified, bringing multifaceted problems and negativities. In this context, human beings have exploited, changed, shaped and destroyed nature as a unilateral commodity in line with their own needs and demands. In fact, rent-seeking approaches in the pursuit of "maximum profit" in economic production and consumption relations and the realization of investments that are not compatible with natural (ecological) systems constitute the basis of the problems (Gül & Kurdoğlu, 2021; Gül & Akten, 2022; Gül et al., 2023).

Human beings, who have damaged nature by intervening in the physical dimension until today, have been working to change the content, genetics, magnetics and frequency of the natural system, especially in recent years, and although it is not yet clear what the effects will be on nature and human life, it is thought that it will bring serious vital problems (Gül et al., 2021; Gül & Kurdoğlu, 2021).

It is accepted that the main cause of the climate change and its negative impacts, which is dictated as a global problem today, is the result of the disruption of the carbon cycle, in particular of greenhouse gases released into the atmosphere as a result of multifaceted and excessive human production and consumption activities.

It is possible to say that sustainability, the balance between meeting the needs of humankind today while ensuring that future generations can meet their own needs, is at the center of the conflict between ecology and economy (Gül & Akten, 2022; Gül et al., 2023).

For a sustainable life on a global scale and to mitigate the negative consequences of climate change and for the adaptation process, it is a priority to put forward nature-based solutions in ecological discourse and action. In fact, the basic approach is to prevent and/or reduce greenhouse gas emissions into the atmosphere and to protect and/or increase greenhouse gas sinks (forests, oceans, lakes, etc.).

The underlying Kyoto Protocol Mechanisms, and in particular Article 5/1 of the "Paris Climate Agreement": "Parties shall, as appropriate, take action to protect and enhance greenhouse gas sinks and reserves, including forests.", while Article 5/2 states: "incentives for reducing emissions from deforestation and forest degradation, the role of conservation, sustainable management of forests and strengthening forest carbon stocks" (UNFCC, 2015).

In the "Sustainable Carbon Cycle" statement adopted by the EU in 2021 within the scope of the "Green Deal", it was stated that it is critical to produce ecosystem-based solutions to offset carbon emissions and increase carbon sequestration, and it was recommended to promote "carbon agriculture" and related industrial solutions. In this context, trees and forests, in particular, are one of the most important strategic actions as their vital multifaceted services and contributions are becoming increasingly important (Gül et al., 2009).

Greenhouse gas emissions/sequestration caused by anthropogenic impacts can be calculated in units of CO_2; therefore, the impact of these impacts on the environment is presented as a "carbon footprint" (Akten & Akyol, 2018). In order to reduce the carbon footprint and/or maximize carbon sequestration, afforestation of private or public areas and the calculation of a certain carbon sequestration on a national basis and the establishment of a carbon standard have become a priority in order to achieve the global net zero emission target coming from the Paris Agreement.

Project preparation, design, carbon calculation methods and estimation will play an important role in the carbon market for carbon sequestration and storage, ecosystem services production, carbon crediting and certification of voluntary carbon sequestration afforestation and reforestation projects.

In this study, the importance and processes of voluntary carbon sequestration afforestation and reforestation projects, carbon calculation methods and estimation are discussed and discussed, and suggestions are made under the conditions of our country.

2. Material and Method

The relationship between climate change and the carbon cycle, which is becoming increasingly important today, the importance of carbon sequestration and storage, carbon certification and carbon calculation methods for reducing carbon emissions are presented based on literature data. In this context, a general framework that can be a guide on the importance, processes and contents of voluntary carbon sequestration

afforestation and reforestation projects has been determined and suggestions for implementation in our country have been made.

3. Findings and Discussion

3.1. Carbon Cycle and Climate Change

The carbon cycle is a vital cycle that underpins all organic compounds in the universe, from the smallest vitamin molecule to the long polymer chains of proteins and DNA. Carbon also has a multifaceted impact on the physical environment and climate. In the carbon cycle, carbon is mostly in the form of gas, carbon dioxide, but can also be found in compounds such as methane and carbon monoxide. In the form of carbon dioxide, carbon is released as a residue during the combustion of fossil fuels and the respiration of organisms. Carbon dioxide can be removed from the atmosphere through photosynthesis in plants, which convert carbon into a solid form (sugars) that can be stored or returned to the air during respiration. It can also be removed from the atmosphere by being absorbed by water, where it becomes available to aquatic plants for photosynthesis and can be used to form compounds such as calcium carbonate (chalk) or returned to the atmosphere when the water is heated (Kennesaw State University, 2024).

The total amount of carbon atoms available on Earth is constant due to the law of thermodynamics. The total carbon follows a certain process, moving from one sink to another in short- and long-term cycles. This holistic cycle is called the “carbon cycle”. In other words, it is the movement of carbon from a carbon source to a carbon store and back again (Pamukçu Albers et al., 2018). For example, every year 120 giga¬tonnes of carbon passes from the atmosphere to plants through

photosynthesis, but in the same year, just as much carbon enters the atmosphere again from plants and animals through decay and respiration. In other words, carbon is in constant motion between sinks.

In a carbon cycle that has reached equilibrium, the rate at which carbon is removed from storage is equal to the amount taken up from the atmosphere (Kennesaw State University, 2024).

It is also known that climate change is caused by a "carbon cycle" problem. Climate change is caused by the imbalance in the cycles between these sinks due to human intervention, with some sinks becoming carbon deficient while others are becoming carbon surplus. The best-known example of this is the release of carbon from these sinks into the atmosphere when humans burn fossil fuels found beneath the earth and oceans for energy production. Some of this carbon "swelling" in the atmosphere is absorbed by the oceans, another carbon sink, and the increased carbon in the oceans creates acidification problems. Another example of human disruption of the carbon cycle is deforestation. Here again, carbon in the form of trees/woody plants on the ground is released into the atmosphere through burning and/or reduction of forest areas.

As a result, the balance between carbon emissions from ecosystems to the atmosphere and carbon sequestration in ecosystems directly or indirectly affects climate change in a positive or negative way. Therefore, climate change is considered as the most important environmental problem of our time.

Climate change can be perceived as a result of the use and management of natural resources, production and consumption activities since it is caused by human impact. It is also tried to be managed with different

methods and approaches. Moreover, although the methods of struggle are quite clear, it is seen as the main reason that managers and decision makers and multinational companies are not willing enough to change the way of life dependent on fossil fuels and do not envision solutions compatible with nature.

According to the Synthesis Report (SYR) published by the Intergovernmental Panel on Climate Change (IPCC, 2023), anthropogenic emissions are damaging the planet due to dependence on fossil fuels, but a resilient and livable future is still possible with rapid action on renewable energy sources and other mitigation actions, and that climate impacts are hitting much harder than previously known, even at lower temperatures, and that it is vital that governments follow the 1.5°C target in the Paris Agreement. Global surface temperature rose 1.1°C above industrial temperatures between 2011 and 2020. In the report; 48% CO_2 reduction in 2030, 65% CO_2 reduction in 2035, 80% CO_2 reduction in 2040, 99% CO_2 reduction in 2050 were envisaged (IPCC, 2023).

3.2. The Carbon Market

It is envisaged that market mechanisms can play an important role in reducing greenhouse gases, particularly carbon. In this framework, a carbon market that will operate according to market rules and a price for carbon dioxide subject to trade is seen as an important instrument in reducing emissions. Mandatory and voluntary project and market-based flexibility mechanisms are envisaged in the Kyoto Protocol to achieve greenhouse gas reduction and limitation targets and to reduce the cost of emission reduction practices (Ülgen & Günes, 2016).

I. Mandatory mechanisms: (Quotas, carbon capture and storage - mandatory market)

a. Project-based mechanisms

- Clean Development Mechanism (CDM)
- Joint Execution Mechanism (JEM)

b. Market-based mechanism

- Emissions Trading System (ETS)

II. Voluntary Mechanisms: (Voluntary reductions are not covered by countries' mandatory mitigation obligations. There is no restriction on market entry).

a. Project-based

- Voluntary Carbon Market

b. Market Based!

- Chicago Climate Exchange (CCX)

The carbon market is a market created to facilitate the voluntary reduction and offsetting of greenhouse gas emissions resulting from the activities of individuals, institutions and organizations, private companies, non-governmental organizations and events. Carbon market consists of the following features (Ecer, 2010);

- It can be project and market based.
- There is no limitation for participation.
- It is a process similar to the flexibility mechanisms implemented compulsorily under the Kyoto Protocol.
- In the Voluntary Carbon Market, the targets of institutions and organizations can be developed independently from the policies and targets set by the state.

- Organizations that want to be carbon neutral can calculate the greenhouse gases they create (emitted to the atmosphere) within the framework of their activities (by measuring their carbon footprint) and reduce these emissions and

They can purchase carbon credits generated by emission reduction projects in order to offset their emissions.

- There are many standards in the market regarding the standards and trading rules of carbon credits generated in voluntary carbon reduction processes (VER - Voluntary or Verified Emission Reduction).

In order to reduce greenhouse gas emissions on a global scale, and to capture and store them in the atmosphere, the legal infrastructure of a market for the production of clean and renewable energy on a project basis and the trade of emission credits earned accordingly is being established.

The basis of the "Voluntary Carbon Market", which is gaining importance in our country, is based on the principle of "carbon dioxide offsetting", which is defined as neutralizing the greenhouse gas emitted from one location by preventing the same amount of greenhouse gas to be emitted from another location or by sequestering/sequestration of the same amount of greenhouse gas in the atmosphere. In this way, projects can trade the emission reduction certificates they produce in this market. However, the Voluntary Carbon Market operates separately from the Kyoto Protocol (Ülgen & Güneş, 2016).

In this context, the implementation, implementation and management of voluntary carbon market-based afforestation or planting projects is

considered an important approach. Achieving success in carbon pricing is only possible with an effective, holistic and stable policy, planning and governance organization of the market system (Gül & Akten, 2022).

3.3. The Importance and Relation of Forests and Trees in terms of Carbon

In order to reduce the imbalance in the carbon cycle, the main goal is to greatly reduce the rate of burning fossil fuels, i.e. carbon dioxide gas, or to remove carbon from the atmosphere or to increase the rate of carbon capture and storage. For this purpose, increasing the number and surface area of trees is accepted as the basic approach (Sedjo, 1989; Gül, 2024).

Trees and forests play a very important role in increasing carbon storage. Forests, which account for 92% of terrestrial biomass, store around 400 G tonnes of carbon. Trees take carbon from the atmosphere and store it in their own trunks, and then, if they are cut down, they continue to store it in the healthiest way by turning it into wood/wood, one of the most valuable products.

During photosynthesis, trees convert carbon dioxide and water into sugar molecules and oxygen through a series of oxidation and reduction reactions. The general equation for the photosynthetic process can be expressed as follows (Kennesaw State University, 2024).

$$6\ CO_2 + 6\ H_2O + \text{sunlight} \longrightarrow C_6H_{12}O_6 + 6\ O_2$$

While some of this sugar is stored, most is used by the tree for other purposes, such as energy and structure. For example, much of the sugar binds together to form cellulose, which provides the structure of the tree. Most of this sugar by mass comes from carbon. The fact that carbon has an atomic mass of 12, hydrogen an atomic mass of 1 and oxygen an

atomic mass of 16 means that 72/180 = 40% of the mass of the sugar molecule comes from carbon. Taking into account the other types of molecules present in a tree (proteins, lipids, etc.), about 45% of the dry mass of a tree (excluding water) is composed of carbon. In other words, a 100-kilogram log of fully dried wood contains about 45 kilograms of stored carbon. Each kilogram of dried wood stores .45 kilograms of carbon, while removing more than one kilogram of carbon dioxide from the atmosphere. This is because each carbon dioxide molecule contains two oxygen atoms. Using the data above, this means that each carbon dioxide molecule has an atomic mass of 12 + 2(16) = 44, of which only 12 are bound to carbon. So for every one carbon atom stored in a tree, 44 atomic mass units of carbon dioxide are removed from the atmosphere. This means that each kilogram of dried wood corresponds to (Kennesaw State University, 2024).

(1 kg dried wood) x (.45 kg C/1 kg dried wood) x (44 amu CO_2/12 AMU C) = 1,65 kg CO_2

According to this formula, the amount of CO_2 bound in 1 kilogram of wood mass is calculated as 1,65 kg.

Such a large amount is the most important justification for using trees to remove carbon from the atmosphere. However, it should be noted that this equation also works in the opposite direction. When a tree is burned or allowed to decompose completely, the carbon in the tree is returned to the atmosphere as carbon dioxide.

The issue of the carbon storage capacity of forest ecosystems is of particular interest to researchers and policy makers because, on a global scale, forests contain 80-90% of the carbon in terrestrial plants and 30-

40% of the carbon in soils (Harvey, 2000; Landsberg & Gower, 1997). Increasing forested land (e.g. by creating plantation forests) is proposed as an effective measure to increase C storage, reduce carbon dioxide (CO_2) concentrations in the atmosphere and thus contribute to preventing global warming (Kurz et al., 1996).

The greatest potential of forest ecosystems for above-ground biomass and C storage are usually tree biomass components (roots, branches and leaves). Dead and standing dry trees also contribute significantly to above- and below-ground biomass (e.g. Whittaker & Woodwell, 1968; Long & Turner, 1975).

3.4. Proposal for Stages and Processes of Afforestation Projects for Carbon Sinks

In order to reclaim idle, eroded or degraded lands and create new carbon sinks for the development of climate change adaptation and mitigation strategies, it is considered an important approach to carry out and implement Voluntary Carbon Market-based afforestation or planting projects by considering the appropriate use of lands with a holistic approach.

Voluntary carbon-based projects can obtain carbon certificates just like renewable energy and energy saving projects. Carbon certificates are certificates given to projects that reduce carbon emissions or sequester carbon from the atmosphere within the scope of carbon trade, one of the tools developed to combat climate change. The 'carbon certificate' obtained with each ton of carbon dioxide equivalent sequestered in afforestation areas is offered for sale in international voluntary carbon

markets at the current market value. However, there are no certified afforestation projects in Türkiye yet.

Afforestation and plantation projects to be carried out for carbon sequestration and storage require the preparation and sustainable management in accordance with the purpose and technique. Carbon sink area afforestation project design processes and stages to be carried out in our country can be suggested as follows;

a. General Information on the Project Owner
b. Project Type, Objectives and Content
c. Project Area General Inventory Information
d. Design Application Project and Technical Information
e. Project Implementation and Management Strategies
f. Project Carbon Accounting and Pricing
g. Project Technical Report
h. Carbon Crediting and Certification Processes

a. General Information of the Project Owner: Project Title, Name and surname of the Project Owner, ID No, Contact Information, ID No, Project partners and Sponsors, Status of rights and responsibilities of the project owner, Certificates for the project owner, carbon crediting utilization status, existence and information on other carbon projects, Compliance of the project with national regulations and laws, Approval status of relevant institutions and organizations for the project area, etc.

b. Project Type, Objectives and Content: Project title, Project responsible and team, Carbon farm project type, Carbon farm project type, Project start and end date, Estimated life of the project (years), Project crediting start date and end date, Objectives of the project,

Sustainable principles of the project, Activities to be implemented in the project, Ecological services and contributions to be provided by the project, Technological tools and measures to be used in the project, Level of stakeholder participation in the project, Database and methodological approach for design implementation projects, Project summary, Additional documents etc.

c. Project Area General Information and Inventory: Site location (Province, District, Neighborhood/Village, Island/Parcel), Geographical coordinates, Site layout plan, Site size (ha), Type of land, Zoning status, Ownership status, Climatic data (Precipitation Average (mm), Temperature average (^{o}C), Temperature average (^{o}C), Temperature min (^{o}C), Temperature max (^{o}C), Humidity average rate), Elevation (m) (max, min, average), Slope status (%) (max, min, average), Available water sources, Major Soil Group (MSG) type, Land Use Capability Class (LUC), Combination of Soil Characteristics (CSC), Depth (cm), Soil Organic Carbon (SOC) (Avg. (t/ha) and total (tC)), Land Productivity Dynamics (LPD) (%), Dynamic Erosion Model and Monitoring System (Demis) (%), CORINE 2018 (%), Land Degradation Prevention Action Recommendations (%) (LDP), Intervention hierarchy (ha), Water resources, Land survey studies, etc.

d. Design Implementation Project, Concept and Technical Information: Identification of the project team and stakeholders, Objectives of the project concept, Design strategies and principles, Design implementation project preparation process (Layout Sheet" (1/500 scale), 'Concept (Proposal) Sheet', 'Landscape Design Implementation Preliminary Project (1/500 or 1/200 or 1/100 scales

according to the size of the land), Landscape design implementation final project' (1/500 or 1/200 or 1/100 scales according to the size of the land), Approval process of the final project, Detail sheet (Scaled detail drawings of all plant and structural materials, reinforcement, plant pattern etc. used in the project), Plant species and characteristics used in the project, Plant pattern types, plant numbers and total areas (%) envisaged in the design, Technical specifications, Bill of quantities and Total implementation cost etc.

e. Project Implementation and Management Strategies: Defining Project Implementation processes and prioritization. Implementation management strategy, Establishment of activity work-time schedule in the management process, Sustainable Land Management (SLM) approach (Intervention Hierarchy), Structural and cultural measures, risks/threats/measures, Identification of monitoring and supervision methods and techniques for implementation and management, Methods of carbon measurement, recording, storage, collection and reporting, Defining institutional structure, responsibilities and staff competencies for management and monitoring activities, Feedback methods, Sampling approach for carbon accounting (sample area size, number, frequency) etc.

f. Project Carbon Accounting and Pricing: Tools and analysis techniques used in the method, emission/sequestration calculations, estimated values of carbon sequestration by plant species in the first year of installation, estimated annual carbon sequestration by plant species during the crediting period, leakages and plans and studies to

reduce/prevent them, projections for buying and selling within the scope of the carbon exchange, etc.

g. Project Technical Report: All the information mentioned above is prepared as a file and made ready for approval by attaching the Project sheets and other documents.

3.5. Carbon Accounting Methods for Afforestation or Reforestation Projects in Voluntary Carbon Market

In voluntary carbon market-based afforestation or reforestation projects within the scope of climate change mitigation, carbon sequestration and storage amounts are generally calculated before the project is started (Ex-Ante) and the calculated amounts are evaluated for the future of the project and used in the carbon certification process (Serengil, 2018).

In the calculation of carbon sequestration and storage as a result of land use and change within the scope of the plant pattern envisaged in the project, the determination of carbon sequestration in biomass, dead wood, dead cover, soil and harvested wood products carbon pools, their spatial distribution and changes, and land use and management effects are taken into consideration.

The rate of carbon sequestration and storage in trees can vary depending on factors such as tree species, growth form and characteristics, biomass, growing conditions (climate, soil, aspect, elevation, etc.) and age. For this reason, it is of great importance to calculate and estimate the biomass of the tree by local measurements for each tree species.

Accurate estimates of tree leaf area and leaf mass are critical for assessing evapotranspiration, atmospheric deposition, biogenic volatile organic emissions, light interception and other ecosystem processes,

particularly carbon accounting. Equations or ratios are often used to estimate leaf area or leaf biomass from easily measurable tree traits such as stem diameter (dbh) or sapwood cross-sectional area (Waring et al., 1982).

Various approaches are used to calculate and quantify carbon storage in vegetation. Carbon accounting methods are mostly scientifically standardized. This allows globally comparable accounting and trade supported in internationally unified and standardized systems (IPCC 2000, 2003; McPherson & Kendall, 2014; Nowak et al., 2013).

Accurate estimates of tree leaf area and leaf mass are critical for assessing evapotranspiration, atmospheric deposition, biogenic volatile organic emissions, light interception and other ecosystem processes, particularly carbon accounting. Equations or ratios are often used to estimate leaf area or leaf biomass from easily measurable tree characteristics such as stem diameter (dbh) or sapwood cross-sectional area. For this purpose, measurements of stem diameter in each tree and allometric and biomass equations are used to calculate the amount of carbon stored (Nowak et al., 1996; Pearson et al., 2007; Stoffberg et al., 2004; Stoffberg & Van Rooyen, 2012).

*Carbon stocks can be calculated in two way*s (VCS, 2015):

a. Periodic direct measurement of sampling by combining assumptions or models. In this method, carbon sequestration is calculated from the forest biomass measured in the sampled area.

b. Projection of appropriate increment models and/or carbon models for project area inventory, etc. with minimum periodic direct monitoring.

The basic principles that should be considered in the carbon calculation and reporting process in voluntary carbon market-based afforestation and reforestation projects can be summarized as follows (Serengil, 2018).

- Scientificity: Scientifically accepted and scientific methods, formulas and parameters should be used in carbon calculations.
- Permenance: Calculation and reporting processes should be designed to be carried out continuously.
- Transparency: It refers to the fact that the data, methods and assumptions used in the inventory are clearly stated. In this way, calculations should be repeatable, controllable and reviewable.
- Accuracy: Calculations should produce results in a way to reach the most accurate results possible. The results should be neither above nor below the actual values, but as close to the actual values as possible. The methods specified in IPCC guidelines should be used, national data with high reliability should be included as much as possible and the level of uncertainty in the results should be kept low.
- Consistency: Calculations should be made using the same methods for all years of the inventory. If different methods are used for some years or periods, they should be transparently explained in terms of consistency. At the national level, it is especially important to ensure that the base year and the final year are calculated using the same methodology. In project-based calculations, the same or similar methodologies should be used when comparing the situation with and without projects.

- Comparability: Inventory calculation results should be comparable with other similar ones. In national inventories, they should be comparable with inventories of other countries; in project-based inventories, they should be comparable with similar projects.
- Completeness: It means taking into account all of the greenhouse gases, sources and pools both geographically and in the calculation.

The factors to be taken into consideration in voluntary carbon market-based afforestation and reforestation projects and carbon calculations can be summarized as follows;

- Pre-feasibility and inventory (especially field survey) studies are important for carbon calculations in the project area. The carbon stock at the time the project started (t0), the increases that will occur in carbon stocks, the calculation of the carbon stock difference in the project and non-project scenarios, or the calculation of carbon stock changes resulting from human impact and natural causes definitely require a terrestrial inventory study.
- Inventory and field survey (natural, environmental, social and economic, etc.) should be made comprehensively and realistically.
- In carbon projects, measurements to be made in different time periods, time plan and silvicultural methods to be applied should be defined.
- In projects, the first inventory measurement data (t0 time) are the basic values for the estimated values to be made about how much carbon gain will be provided in the project implementation and management process. Therefore, the biomass and carbon

calculations to be made require the first measurements to be made sensitively and accurately in the sampling areas to be selected to represent the area.

- In the plant pattern design appropriate to the purpose of the carbon-focused project, a combination of trees, shrubs and herbaceous plants should be aimed, especially tree-based ones.
- Applicable and internationally accepted carbon accounting methods should be used in the project.
- The project management process (maintenance, repair, renewal, control and monitoring, reporting, security, workforce, budget, etc.) should be organized in a sustainable manner.
- All possible risks/threats and possible leakages should be determined during the implementation and management process.

In our country, the coefficients determined by Asan et al., (2002) are used to determine the carbon storage capacities of sample areas. The volume amounts obtained from the measurements made in the sample areas were multiplied by the coefficients specially calculated for each tree species group in the forests of Türkiye to determine the carbon storage capacities of the sample areas. For this, the following coefficients are taken into account (Asan et al., 2002).

• Above Ground Biomass Amount (broad-leaved species) (AGBA)= Planted Trunk Volume x 0.640 x1.25

• Above Ground Biomass Amount (coniferous species) (AGBA)= Planted Trunk Volume x 0.473 x1.20

• Below Ground Biomass Amount (broad-leaved species) (BGBA)= Above Ground Biomass Amount x 0.15

• Below Ground Biomass Amount (coniferous species) (BGBA)= Above Ground Biomass Amount x 0.20

• Above Ground Dead and Live Cover Biomass Amount (AGDLCB)= (AGBA Total+ BGBA Total) x 0.40

• Total Above Ground and Under Ground General Biomass Amount (TGGB)= AGBA + BGBA + AGDLCB

• Carbon Amount in Total Biomass = TGBK x 0.45

• Carbon Amount in Forest Soil = (TGBK x 0.45) x 0.58

In International Panel on Climate Change-based methodologies, annual calculations of carbon emissions and sequestrations in afforestation project areas are divided into 3 subcategories (IPCC, 2006):

a. Calculation of carbon stocks in biomass (above and below ground biomass): Calculation of all living biomass above ground, including trunk, stump, branches, bark, seeds and leaves. In the total living biomass of living roots, fine roots with a diameter of less than 2 mm (recommended) are excluded, as they are generally not empirically distinguishable from soil organic matter or litter.

b. Calculation of carbon stocks in dead organic matter (dead wood and litter): Includes all non-living woody biomass not found in the litter, standing, on the ground or in the soil. Dead wood includes wood lying on the surface, dead roots and (for example) logs with a diameter equal to or greater than 10 cm (for example). Includes all non-living biomass with a diameter of less than 10 cm (for example) in various states of decomposition on top of mineral or organic soil. This includes litter, fumic and humic layers. The specified living fine

roots are included in the litter where they cannot be empirically distinguished from it.

c. Annual variation of soil carbon stocks; Includes organic carbon in mineral and organic soils (including peat) to a specified depth and is applied consistently. The specified diameter living fine roots are included in the soil organic matter where they cannot be empirically distinguished from it.

3.5.1. A Methodological Approach for Estimation of Carbon Stock from Living Biomass for Afforestation and Reforestation By CDM

This methodology developed by CDM is proposed to be used for estimating the carbon stock in living biomass for afforestation and reforestation of any land that does not fall into the wetland category.

The methodology limits the extent of soil degradation in the project to no more than 10 per cent when the Soil Organic Carbon (SOC) content is expected to be higher in the primary land use of the land than in the 'forestry' land use.

If the distribution of plant pattern biomass over the project area is not homogeneous, different strata can often be created according to the main plant species and their canopy cover and/or land use types to increase the precision of the biomass estimate.

The Stages of the Carbon Stock Estimation Methodology from Living Biomass for Afforestation and Reforestation can be summarized as follows; (Clean Development Mechanism. (CDM). 2015; Troy, 2019).

3.5.1.1. Calculation of Carbon Stocks in Biomass (Above and Below Ground Biomass):

a. Calculation of Aboveground Tree Biomass:

The simplest method (Level 1) to calculate aboveground biomass is to follow the default parameter values of the Intergovernmental Panel on Climate Change (IPCC) for Türkiye. According to this approach, the total assets and annual growth rate of broad-leaved/- tree species (leaved shrub trees, etc.) and coniferous trees are taken into account in the calculation of the planted tree trunk volume. According to the layered tree species (almond trees, lime trees, mahaleb-wild cherry trees, wild pear trees and acacia trees), the trunk volumes of trees living at the layer level are multiplied by the Carbon Fraction (CF) previously determined for Türkiye Forests by Asan (1995). First, the volume of each planted sapling is found and then the oven-dried weight is obtained and finally the result is converted to the aboveground biomass weight.

With the sampling method to be selected in the project area, the volume of each living tree in the sample area is measured. All measured values are averaged and determined (m^3). The average value obtained is multiplied by the total number of existing trees in the area and the total above-ground volume in the area is estimated in hectares.:

Volume calculation equation for each tree

$$\mathbf{V_t = \pi . DBHr^2 x\ BH} \qquad \mathbf{(1)}$$

In this formula;
V_t : Volume of the standing live tree trunk (m^3)

$DBHr^2$: Square diameter of the breast height of the living tree trunk (cm)
BH: Breast height of the standing live tree trunk / stem (m)
π = 3,14
BH=130 cm

$$\text{Vt (1 tree volume)} = \frac{\text{cm}^3}{1\ 000\ 000} = \ldots\ldots\ \text{m}^3$$

V_{abst} (average biomass of sample trees): $V_{n1}+V_{n2}+ V_{n3}\ldots\ldots\ldots/ n = m^3$
TVm^3=Total of Number of trees/ha x $\mathbf{V}_{abst}$ = m^3 / total volume per hectare

Calculation Equation for Aboveground Biomass:

To calculate the above-ground biomass in the area (tonnes/ha), it is obtained by multiplying the average volume value according to the tree species (*broadleaf or coniferous trees*) per hectare, dried weight coefficient and carbon ratio. These coefficients are IPCC values converted according to the conditions in Türkiye.

AGB ton/ha = TVm^3x DWx CF (2)

In this formula;
ABG ton/ha: Aboveground biomass of a living tree (ton/ha)
Vm^3: Each living tree planted /total trunk / trunk volume (m^3)
DW: Oven Dried Weight (for broadleaf trees: 0.640) (for coniferous trees: 0.473)
Transforming Factors for Türkiye – IPCC values
CF Carbon Ratio: (For broadleaf trees: 1.25 and for coniferous trees: 1.20)

b. Calculation of Underground Biomass:

The amount of biomass (root) under the ground is also determined using general ratios for tree species groups. Underground biomass amounts are

obtained by multiplying the aboveground biomass of species groups by 0.15 for leafy trees and 0.20 for conifers by the root ratios.

The calculation equation for underground biomass is;

UGBton /ha = AGBton/ha x CF (3)

In this formula;
UGBton/ha: Underground Biomass (Ton/Ha)
ABG: Aboveground Biomass (Ton/Ha)
FC Conversion Factor for root ratio factors: (0.15 for broadleaf trees and 0.20 for conifers) are IPCC Default parameters for Türkiye.

3.5.1.2. Calculation of Carbon Stocks in Above round Living and Dead Organic Matter (Dead Wood and Dead Cover)

The live biomass calculated above shows the total biomass of saplings with a breast height diameter of 7 cm and shrubs with a diameter of 4 cm and above in the project area. In this measurement step, the total biomass of the dead cover of trees, shrubs, branches, cones and leaf residues is calculated by multiplying the ratios determined according to the results of researchers in different countries of the world. This ratio is 40% for semi-arid latitudes where Türkiye is located.

Calculation equation for aboveground living and dead cover:

AGB live and dead cover = (AGBton/ha + UGBton/ha) x CF (4)

Here;

AGB live and dead cover: Live and dead cover aboveground biomass (tons / Ha)
AGB Aboveground Biomass (tons / Ha)
UGB Belowground Biomass (tons / Ha)
CF Conversion Factor ratio: 0.4 – The ratio given for Türkiye in the semi-arid climate zone latitude – is the IPCC Default Value for Türkiye.

3.5.1.3. Calculating the Amount of CARBON in Total Biomass

The total amount of biomass is calculated by adding the results of aboveground biomass, belowground biomass and aboveground biomass (tons / ha) and then the total amount is multiplied by the Carbon Conversion Factor Ratio at the project sites. The carbon conversion factor ratio for Türkiye is given as the default value by the IPCC. Because Türkiye is located in the semi-arid mid-latitude agricultural region where agroforestry afforestation is carried out, the CF Default Value is 45% (Brown 1997; Asan 1999).

Calculation equation for carbon content in total biomass:

$TBCA_{ton/ha}$ = TB (AGB+UGB+AGB live and dead cover)x CF… (5)

Where
TBCA ton/ha Total Biomass Carbon Content (ton / Ha)
TB Total Biomass (AGB + UGB + AGB live and dead cover) (ton / Ha)
CF Conversion Factor Ratio IPCC Default Value for Türkiye (0.45)

3.5.1.4. Calculation of the Amount of Carbon Held in the Soil

The amount of carbon held in the soil is multiplied by the average rates of carbon in the total biomass given by geographical regions. Since Türkiye is located in the semiarid agricultural climate zone with mid-latitude climate conditions, the rate for Türkiye is 58% (Brown, 1997, Asan, 1999).

The calculation equation for the amount of carbon held in the soil is:

SCton / ha = TBCA ton / ha x CF (6)

In this formula:
SC ton / ha the amount of carbon held in the soil (ton / ha)
TBCA The amount of carbon in the total biomass (ton / ha)
CF The carbon conversion factor rate given to Türkiye (0.58)

3.5.1.5. Calculation of annual volumetric carbon increase depending on the growth characteristics and speed of trees in the project area:

The volume of growth of trees planted in agroforestry – afforestation project sites is very similar to the growth rate of trees in natural forests. The cross growth of a tree is called "growth". In some conditions, this assumption is greater and faster than forest trees due to the factors of sunlight intake, irrigation systems, and natural fertilization.

For example, the lime trees planned in the project grow at a moderate rate of 13 to 24 inches per year from the seedling stage. Acacia trees are fast-growing. Depending on the species, they can grow anywhere from 1 to 3 feet per year. Keeping these facts in mind, the conversion factor for the annual period is considered to be approximately 5%. The volume of growth of the annual carbon increase is repeated one by one for 30 years. Calculation equation:

TBC increment volume = TBCA X CF **(7)**

In this formula:

TBC increment volume Total biomass carbon increment volume (m^3)
TBCA Total Biomass Amount (AGB + UGB + AGB live and dead cover + SC) (tons/ha)
CF Conversion factor of annual increment volume (0.5)

3.5.1.6. Calculation of Total Carbon Dioxide Emission Stocks

Calculation of Carbon Dioxide Emission (tCO_2 e) equivalent (tons / ha) is done by multiplying the Grand Total of Total Aboveground Carbon, Total Belowground Carbon, Total Aboveground Living and Dead Cover and Total Biomass Growth Carbon by the Carbon Dioxide Molecular Weight (44/22) Conversion Factor. And then, soil carbon dioxide equivalent is added to the result. Finally, the Grand Total Carbon Dioxide Emission Stocks are obtained by multiplying the results by the number of project areas and multiplying the years of the crediting periods.

Calculation equation:

$GTCO_2$ e y-1 = Σ (TAGBC + TUGBC + TAGBC l, d, c) x CF + TSC x TPA x T (t1 – t2)x Inc Ratio (8)

In this formula;
$GTCO_2$ e: Total Carbon Dioxide Emissions (tCO_2 e y-1)
TAGBC: Total Aboveground Biomass Carbon (tons / ha)
TUGBC: Total Belowground Biomass Carbon (tons / ha)
TAGBC l,d,c :Total Aboveground Biomass Live and Dead Cover (tons / ha)
CF: Carbon Dioxide Molecular Weight Conversion Factor (44/12)
TSC Total Soil Carbon (tons / ha)
TPA Total Project Area
T (t1 - t2): Total Crediting Period Years

3.5.1.7. Carbon Leakage Approach and Management in the Project

In the afforestation project and carbon crediting process, possible risks and threats should be defined as 3 factors.

• In-area risks,

• Out-of-area risks

• Natural risks.

Necessary measures should be foreseen for these possible risks and threats. All activities/actions to be carried out in the proposed carbon storage afforestation project aim at sustainable management of multi-purpose land, obtaining multiple products per unit area, increasing and diversifying farming incomes, diversifying energy sources and technologies, reducing soil and water loss, combating erosion, improving soil quality, protecting biodiversity, evaluating plant residues as compost, etc. In short, the project should be carried out with special care to limit potential greenhouse gas emissions at every stage. For this purpose, land preparation, material supply, planting and sowing activities, maintenance, transportation, compost fertilizer supply, etc. expenditure items should be planned to be carried out at the lowest cost.

To this end, annual calculations should be made and documented in tabular form, with a transparent preliminary estimate of emissions (or, where appropriate, direct calculations of emission reductions) over the project period and expected leakage emissions and net GHG emission reductions over the crediting period of the project.

Net GHG Emission Reductions are calculated as follows:

$$EMy = BEy - PEy - LEy + \ldots \quad \textbf{(9)}$$

In this formula;

EMy = Net GHG Emission Reductions in year y (tCO2-e)
BEy = Base Emissions in year y (tCO_2-e)
PEy = Project Emissions in year y (tCO_2-e)
PLy = Project Leakage in year y (tCO_2-e).

3.5.1.8. Monitoring Plan

In afforestation projects for the purpose of creating carbon sink areas and in the carbon crediting process, the monitoring process should be carried out in two stages.

1) During the Project Preparation Process: All activities to be carried out during the project preparation process should be defined in detail within the work schedule in line with the methodological framework. In particular, after the project implementation, the holistic Monitoring Plan framework, methodology, parameters, criteria, measurement tools and equipment, recording and reporting, etc. are defined in accordance with the project purpose, all activities and methodology.

2) During the Plan Implementation and Management Process;

• Implementation and monitoring can be carried out by the relevant project managers within the scope of the Monitoring Plan envisaged in the project according to the work schedule.

• The monitoring plan implementation tools, including data management and quality assurance and quality control procedures, should ensure that the emission reductions achieved/resulting from the project activity can be reported and verified and documented in tables.

4. Conclusion and Suggestions

One of the most important approaches to developing climate change adaptation and mitigation strategies, carbon sequestration and combating soil erosion is afforestation and reforestation activities. In voluntary carbon-based afforestation projects, just like renewable energy and energy saving projects, a carbon certificate is obtained and the ‘carbon

certificate' obtained with each ton of carbon dioxide equivalent sequestered in afforestation areas can be sold at the current market value in international Voluntary Carbon Markets. In this context, the project design and land management process will play a major role in both creating carbon sink areas and ensuring that carbon crediting and certification are sustainable, measurable, traceable, and that carbon emission trading can be processed in the form of a real market and in guaranteeing this process.

In voluntary carbon-based afforestation projects, carbon certification and crediting processes require the holistic handling and organization of all relevant processes such as the pre-feasibility of the project, design and approval of a suitable implementation project, its implementation, sustainable governance, measurement, calculation, evaluation, monitoring, reporting, auditing, approval of carbon sequestration and stock changes in the project area, development of institutional structure and capacity, and compliance with legislation.

The recommendations that need to be made in our country's conditions within the scope of calculating and monitoring carbon capture and storage in voluntary carbon capture afforestation and reforestation projects can be summarized as follows;

- National legislation regarding voluntary carbon sequestration afforestation project processes should be revised to be in line with international legislation.
- The official institution should assume authority and responsibility for processes such as project approval, supervision, and organization, and institutional structuring and organization should be provided. This

organization should be done by state institutions. Otherwise, if this task is given to private agencies, it may lead to monopolization and a rent-seeking system (Gül & Akten, 2022).

- The principles of transparency, reliability, consistency, comparability and integrity, which are emphasized by the IPCC guidelines (IPCC, 2003; IPCC, 2006), should be taken into account in carbon sequestration calculations prepared on the basis of voluntary carbon sequestration afforestation projects.
- Afforestation carbon calculation methods should use scientifically accepted and scientific methods, formulas and parameters. In particular, they should be compatible with international carbon calculation techniques.
- In the plant pattern design appropriate to the purpose of the carbon-focused project, it should be aimed to create a combination of tree-based trees + shrubs + herbaceous plants. In this context, agroforestry systems and carbon farming practices should be given priority.
- The rate of carbon capture and storage in trees may vary depending on factors such as tree species, growth form and characteristics, biomass, growing conditions (climate, soil, aspect, altitude, etc.) and age. Therefore, it is of great importance to calculate and estimate the biomass of the tree for each tree species using ground measurements.
- When determining the carbon storage capacities in the project area, biomass conversion coefficients should be determined for each tree or shrub species used and the amount of carbon in the biomass should be calculated accordingly.

- The lowest cost, minimum tillage, use of waste and residues in the field, water and soil protection, organic farming and practices that increase the amount of carbon in the soil, etc. should be targeted in the design and implementation of the project.
- The lands to be selected as project areas must be suitable in terms of ownership status, usage rights and zoning status, usage restrictions, protection status, legislation, actual status and the status of occupants. In particular, land ownership and rights status must be clearly defined in the project.
- Voluntary carbon sequestration afforestation projects should be implemented on privately owned lands, treasury lands, lands belonging to public legal entities (University lands, lands belonging to public legal entities such as Bar Associations, etc.), and lands belonging to local administrations (land belonging to village legal entities, lands belonging to municipalities).
- For voluntary carbon sequestration projects, treasury lands should be allocated primarily to local people and local cooperative enterprises.
- Project areas that will be subject to carbon certification must be at least 3 hectares in size.
- In afforestation projects for carbon sink purposes, a projection of at least 30 and at most 50 years should be targeted for the certification of carbon stock. It is an important feature for certification institutions that the harvested trees will not release the atmospheric carbon they hold for 30 or 60 years back into the atmosphere.
- The concept and plant pattern design of voluntary carbon sequestration projects should be compatible with the general

characteristics of the land and Sustainable Land Management (SLM) and Sustainable Forest Management (SFM) strategies (Erpul et al., 2023).

- Voluntary carbon sequestration projects should target not only carbon sequestration but also other additional benefits (soil and water protection, water production, product and income generation, compost fertilizer production, erosion prevention, biodiversity enhancement, environmental quality, social benefit and responsibility, etc.).
- Full and effective participation of relevant stakeholders, especially local people, should be ensured.
- Necessary precautions should be foreseen for existing and potential risks and threats during the project. In addition, protective measures should be taken.
- Insurance and damage compensation mechanisms should be established because voluntary carbon sequestration projects have a long administrative process.
- Measurement, evaluation and reporting (MRV) and auditing opportunities should be provided throughout the project.
- The IPCC (2006) guideline provides valid values that can be used in carbon calculations. In order to use local, regional and national values in calculations, it is of great importance that these data are calculated with model approaches and methods developed on a national basis through field observations and measurements. Therefore, updates should be made with scientific research on national and regional conditions and plant species.

- The project management process (maintenance, repair, renewal, control and monitoring, reporting, security, workforce, budget, etc.) should be organized in a sustainable manner,
- • The amount of carbon stored during the project process should be calculated and modeled using estimated artificial intelligence software.

Today, instead of the sustainable development approach that does not question the current neoliberal policies and profit-oriented production and consumption economic activities and prioritizes preserving the traditional economic development approach, there is a need for new green economy approaches that prioritize protecting nature and ecological solutions, while emphasizing fair, equal, ethical and social rights. Capital-oriented economic production and consumption activities that have lost their naturalness create damage and pressure on the natural environment. Interventions to nature without understanding the basic principles and laws of ecology both cause destruction and make people pay heavy prices in a later period. The upheaval of ecological and economic balances in the world necessitates that environmental, political, cultural and economic problems be addressed in an integrated and continuous manner that affects each other (Gül et al., 2023).

The new “low-carbon economy” or “green and circular economy” order that the current economic order has evolved into should be accepted as an ethical tool for the protection and sustainability of human health, natural ecosystems and the cultural environment, first and foremost. Carbon pricing should be organized in line with this basic goal (Gül, 2024).

In our country, the success of carbon capture and storage strategies will be possible with comprehensive laws and administrative decision processes that include and prioritize equality, justice, ethics, nature protection and ecological approaches in the processes of appropriate project design, implementation, multi-level governance, institutional organization, capacity, approval, reporting, control, monitoring, evaluation, participation, resource allocation, certification, etc.

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Author Contribution and Conflict of Interest Declaration Information

All authors contributed equally to the article.

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