ARCHITECTURAL SCIENCES AND ECOLOGICAL APPROACHES

EDITORS

Dr. Hüseyin Berk TÜRKER

Dr. Fatmagül BOLAT

May-2023

İKSAD Publishing House

Institution of Economic Development and Social Research

(The License Number of Publisher: 2014/31220)

TÜRKİYE TR: +90 342 606 06 75 USA: +1 631 685 0 853

E mail: iksadyayinevi@gmail.com

www.iksadyayinevi.com

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Iksad Publications – 2023©

Architectural Sciences and Ecological Approaches

ISBN: 978-625-367-073-3

Cover Design:
Dr. Gizem DİNÇ

May, 20, 2023
Ankara / Türkiye
Size = 16x24 cm

Architectural Sciences and
Ecological Approaches
May 20, 2023
ISBN: 978-625-367-073-3

PREFACE

Our ecological challenges call for innovative approaches that transcend traditional disciplinary boundaries. It is with great pleasure that we present this book, "Ecological Approaches," which brings together diverse perspectives from spatial planning and design and agriculture.

This book embraces the ethos of interdisciplinary collaboration, aiming to foster a deeper understanding of the complex relationship between the built environment and the natural world. By integrating architectural sciences, we believe in the potential to shape a more livable world that harmonizes human needs with ecological sustainability.

In the spirit of fostering knowledge exchange and scholarly discourse, this book extends the pioneering efforts initiated by the "Journal of Architectural Sciences and Applications (JASA)." Since its inception in 2016, JASA has provided a platform for collective studies in related disciplines. The dedicated editors of JASA have played a crucial role in curating original works and disseminating the latest developments in the field through various publications.

This volume, curated by esteemed experts in the field, showcases a rich collection of research and innovative practices that highlight ecological approaches within spatial planning and design.

ISBN: 978-625-367-073-3

We hope this book serves as a valuable resource for academics, researchers, practitioners, and students, inspiring further exploration and contributing to advancing ecological thinking in our built environment.

We extend our sincere gratitude to the contributors who have shared their expertise and insights and the diligent researchers who have dedicated their time and effort to bring this publication to fruition. We invite readers to embark on a journey that explores the interconnectedness of ecological principles and spatial design, paving the way for a more sustainable and resilient future.

18.05.2023

EDITORS

Dr. Hüseyin Berk TÜRKER
Dr. Fatmagül BOLAT

ISBN: 978-625-367-073-3

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Biotechnical Approaches for Landscape Repair of Marble (Stone) Quarries

Prof. Dr. Atila GÜL [1]

[1]Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture, West Campus, Isparta/Türkiye.
ORCID: 0000-0001-9517-5388
E-mail: atilagul@sdu.edu.tr

İskender Emre GÜL [2]
[2] Akdeniz University, Institute of Science, Antalya/Türkiye.
ORCID: 0000-0003-3319-4801
E-mail: iskenderemregul@gmail.com

Citation: Gül, A. & Gül, İ. E. (2023). Biotechnical Approaches for Landscape Repair of Marble (Stone) Quarries. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches.** 2023, Chapter: 1, 1-50. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

Today, as a result of rapid population growth, urbanization, and social, economic, cultural, and technological developments, demands for multi-purpose products such as raw materials, energy, and by-products have increased and diversified. As a result of the excessive use and consumption of underground and aboveground natural resources to meet these needs, it has brought about multifaceted negative impacts (Li et al., 2008; Gül et al., 2014). In particular, the methods and techniques of raw material production of natural resources have increased the negative environmental impacts. All types of human-induced activities have direct or indirect negative impacts on nature. Therefore, it is now an accepted fact today that it is not possible to use natural resources without harming nature or the environment. However, it is also an accepted approach to bring surface and underground natural resources into the national economy and to use them for the benefit of humanity (Gül et al., 2014).

Natural stones are the most important materials that have been widely used both in the building sector and art since ancient times. Throughout history, natural stones have been used in interior and exterior architecture, construction, cladding, flooring, ornamentation, sculpture, tombstone making, gravel, porcelain and glass industry, optical industry and ornamentation, and so on. Natural stones maintain their importance in today's modern building sectors due to their resistance to atmospheric agents, their workability, and their wide range of uses. The activities and trade of the marble and stone industry have increased worldwide and especially in Türkiye. Türkiye is one of the countries with the richest marble deposits in the world and has approximately 5.1 billion m^3 (13.9 billion tons) of marble reserves. This value represents 33% of the world's total reserves, which are estimated at 15 billion m^3. The Turkish natural stone sector occupies an important place in the world natural stone market due to the richness of varieties and reserves, the experience of the sector, the abundance of raw materials, the ease of transportation by sea, the dynamic structure of the sector, the new technologies used, and the wide range of colors (Ticaret Bakanlığı, 2021).

The production activities of marble quarries, especially those carried out by the open pit method, cause many negative impacts (e.g. negative changes in topography and visual landscape, complete removal of vegetation and topsoil, changes in water regime, water pollution, destruction of natural habitats, damage and displacement of wildlife, blasting, vehicle traffic, noise, intense dust generation, marble residues, etc.) (Sengupta, 1993; Mouflis et al., 2008; Wang, et al., 2011; Gül et al., 2014; Akten et al., 2014; Oğurlu et al., 2014; Zhang et al., 2018).

It may not be possible or may take many years to restore the land, which is destroyed during or after the production activities of marble quarries and whose natural balance is disturbed, to return to its original state or to repair itself when left alone. For this reason, there is a need for landscape/nature repair of these areas that have been degraded and destroyed by human technical intervention and support. The main objective of landscape/nature repair is to restore and develop these areas to their ecological, visual, and socio-economic values within the framework of appropriate decision options according to the type of use (restoration, rehabilitation, and reclamation) in harmony with the environment and a sustainable manner (Gül et al., 2014; Eraslan & Gül, 2014).

Rehabilitation or reclamation activities for degraded marble quarries restore one or more ecosystem functions, processes, or services, provide land stabilization, ensure public safety, provide aesthetic enhancement, and often provide economic benefits in a regional context. Pinto et al., 2001; Boscutti et al., 2017; Carrick & Krüger, 2007; Damigos & Kaliampakos, 2003; Chenot et al., 2017).

"Landscape/Nature Repair" is the planning, designing, protecting, and management of landscape areas that have been degraded or destroyed as a result of human activities or natural disasters within the framework of renewal (restoration), improvement (rehabilitation), and development for various purposes (reclamation) using biological and technical methods by environmental, social and economic conditions (Gül et al., 2014).

The environmental, economic, and social aspects of ongoing or abandoned marble production activities in rural areas, especially near settlements, are a matter of public concern and debate. Factors such as the high cost of remediation, the unwillingness of private marble managers, and the lack of involvement of local authorities are major obstacles to implementing solutions and eliminating the negative impacts in these areas.

All processes such as the permitting process for marble and stone quarrying activities, site selection criteria, pre- and post-activity repair activities, use and recycling of marble residues, planting, and technical applications, which are perceived as an important problem, should be addressed with a holistic perspective and common solutions. In marble and stone quarries, there is no suitable environment for planting due to the complete removal of the top vegetative soil, high-step marble mirrors, and hard marble surfaces resulting from the production activity. It is particularly important to determine the content and form of biotechnical repairing (vegetative and structural) applications for improvement and development according to the type of use of marble quarries (Gül et al., 2014).

Land preparation, soil improvement, and planting works have an important place in the landscape/nature repair process. Depending on the conditions of the study area, it will be possible to recreate the ecological, economic, and aesthetic values of the area by using appropriate plant species and effective planting techniques. These studies, which require time, labor, funding, and expertise, must be undertaken with a holistic approach to be successful.

This study aims to discuss and develop solutions to bio-technical approaches to landscape/nature repair of degraded and destroyed areas resulting from "Marble Quarries Activities”.

2. Open Marble Quarry Activities and Negative Consequences

In geological terms, limestone that has undergone metamorphosis is called marble. However, for many years, the term marble has been used commercially to refer to rocks that have a pleasant appearance, can be cut and polished, and are very different in terms of origin and lithology. In the Mining Law dated 24 June 2010, and number 27621, Group II.B minerals are defined as *"stones produced in blocks such as marble, travertine, granite, andesite, basalt and natural stones used for decorative purposes*".

Marble quarries in each marble deposit have their specific working methods according to the texture and structure of the rock. For a stone with sufficient reserves to be exploited, it must be of a certain quality. In other words, it must have saleable and usable characteristics. These characteristics are color, pattern, appearance, hardness, transparency, resistance to external factors, homogeneity, and workability (cutting and polishing), The extent to which a stone has these characteristics is determined by physicomechanical tests carried out by standards (MEGEP, 2011).

In open pit natural stone mining, all excavation and block natural stone production activities take place in an open area and natural environment. In underground natural stone mining, all excavation and block natural stone production activities are carried out underground, and partially outside the natural environment (Kulaksız, 2012; Alkaçır, 2016). According to the continuity of the cutting process in block extraction; a- Intermittent natural stone production methods and b- Continuous (uninterrupted) natural stone production methods are used. According to their geomorphological location, marble and stone quarries are located on a- Plains, b- Hills, and c-Sloping (Figure 1a-1b). Accordingly, open-cast quarries are named according to the morphological structures identified above. In addition, these structures can also be in the form of transitions and combinations. For example, a slope-type quarry may change to a flat-type quarry as a result of production. In open pit quarry operation methods, stepped structures can occur in the form of single or multi-stage boiler types (Kulaksız, 2012; Alkaçır, 2016).

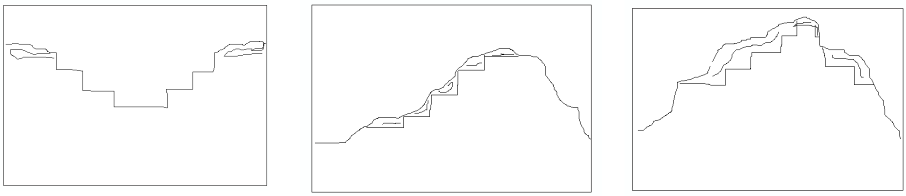

Figure 1a. Types of marble and stone quarries (MEGEP, 2011).

Plain-type marble quarry	Sloping backs type marble quarry	Hill-type marble quarry

Figure 1b. Pictures of marble and stone quarries (Original)

Abandoned quarries generally consist of four parts: (1) the quarry rock, which is, the bare wall left after ore extraction; (2) the quarry pit, which is the pit formed as quarrying progresses; (3) the rock dump, which is an area of flat land created by the removal of topsoil and debris during the mining process; and (4) the storage and transport platform, which is the ore storage, processing, and transport platform after mining (Zhang et al., 2018).

The problems generally encountered in open pit marble quarry operations can be summarized as follows; (Darmer, 1992; Sengupta, 1993; Görcelioğlu, 2002; Gül et al., 2014; Oğurlu et al., 2014; Zhang et al., 2018).)

- Destruction of the physical environment (landscape, topography, etc.) and natural environmental morphology.
- Aesthetic degradation and visual pollution in the environment.

- Destroys the vegetation cover and thus damages the natural food chain and biogeochemical cycles.
- Causes damage to or displacement of local fauna in the area.
- Contaminates underground and surface water resources, affecting their quality and quantity.
- Changes in the drainage pattern and water management in the area.
- Contaminating the groundwater of improperly selected dumping sites for stripping and covering layers containing toxic and hazardous substances, causes changes in their acidity and hardness.
- Production residues in various sizes cause environmental pollution as a result of indiscriminate storage in the area.
- Changes in the microclimate of the area.
- Destruction of agricultural and forest land.
- Damage to recreational areas.
- Causes noise and dust due to the intensive use of large tonnage vehicles used for fieldwork.
- Affects human health by causing diseases such as asthma, bronchitis, and COPD.
- Quarry dust clogs the "stomata" of plants, negatively affecting the development of both cultivated and naturally growing plants, and also prevents soil aeration by clogging pores in the soil, leading to reduced yields.
- Dust from the quarry can enter water bodies through the air and water, affecting water quality, pH changes, etc. and negatively impacting aquatic habitats.
- It disrupts the structure of existing roads and hurts the ecosystem as a result of new road construction works.
- Loss of fertile topsoil and erosion.
- Vibration and other related hazards arise from blasting, etc.

The land that has been destroyed during or after marble quarries activities and whose natural balance has been disturbed, may not be able to return to its original state or repair itself when left alone, or it may take many years. For this reason, there is a need for landscape/nature repair of these areas that have been degraded and destroyed by human technical intervention and support. Marble quarry production and repair activities are temporally, technically, and processual different and procedurally distinct and interrelated, requiring a "holistic project design".

3. Landscape/Nature Repair" Concept

The repair or rehabilitation of an area that has been degraded or destroyed as a result of human activities or natural disasters, or other related concepts is widely used. For example, different concepts such as "nature repair or nature restoration", "landscape repair" restoration", "reclaiming to natural", "return to nature", "reclamation", "improvement", "rehabilitation", "revegetation", "vegetation cover", "recultivation", "land arrangement", "soil improvement", "biological improvement", is now used by different professional disciplines today. This situation can lead to confusion in practice (Eraslan & Gül, 2014).

Today, the terms "nature repair" and "landscape repair" are fully inclusive of the other concepts mentioned above. The difference between these two terms is that nature repair only includes the restoration of natural areas, while landscape repair includes the restoration of natural or cultural areas that have been destroyed or degraded by both natural disasters and human activities. In this study, the concept of landscape repair is preferred because it is more inclusive.

According to the European Landscape Convention (2000), the landscape is an important concept for people everywhere: in rural or urban areas, in high quality as well as in degraded areas, in ensuring the quality of life and sustainable development, in achieving balance and harmony in the relationships between social needs, economic activities and the environment (Council of Europe (COE), 2000).

According to the Regulation on "*Reclaiming to Nature the Degraded Lands Degraded by Mining Activities*" (Dated 23.01.2010 and numbered 27471); The concept of “Reclaiming to Nature” is defined as "the rehabilitation of areas whose topography has been changed during or as a result of mining exploration and exploitation activities, by ensuring environmental safety and by the project, making them compatible with the environment through the relevant legislation and rehabilitation" (Madencilik Faaliyetleri Nedeniyle Bozulan Arazilerin Doğaya Yeniden Kazandırılması Yönetmeliği, 2010).

“Landscape Repair” can be defined as "the planning, design, and management of landscape areas that have been degraded or destroyed as a result of human activities or natural disasters, by environmental, social, and economic conditions, within the framework of original renewal (restoration), improvement (rehabilitation), development for different purposes (reclamation) and protection by biological and technical methods".

“Landscape Repair” can be grouped as “restoration”, “rehabilitation” and “reclamation” according to the intended use of the area (Gül et al., 2014; Eraslan & Gül, 2014; Şahin et al., 2014) (Figure 2).

***Restoration (=Original renewal)**: It is the process of transforming the natural and cultural areas that have been degraded or destroyed to an equivalent (original) state before the activity or recreating their old function. Or it is the reorganization of the area according to the conditions of use before the degradation.

***Rehabilitation (improvement):** It is the process of improving the degraded or destroyed areas in a different way from the original state or improving them close to their old function. Or it is the creation of new and different conditions in the area.

***Reclamation (development with different uses)**: It is the process of transforming or developing the area from its former use to a condition suitable for different uses. Or it is the development of different types of use. It is the arrangement and creation of the most appropriate uses (agriculture, forest, recreation, settlement, industry, nature conservation, water storage, energy generation, solid waste storage area, etc.) within the framework of the existing conditions. The purpose of reclamation is to "make the land suitable for the new use function to be realized on the land". Here, the desired state must be very well defined.

***Bio-technical works**: Biological (plantation) and technical (structural) methods and materials are used in combination to restore, improve and develop degraded or destroyed areas sustainably and rationally.

***Replantation (=revegetation)**: It can be defined as all the work of introducing, establishing, and maintaining the intended plantation cover on the land after filling and arranging degraded and destroyed land.

The aim of LANDSCAPE REPAIR of degraded and destroyed areas or ecosystems resulting from marble and quarry activities is aimed to improve the ecological, visual, and economic value of these areas for restoration or rehabilitation, or reclamation purposes in a sustainable and environmentally friendly manner.

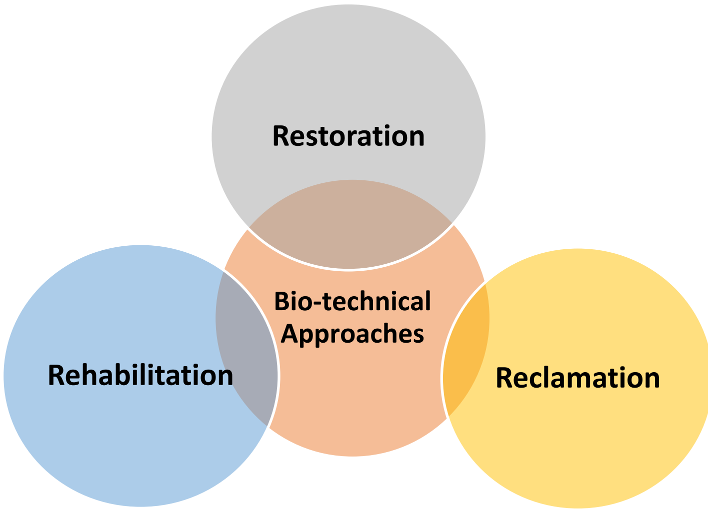

Figure 2. Types of landscape repair.

In marble quarries, there is no suitable environment for planting due to the stepped and hard surfaces left after production activities. In addition, due to the complete change in the structure of the land, it is not possible to restore the (original) ecosystem. Therefore, restoration is not an effective and efficient solution for marble and quarries. For this reason, the purpose of landscape repair of marble quarries is primarily to ensure the reconstruction and improvement of the degraded ecosystem (rehabilitation) or to ensure the recovery and development of these areas whose natural structure has changed by using them for other purposes (reclamation).

Basic principles of landscape repair;

- Environmentally acceptable (visually and functionally)
- Sustainable
- Minimum effort and cost
- Ecological, economic, and social benefits and,
- Use of biotechnological methods for rapid improvement and development.

Objectives of Landscape Repair in Marble Quarries;

- To minimize the long-term negative environmental, social, and economic impacts after the cessation of production,
- To relate and integrate with the surrounding landscape,
- To restore the area to a natural structure, both visually and functionally, using biotechnological methods, to ensure its ecological balance and to make it sustainable, taking restoration, rehabilitation, or promotion decisions according to the environmental, social, and economic conditions of the area.
- To restore natural plant formations,
- Limiting soil erosion and taking necessary measures,
- Protecting and improving water resources and ensuring the water cycle,
- Improve biodiversity (flora and fauna) on-site through habitat creation and management,
- Increase biomass and store carbon on-site,
- Provide education and research,
- Make them safe and stable for future use.
- To increase and enrich their population density.
- To stabilize the ecosystem, and so on.

“Landscape Repair Planning” for degraded and destroyed marble and stone quarries requires a "Holistic Project" since the production and repair activities are closely related to each other, although they are different in terms of temporal and technical dimensions and processes. The Landscape Repair Holistic Planning approach is proposed in 4 stages (Eraslan & Gül, 2014).

1. Production planning phase
   1.1. Pre-activity preparation
   - Actions to be taken before the permitting and allocation of the area.
   - Actions to be taken after the area is suitable for allocation and production and approval has been obtained,

   1.2. Production activity
   - Technical report,
   - Marble and stone production activity land use planning and extraction planning.
2. Post-production landscape repair phase
   2.1. Post-activity landscape repair project design phase,
   - Inventory/survey of the area destroyed and degraded by production activities,
   - Identification and prioritization of strategic goals, type of landscape repair use and objectives,
   - Proposed landscape repair development plan,
   - Biotechnical repair (structural and vegetative) design implementation projects (land preparation, soil improvement works, and appropriate planting designs),
   - Budgeting and costing, the establishment of timetables and priorities for implementation,

- Preparation of implementation action programs and preparation of structural and planting technical specifications for implementation,
- Preparation of maintenance and monitoring programs.

3. Approval and implementation phase.
4. Management, monitoring, and maintenance phase.

Irrespective of the type of landscape repair used in marble quarries, it is essential to use appropriate biotechnological applications in all cases. Biotechnical applications include land preparation, soil improvement, inanimate and living materials (plantations), and combined design.

4. Biotechnical Methods and Stages for Landscape Repair in Abandoned Marble Quarries

Landscape repair works can be divided into 3 types according to the type of materials to be used: a. Biological repair (living materials), b. Technical repair (non-living materials) and c. Bio-technical (combined) repair (Köseoğlu & Özkan, 1984; Akpınar et al., 1993; Eraslan & Gül, 2014);

The natural ecological recovery process is essentially a synergy of the development of soil and plant systems. The degree of landscape repair is directly related to the characteristics and combinations of soils and vegetation at different stages.

These degraded and destroyed areas require the use of living and non-living materials compulsory due to negative effects such as a complete change in the topographic structure, the emergence of a sloping structure, lack of soil and vegetation cover, lack of water capacity, and erosion. For this reason, the use of a combined repair method is the most rational approach in terms of time, cost, sustainability, and successful results. Landscape repair aims to create harmony and integrity between the landscape elements and the environment within the degraded ecosystem by using non-living and living materials in combination with the objectives of landscape repair and to optimize the relationship and interaction. In the case of biotechnological applications for landscape repair, activities are first carried out to regulate the soil structure and improve the soil. Then, applications are carried out by combining plants and non-living materials in line with the objectives (Eraslan & Gül, 2014).

4.1. Processes of Land Structure Regularization and Soil Improvement for Landscape Repair of Marble Areas

Biotechnical methods should be applied according to the characteristics of each open marble quarry site and the graded structure created by the working methods. The success of biotechnical applications in marble and stone quarries can vary depending on the soil preparation of the areas to be planted according to the purpose, the way of arrangement, the economic dimension, and the selection of plant species suitable for the purpose.

Factors such as the preparation and arrangement of the land, the thickness of the soil, the physical and chemical properties of the soil, etc. form the basis for planting in landscape repair.

In this context, the land preparation and soil improvement work in the field can be summarized as follows;

- As a result of the production in marble quarries, multi-story marble mirror formations and the absence of soil pose a serious problem for biological repair (planting) works. For this reason, the top vegetative soil should be removed at the beginning of the production activity and stored in a separate place to be used later for planting purposes.
- During the production process, a "stripping plan" should be prepared which includes various activities such as removal of the top layer,

loosening of the top layer, digging, loading, transport, pouring into the soil threshing, laying, leveling of the threshing area, construction, and maintenance of the soil threshing and grading roads.

- During the production process, marble residues should be sorted according to size, and marble residues with large rust should be stored in a separate place. Marble residues and stored vegetation soil should be considered the most basic soil/material preparation process for the formation of slopes and fills.
- Before landscape repair works, it is essential to carry out land shaping (grading-excavation-filling, etc.) and preparation of the land for the intended use.
- Land preparation and shaping processes; factors such as landscape character, existing topographical structure, wildlife, erosion, surface and underground water resources, drainage structure, and area safety should be taken into account for repair purposes.
- Where stored topsoil is insufficient, the soil should be taken from outside the area and compost fertilizer should be made from plant residues and stored.
- Slope angles and step sizes of steep marble mirrors should be calculated taking into account long-term stability. This calculation should take into account the topographical conditions, the slope's ability to hold itself, and the operating technique. Where it is not compulsory, all slope surfaces should be designed to be stable in their natural state without being supported by a retaining wall. The lower mirror should be sandblasted and toothed to prevent the slope from slipping.
- Marble mirrors can be converted to a slope with a maximum gradient of 45° by blasting from above (Figure 3). In addition, the main marble block can be cracked from the outside to the inside. The slopes of the upper mirrors should not exceed 30° under normal

conditions. Again, if mulch and hydrogels are used, this slope should not be exceeded to allow them to adhere.

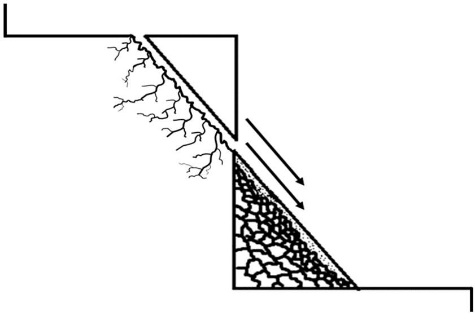

Figure 3. Top blasting of marble mirrors to create a slant (max 45°) (Güngöroğlu et al., 2014)

- In areas intended for daily use, the slope and angle of inclination should not exceed 30° and the step height should not exceed 3 m, and the step width should be at least 5 m.
- Piles made from existing piles or blasted material may be used for slopes to be formed by rising from the step surface to the mirror section surface,
- The upper slope made uneven, fissured, and cracked by blasting, can prevent large amounts of soil or small-grained material from being transported by rain and wind.
- In areas worked by cutting, wedging, and nailing methods, no additional measures are taken to ensure slope and slope stability, and steps and slope angles are left as they are.
- Residual marble of various sizes resulting from production in the area or from the creation of a marble mirror slope should be used for infill purposes as appropriate. Large residues should be placed at the bottom and smaller sized residues should be placed on top. Organic soil should be spread on top and made suitable for vegetation.
- In addition, large-sized residues can be used for retaining walls, embankments, boundaries, decorative purposes, etc. In particular, they can be used by placing them in wire cages called gabions of

various sizes (e.g., 1 x1 x 2m; 1 x 1 x1m). In this way, it will be possible to make functional use of the large-sized residues in the area and to economically reuse the large marble residues without disturbing the natural structure.

- Geological surveys to be carried out in landscape repair areas should identify the topographic slope, slope directions, natural surface drainage networks, geomorphological elements such as sinkholes, avalanche deposits, and hydrological and hydrogeological features. By these data, the surroundings of the activity area should be made safe concerning surface water or water flows that may occur after precipitation. Watercourses should be designed so that the surrounding natural drainage system is adequate under the most intense rainfall conditions in the region.
- Adequate measures should be taken against the possibility of flooding of the hollow area in the area. Adequate water collection channels, basins, and drainage systems should be installed in the facilities intended for human use, especially in areas that do not have natural drainage facilities due to their hollow structure, and it should be ensured that the connection to the main drainage system to which the discharged water will be directed is always open.
- Water collection and drainage channels around the site should be positioned so that they remain below the natural surface, especially in areas where people will be constantly present at all times. The surroundings of the activity area should be made safe concerning surface water run-off or possible water flow after rainfall.
- The slope stability of the pit should be ensured in the excavation areas in the form of a pit that narrows from the surface to lower elevations.
- In areas where people and wildlife may be harmed during repair work, the site must be fenced off with suitable material such as wire mesh, and wall and warning signs must be posted.
- Planting pits of 50 x 50 cm or 1m x 1m can be dug on the marble mirrors for planting purposes. However, opening the planting pits one

at a time can be detrimental in terms of ecological integration, cost, and time. Instead, 1 m wide channels can be created on the marble mirrors, running along the entire step, in front of the level, and behind the slope.

- To open these channels, a hole of up to 1 m can be drilled and a successful loosening blast can be carried out using dynamite and NONEL capsule without the need for ANFO, resulting in a trapezoidal profile pit section. In this way, holes and cavities can be created in the soil in a direction that speeds up planting in the soil, as the equipment does not move directly on the soil.
- After soil preparation and backfilling, the topsoil should be mixed with vegetable residues and, if necessary, green-manured by sowing legume seeds.
- In cases where there is no vegetative soil and it is not economical to provide it, the use of all types of organic waste and residues will be of great benefit in such areas.

4.2. Planting Techniques and Applications

4.2.1. Functions of planting in landscape repair

Enhancing biodiversity is fundamental to landscape restoration. In particular, increasing and maintaining plant diversity provides a material basis for ecological diversity and promotes ecosystem diversity.

It can also create diverse heterogeneous habitats that support a greater number of species communities, and the multi-layered roots of different plants lead to diverse soil microhabitats that support a variety of soil animals and microorganisms (Peng, 2007).

According to the vertical structure of its plant community, an ecological system can be divided into several layers, such as trees, shrubs, herbs, and the surface layer (mosses and lichens) (Li, 2011). The tree layer has tall stems and leaves that perform photosynthesis and regulate gas exchange. Leaf transpiration can prevent high temperatures and increase air humidity to regulate the microclimate. Trees, shrubs, and herbs combine to form a landscape, that provides scenic and recreational services for society. In the community ecosystem, pollination and seed dispersal for reproduction can be conducted via wind energy. Green plants primarily produce energy through photosynthesis and chemical energy bacteria to provide a variety of crops, fruits, prey, and other resources for consumers (humans and animals). The plant community is the primary producer, and it is also the habitat of animals.

The ground layers (lichens or mosses and other plants) can be used for water infiltration and as an adsorbent for water conservation to achieve effective water regulation. The soil is held in place by the root systems of plants, thereby preventing soil collapse and soil erosion. Microorganisms and fungi in the soil decompose biological debris to generate, store, and accelerate the internal cycling of nutrients (Zhang et al., 2018).

The functions of plants, whether herbaceous or woody are listed below (Çelem, 1988; Akpınar, 2005; Gezer & Gül, 2009; Yelsiz & Yücedağ, 2022; Yaşlı et al., 2023);

- It protects the soil surface by absorbing the energy of raindrops with its aerial parts and preventing them from hitting the soil directly.
- It prevents the movement of water and air on the surface by covering them at a certain height on the soil surface and reduces their erosive effects.
- With its subsoil parts, it prevents the soil masses from mobilization by keeping them deep.

- Reduces the susceptibility to erosion by reducing soil evaporation through shading.
- Increases the amount of organic matter and the water-holding capacity of the soil with its residues.
- Contributes to the water cycle through transpiration.
- Plants do not face the problem of destruction and fragmentation due to climatic and temporal conditions. On the contrary, they become more stable and more effective over time (Köse et al., 1993).
- They reduce the speed of the wind and direct it in the desired direction,
- It makes a positive contribution to air circulation.
- They have a cooling effect,
- It filters dust and particles,
- It regulates the ratio of CO_2 and O_2 in the air, and purifies the air,
- It regulates the humidity,
- They cover the upper part of the soil in difficult environments such as sloping, rocky, wet, or shady areas.
- They prevent water and wind erosion, regulate the water regime, and play an important protective role such as increasing soil fertility.

4.2.2. Selection of plant species

Many factors should be taken into consideration when selecting plant material to be used in the landscape repair process in marble quarries. These factors can be categorized into 5 groups: (Güney, 1989; Akpınar, 2005; Gül et al., 2014; Akten et al., 2014)

a. Environmental conditions: Plants should first adapt to the region in which the area is located and then to the micro-ecological characteristics of the area. Annual temperature distribution and maximum and minimum temperatures, rainfall, soil and air humidity, salinity, lime status, wind, soil pH, air, soil, and water pollution, aspect, etc. are important for species selection.

b. Intended use: The use of appropriate plant species for the purpose will increase the chances of success. For example, climbing plants for vertical surface planting, species with rhizomes and stolons to cover the soil surface, leguminous plant species to enrich the soil with nitrogen, evergreen species to create a continuous green texture, shallow-rooted species in places with low soil depth, species with a broad crown to create a shading effect, species suitable for fencing, species suitable for windbreaks, species suitable for color composition, etc. should be selected and used for the purpose.

c. Individual characteristics of the species: The natural lifespan of the selected plant species, stem shape, size, and height of the plant, growth characteristics of the plant, crown shape, size and degree of ground cover (shading), branching and leafing, whether it sheds its leaves or not, the resistance of the plants to pruning or mowing, resistance to plant diseases and pests, resistance to drought, and frost resistance, resistance to air pollution and dust, light and moisture requirements, altitude and aspect requirements, soil and water requirements, salt resistance, toxicity, the root structure of the plants, etc. should be known.

d. Cost: The species with the simplest and most cost-effective production techniques (sowing and planting), supply of plant species material, labor, soil preparation, transportation, protection, maintenance and renewal work, etc. should be preferred.

e. Maintenance and renewal: For all types of maintenance (fertilization, spraying, irrigation, pruning, etc.) and renewal before and after the application, the most suitable and low-maintenance, resistant, and highly adaptable species should be preferred.

4.2.3. General characteristics of the plants to be used and preferred in biological repair;

- They should be selected from the natural species of the area.
- They should be easy to produce and maintain.
- They should show rapid growth and spread.
- Plants should have a deep and strong root system. Shallow-rooted species should be preferred where the soil depth is shallow.
- It should have a high-water holding capacity.
- They should have sound and wind-blocking properties.
- Plants should be resistant to adverse conditions and climates.
- It should be resistant to shallow, calcareous, rocky soils and areas prone to erosion,
- They should be able to tolerate extremes of pH, soil temperature, humidity, and nutrient deficiencies.
- Species from the legume family should be preferred because of their nitrogen supply.
- It should be able to enrich the soil in terms of nutrients with its abundant leaves.
- The costs of material supply, establishment, and maintenance practices should be reasonable.
- It should be compatible and complementary with other plants for aesthetic and functional purposes.
- The plant composition should be created taking into account the size, texture, color, shape, etc. characteristics of the plants.
- Fruitful species and species with edible leaves should be used to provide food sources for wildlife.

4.2.4. Seeding and planting methods for planting

When planting in marble quarries, existing plants in the area should be protected so that they are not damaged before and during the activity. Seeds, cuttings, and bulbs of plant species growing in the vicinity of the quarry should be collected, prepared, and stored in a suitable place. A variety of sowing and planting methods can be used for planting during repair work. Factors such as the type and quantity of plant material available, application equipment, financial resources, and labor availability play a role in their selection (Güney, 1989).

In the planting technique, after land preparation, a composition of herbaceous+shrub and tree combinations is formed according to the purpose. Herbaceous groundcover plants increase the organic matter content of the soil, improve soil metabolism, protect the topsoil from erosion, provide shade, improve the physiological and biological conditions of the soil in the root zone, and make it favorable for subsequent cultivation and vegetation by developing on the raw soil within 1-4 years. Combinations can be made with shrubs and trees for pre-planting in the area. The ecosystem is then developed with primary and permanent tree species. The formation of natural vegetation in marble quarries can take 70-80 years or even longer (Görcelioğlu, 2002; Özalp et al., 2008; Kuter, 2014).

Methods to be applied to herbaceous and woody plants;

1. **Sowing methods:**

Herbaceous or woody plant seeds can be sown in the field by different methods.

a) Sowing of woody plants: Although their growth rate is generally slower than that of herbaceous plants, their post-sowing care and mulching increase the chances of success. They can be sown in pits, islands, or rows using a seed drill or by hand.

b) Sowing herbaceous crops: These can be sown by hand, with a seed drill or sprayer, or applied to the field in the form of broadcast seed. Spray sowing involves mixing seeds with water, fertilizer, mulch, and adhesives. This makes sowing easier and quicker and increases the chances of retention. Seed blankets are applied by placing seed mixtures between two fibrous materials and laying them on the field like a blanket. Although the mixture increases the chances of success, the need for very fine leveling of the area and compaction of the seed mixtures with wire can increase labor costs.

2. Planting methods using cuttings and separation:

a) Planting of woody plants: For some of the woody plants, seed production is very difficult, and it takes a long time for the plants to reach the size to fulfill their functions. In this case, the method of planting cuttings is preferred, and the bush bundle is shaped like a lattice fence and is also used as a structural element. Many methods have been developed for the application of woody cuttings.

b) Planting of herbaceous plant cuttings: Some plants, especially those capable of vegetative propagation, are planted by separating or taking cuttings from the mother plant.

3. Use of grass cuttings: In regions where there are not long dry periods, the pieces cut from the grass cover, which do not form deep roots, are used in the form of strips, cages, or checkerboards on the field, as well as retaining walls by laying them one on top of the other in front of slopes with a backward slope.

4. Use of soil seedlings: This method, which has a very high chance of survival and development rate, has disadvantages such as the need for nursery work and requiring more labor than planting methods. Plants placed in plastic, paper, and compressed peat containers can be placed in the field parallel to the elevation curves, at diagonal angles, in a diamond shape, and a cage shape. The use of soil seedlings has a higher chance of success than the others.

5. Combined methods: Some methods combine living and non-living material and take advantage of both. It is also possible to combine seed sowing, cutting, and planting (Güney, 1989).

4.2.5. Species of plants that can be used in the repair of the landscape of marble quarries

The herbaceous and woody plants to be used in the repair process of marble quarries should be selected by taking into account the basic factors such as climate, soil, altitude, aspect of the area, the purpose of use, and the individual characteristics of the plants.

Depending on the use of the area, combinations of herbaceous, shrub, and tree species to be selected from the natural plant species of the region can help to speed up both the success rate and the ecological balance.

Some important species that can be used in the landscape repair of marble quarries according to the current conditions of the Lake Region or Isparta Region in Turkey are given in Table 1 (Orçun, 1975; Köseoğlu & Özkan, 1984; Görcelioğlu, 2002; Yavuzşefik & Uzun 2005; Akpınar, 2005; Gül, et al., 2012; Gül et al., 2014; Akten, et al., 2014; Uzun, et al., 2014; Cındık & Acar, 2010; Gül & Özçelik, 2016; TUBİVES, 2023; Özçelik, 2023).

Table 1. Some important species that can be used in landscape repair of marble quarries in the Lakes Region or Isparta Region in Türkiye

Trees
Acer negundo L., *Acer campestre* L., *Ailanthus altissima* L., *Alnus glutinosa* L., *Alnus incana* L., *Alnus orientalis* L., *Betula pendula* Roth, *Cercis sp., Cupressus sempervirens* L. *Eleagnus angustifolia* L., *Eucalyptus amygdalina* Labill., *Fraxinus* sp., *Gleditschia triacanthos,* Hippophae rhamnoides L. *Pinus* sp., *Populus tremula* L., *Populus alba* L, *Prunus mahalep* L., *Prunus* sp., *Pyrus amygdalus* L., *Quercus* sp., *Robinia pseudoacacia* L.,, *Salix* sp., *Sambucus nigra* L., *Sorbus* sp., *Tilia platyphyllos* SCOP., and others.

Shrubs
Amelanchier sp., *Aristolochia maurorum* L., *Artemisia absinthium* L., *Asparagus* sp., *Astragalus* sp., *Berberis cretica* L., *Calluna vulgaris* (L.) Hull, *Capparis spinosa* L., *Caragana arborescens* Lam.,, *Cistus* sp., *Colutea arborescens* L., *Cornus* sp., *Cotoneaster* sp., *Crataegus* sp., *Daphne* sp,. *Erica* sp., *Euonymus latifolius* (L.) MILLER, *Eriolobus trilobatus* (Labill. ex Poiret) M. Roem., *Foeniculum vulgare* L., *Genista* sp., *Glycyrrhiza glabra* L., *Hibiscus syriacus* L., *Lavandula* sp., *Ligustrum* sp., *Lonicera xylosteum* L., *Lycium* sp., *Maclora pomifera* (Raf.) Schneid., *Myrtus comminus* L., *Paliurus* sp., *Pyracantha coccinea* M.Roem., *Quercus coccifera* L., *Quercus ilex* L., *Rhamnus* sp., *Rhus* sp., *Ribes* sp., *Rosa canina* L.,, *Rubus* sp., *Spartium junceum* L., *Salix purpurea* L., *Tamarix* sp., *Teucrium montanum* L., *Vitex agnus castus* L., *Vaccinium myrtillus* L., and others.

Ivy Plants
Ampelopsis quinquefolia Michx., *Convolvulus* sp., *Hedera* sp., *Jasminum fruticans* L., *Jasminum nudiflorum* Lindl. *Lonicera nummulariifolia* JAUB. ET SPACH, *Lonicera tatarica, Lonicera* sp., *Polygonium* sp., *Parthenocissus tricuspidata* (Siebold&Zucc.) Planch., *Wisteria* sp., and others.

Herbaceous Plants
Acantholimon sp., *Achillea* sp., *Aethionema* sp., *Agropyron* sp., *Agrostis* sp., *Alkanna incana* BOISS., *Alopecurus* sp., *Althaea officinalis* L., *Anchonium elichrysifolium* DC.) BOISS, *Alchemelia alpina* L., *Alyssum* sp., *Anthemis* sp., *Anthyllis vulneraria* L., *Anthoxanthum odoratum,* Carl Linnaeus, *Arabis caucasica* WILLD subsp. brevifolia (DC.) CULLEN, *Arenaria tmolea* BOISS., *Artemisia* sp., *Aspilenium viride* Huds., *Aster alpinus* L., *Athyrium sp., Aubrieta anamasica* PEŞMEN ET GÜNER, *Aubrieta canescens (*BOISS.) BORNM, *Aubrieta pinardii* BOISS., *Brachypodium sylvaticum* (HUDSON) P. BEAUV., *Bromus inermis* Leyss., *Bolanthus minuartioides* (JAUB. ET SPACH) HUB.-MOR. *Campanula lyrata lam.* subsp. *Lyrata, Carex* sp., *Centaurea* sp., *Cerastium* sp., *Crupina* sp., *Convolvulus althaeoides* L., *Chrysanthemum* sp., *Crepis* sp., *Cryptogramma crispa,* (L.) R.Br. ex Hook., *Cucurbita* sp., *Cynodon dactylon,* (L.) Pers., *Cystopteris fragilis* (L.) Bernh., *Dactylis glomerata* L., *Dactylorhiza* sp., *Delphinium gueneri* P.H. DAVIS, *Descampsia cespitosa* (L.) P. Beauv., *Dianthus micranthus* BOISS. ET HELDR., *Dryopteris* sp., *Deschampsia flexuosa* (L.) Trin., *Echinops viscosus DC, Epilobium* sp., *Erodium* sp., *Erigeron cilicicus* BOISS. EX VIERH., *Festuca* sp., *Foeniculum vulgare* Miller., *Galium saxatile* L., *Geranium robertianum* L., *Galanthus* sp., *Glaucium leiocarpum* BOISS., *Helichrysum* sp., *Hypericum* sp., *Hieracium* sp., *Iberis sempervirens* L., *Jurinella moschus* (HABL.) BOBROV, *Lathyrus* sp., *Linaria grandiflora* DESF., *Linum catharticum* L., *Lupinus albus* L., *Lolium perenne* L., *Lotus corniculatus* L., *Malva sylvestris* L., *Matthiola montana* BOISS., *Melilotus* sp., *Medicago sativa* L., *Melica penicillaris* BOISS. ET BAL., *Minuartia anatolica* (BOISS.) WORON, *Onobrychis* sp., *Origanum* sp., *Paronychia* sp., *Pilosella* sp., *Poa* sp., *Polygala supina* SCHREB., *Polygala anatolica* BOISS. ET HELDR., *Portulaca oleracea* L. *Potentilla* neumanniana Rchb., *Reseda lutea* L., *Racomitrium lanuginosum* (Hedw.) Brid. *Rosularia sempervivum (*M. BIEB.) BERGER, *Rumex* sp., *Salvia* sp., *Sideritis* sp., *Silene* sp., *Saxifraga* sp., *Senecio othonnae* BIEB., *Sesleria alba* SM., *Scrophularia* sp., *Scutellaria altissima* L., *Tragopogon* sp., *Taraxacum* sp. *Trifolium* sp., *Tymus* sp., *Vaccinium myrtillus* L., *Valeriana oligantha* BOISS. ET HELDR., *Vicia* sp., *Vincetoxicum canescens* (WILLD.) DECNE, and others.

5. Biotechnical Approaches According to The Type of Marble Quarry

5.1. Planting and Transplanting Plants in Manually Dug Pits;

Depending on the type of tree, shrub, or herbaceous plant, the pits are opened on the marble surface or the mirror slope, and the plants are planted or sown. Pits with dimensions of 1 x 1 x 1m for trees, 05 x 0.5 x 0.5m for shrubs and ivy plants are opened and planting and transplanting is carried out by filling with vegetable soil (Figure 4).

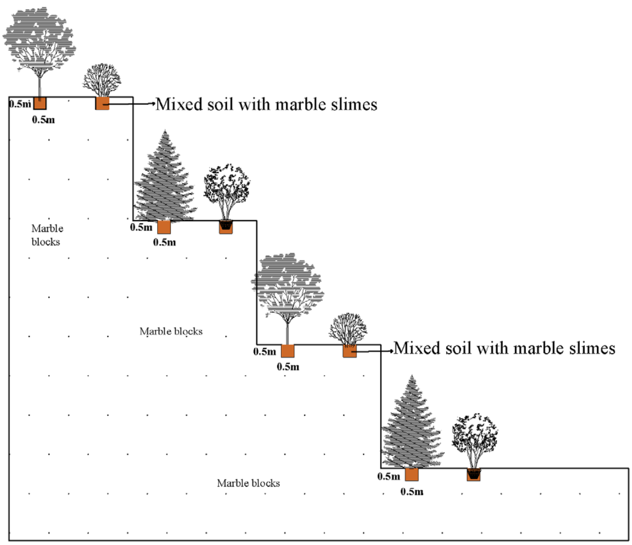

Figure 4. Planting and transplanting plants in hand-dug pits

5.2. Planting or Sowing Plants by Creating Channels in The Marble Floor;

This method can be used to create 2 or more separate channels, one in front of and one behind the slope, approximately 1m wide and running the length of the step. The planting pits, usually 50 x 50 cm, can be wider in areas such as marble quarries, which are devoid of soil cover and any biological activity. As opening the planting pits one at a time is detrimental to ecological integration and is costly and time-consuming, it may be preferable to continue the channels along the slope (Figure 5).

To open these channels, holes up to 1 m long are drilled and a successful loosening blast can be carried out using dynamite and NONEL capsule, resulting in a trapezoidal pit section. As the equipment does not move directly over the soil, holes, and gaps are left in the soil in a direction that accelerates planting. The blasted material in this pit is then removed by backhoes. Soil material is then placed into these trapezoidal pits using rear dump trucks.

The point to remember when planting seedlings is not to plant shallowly or deeply so that the seedling container or root length remains above or below the root collar in the hole. It should also be tied down with a heckle (pole) depending on the prevailing wind direction. After each planting, the first watering should be done, called life watering. Mixing compost fertilizer made from vegetables and organic waste and residues into the plant holes will be of great benefit.

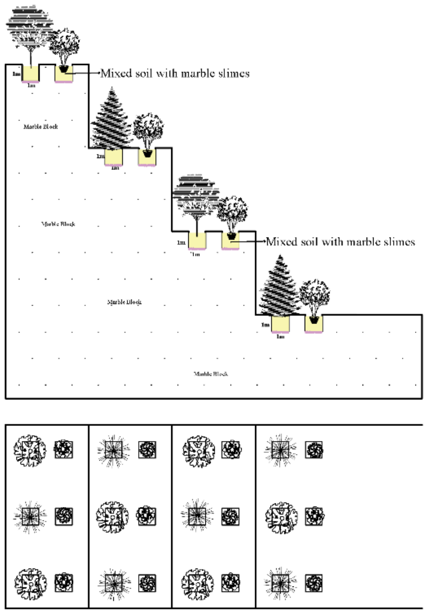

Figure 5. Planting and sowing of plants by opening channels in the marble floor

5.3. Planting and Sowing of Plants in The Soil Area Delimited by Gabions on The Marble Floor

On the stepped marble surface, which is the result of the production process, it is possible to make a soil filling in the form of a cushion of organic soil mixture with fine rust material at various depths and plant composition of trees, shrubs, and herbaceous plants. A 10 cm thick layer of coarse marble should be placed under the organic soil. The top of the soil should be leveled with a 2% slope. For combinations of trees, shrubs, and herbaceous plants, the soil should be prepared to a depth of at least 1 meter. However, it can be prepared at least 20 cm deep for perennials and groundcovers, at least 30-40 cm deep for ivy and small shrubs, at least 50 cm deep for tall shrubs and small trees, and at least 100 cm deep for tall trees. To prevent the soil from overflowing and flowing, and for the healthy development of the plants, the edges of the soil filling can be limited by a gabion with a wire cage of 1m x1m x1m or other sizes. The gabion (wire cage) should be filled with large pieces of marble thrown into the area. In this way, it will be possible to clean the large marble remnants in the area and to evaluate them in the gabion to store the remnants in an organized way. However, instead of gabions, large marble boulders, stones, logs, etc. can be used for demarcation purposes. The width and length of the soil-filled cushions can vary according to the characteristics of the area and the purpose of the planting (Figure 6).

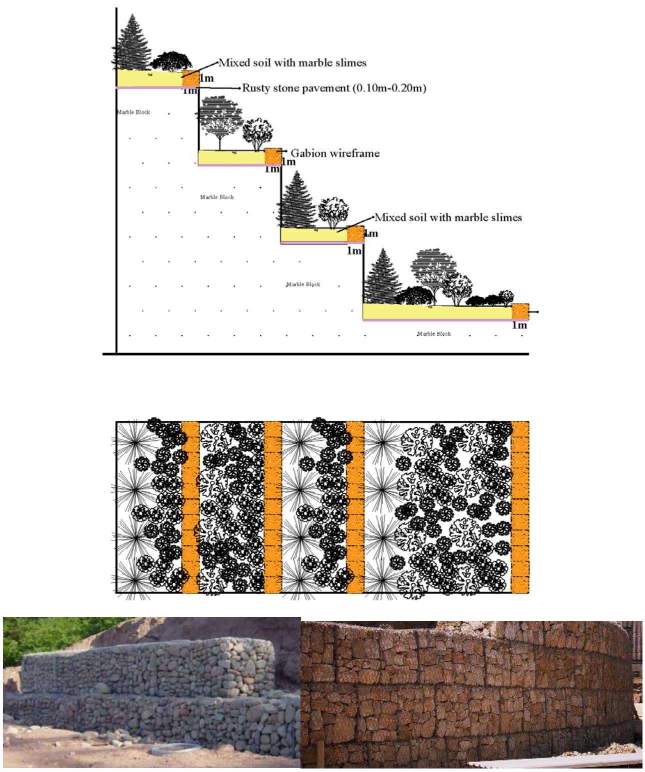

Figure 6. Gabion wire cages of various sizes filled with marble residues (Original)

5.4. Planting of Trees and Shrubs in Crates or Plots with Soil on a Marble Base

Where soil material is limited, trees and shrubs can be planted in various sizes of wooden logs or large marble blocks with a depth of at least 50 cm. Alternatively, trees and shrubs can be planted in various sizes of gabion boxes at least 1 m deep (Figure 7).

Figure 7. Planting areas with soil made of wooden logs on a marble surface (Original)

5.5. Planting Technique of Marble Mirrors Covered with Steel Mesh

This application is the method of wrapping ivy plants on steel mesh covering high marble mirrors. In this way, ivy plants can quickly camouflage the stepped structure of marble quarries.

In this method, the ivy plants can be hung from the top of the marble mirror or wrapped from the bottom up. In this way, it is possible to cover the marble mirrors with ivy plants by creating a cushion of soil at least 2 m wide and at least 50 cm deep at the top or bottom of the marble mirrors.

Perennial ivy species that can adapt to local conditions, are fast-growing, climbing, dense foliage, and durable can be used (Figure 8-9-10).

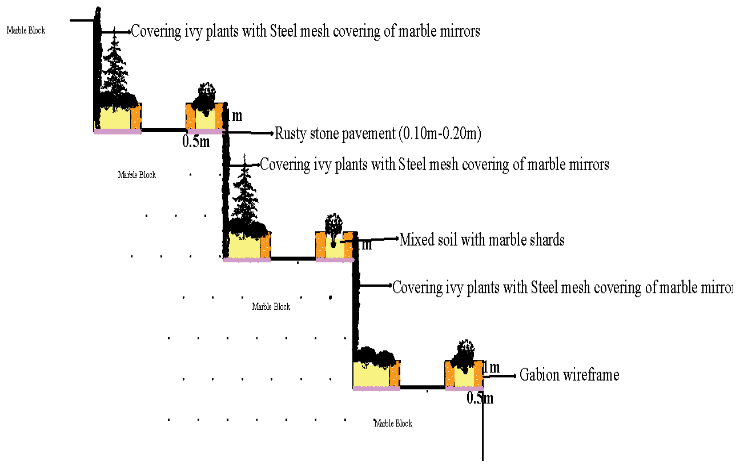

Figure 8. Planting technique for marble mirrors with steel mesh covering (Original).

Figure 9. Planting technique for marble mirrors (Original).

Figure 10. Steel mesh coating technique on marble mirrors and curved surfaces.

5.6. Planting with Geotextile Material

Geotextile is a material made of 100% continuous polyester or polypropylene fibers. Polyester geotextiles have a higher modulus of deformation, higher tensile strength, higher resistance to high temperatures, higher resistance to sunlight (this property is a great advantage in storage), and higher yield strength than polypropylene geotextiles (Toğrol et al., 2004).

Natural fibers can also be used in the production of geotextiles in applications where the geotextile is expected to perform its function for a limited period: Natural fibers such as flax, cotton, jute, sisal, abaca, and kenaf... are preferred. In addition, due to the resistance of coconut fibers to decay, mud, and moisture, porous nonwovens made from them can be used to prevent soil erosion and improve soil conditions (Mecit et al., 2007).

In this context, methods such as terracing, consolidation of rotten slopes (by line weeding, knitted fences, etc.), and stabilization with ditches and living material are most commonly used. As these methods are costly and time-consuming, new techniques need to be developed and/or compared with existing techniques.

Geotextiles with a coarse mesh structure provide a suitable environment for seed germination. This allows the vegetation layer to develop rapidly on slopes that will be formed as a result of marble and stone activities. Slopes that cannot be planted due to the geological characteristics of the soil (rock, slag, etc.) can be planted with geocells.

Slopes or walls with geocells, whose outer cells are filled with vegetative soil and planted, facilitate the adaptation to the environment with their natural colors. The slopes are covered with geotextile material and the soil and grass get a green and aesthetic appearance (Kocaer, 2011). Geotextiles can be used in landscape repair due to their technical advantages such as material control, space-saving, construction quality control, cost efficiency, technological superiority, and environmental sensitivity, as well as allowing the production of low-cost solutions (Figure 11).

Figure 11. Use of Geotextile materials on sloping surfaces (Alibaba, 2023).

6. Conclusion and Proposals

The mining sector is the most basic and well-established source of industry in the world and is a locomotive sector that directly provides raw materials/inputs to many sectors and is specifically extracted from the natural environment (Kulaksız, 2012). The marble and stone sector is an important sector with long, costly, and risky production processes and repair activities. For this reason, "Mining?" - "Nature conservation?" should never be favored over each other.

In recent years, marbling activities have been increasingly on the agenda, especially concerning environmental issues. Due to social sensitivity, the balance and harmony between marble extraction and nature conservation should be ensured by taking into account ecological factors. In this context, all mining activities require holistic planning and management with multidimensional approaches such as ecological, social, economic, and technological, by abandoning traditional habits.

Landscape repair (restoration, rehabilitation, and reclamation) of marble and stone quarries, that have been degraded as a result of human activities, requires the production of the most ideal solutions in terms of environmental, social, and economic aspects with a sustainable, holistic, and rational approach. Therefore, humanity-environment and mining are inseparable parts of each other and should be considered as a whole. (Kulaksız, 2012). In this context, differences may arise between the relevant stakeholders (marble operators, managers of institutions responsible for the area, non-governmental organizations, local people, academics, etc.) due to their expectations or perspectives towards the marble production and repair process. For this reason, it should be reconciled to find common solutions, especially among all stakeholders.

The type and process of landscape repair should be determined according to the production type, land use, operating conditions, and environmental, social, and economic conditions of marble and stone quarries. Stepped and hard marble surfaces resulting from the production activities of marble quarries are not suitable for planting and are a major problem. For this reason, it is important to use soil preparation, soil improvement, appropriate plant species, and planting techniques in biotechnological applications in the landscape repair process.

The main objective of biotechnical applications for landscape repair should be considered as the creation of a sustainable ecosystem in harmony with the environment in a way that ensures the integration of *" structure-process-services "*, guarantees physical stability and safety, and reduces negative environmental impacts. Landscape repair of marble quarries focuses on achieving the integration of *"structure-process-services"* of an ecosystem that can promote self-repair and eventually achieve a dynamic balance and self-renewal.

Landscape restoration of marble quarries with biological and technical materials is a technical and scientific process. Therefore, it requires a multidisciplinary study compulsory (Uzun et al., 2014; Eraslan & Gül, 2014). Structural or technical measures in landscape repair: Slope breakers, slope breaker discharge channels, gabions, erosion silt, ground rock, retaining walls, shotcrete, etc. (Uzun, 2014). The success of planting activities in biotechnical applications is directly related to land studies, soil preparations, structural arrangements, selection of appropriate plant species and application of appropriate planting methods, monitoring, and maintenance activities. Principles and recommendations for biotechnical applications for landscape repair of degraded and destroyed marble quarries;

- Landscape repair projects should be prepared and implemented by a project team consisting of specialized and multidisciplinary professionals.
- The landscape repair process should start with the process of marble and stone production activities and should be carried out together.

- The landscape repair planning/design process should first prepare the holistic environmental (ecological) social and economic inventory of the area in detail and the current status of the area should be revealed through survey studies.
- Biotechnical application approaches in the landscape repair planning/design process; the shaping of the land suitable for the purpose, soil preparation and improvement, determination of the plant species suitable for the purpose, identification of pioneer and climax plants, production and cultivation techniques of the plants to be used, procurement of materials such as seeds, cuttings, bulbs, seedlings, etc., sowing and planting methods, measures and forecasts for biotechnical practices such as the techniques of using plants together with structural materials, mulching, fertilization, transportation and storage of plants, afforestation techniques, weed control, maintenance and monitoring, labor, implementation costs, provision of financial resources, etc. should be determined.
- Necessary precautions should be taken before and during the marble extraction operations in order not to damage the flora, fauna, vegetative soil, existing water resources, etc. in the area. In particular, the top vegetative soil should be removed and stored in a suitable place. This soil should be returned to the area during the repair process. Existing plants in the area should be removed from the soil and stored in another area. They should then be replanted in the area.
- During the land and soil preparation process, marble residues of different sizes in the area should be prioritized for filling, retaining walls, borders, etc.
- Accumulated plant residues and waste should be used as soil improvement material or mulch material.
- Slopes to be built on marble mirrors should not exceed 45°.
- Plant species compatible with the natural environment and suitable for the purpose should be used in landscape repair. Natural plant

species should be preferred. Where necessary, exotic species that can adapt to the region can be used.

- When selecting plant species, preference should be given to plants that cover the soil surface, have dense branches and leaf tissue, prevent water and soil movement on the surface, have deep and strong root structures, are spreading, resistant to cold and heat.
- One of the main problems in planting is the inability to provide the desired quantity and variety of seeds, cuttings, seedlings, or saplings of natural woody and herbaceous species. Priority should therefore be given to the provision of seeds and cuttings and the production and cultivation of natural plant species (trees, shrubs, and herbaceous plants). Greenhouses and nurseries should be established and made compulsory for the production and cultivation of such plants in the area during the marble production process. In addition, private nurseries should be encouraged and incentivized for these studies.
- Urban agriculture and agroforestry approaches, which provide contact with nature and food, provide social, cultural, psychological and economic benefits for urban people (Türker & Akten, 2020; Türker, 2021; Türker & Akten, 2022; Gül, 2022;). In this context, the use of urban agriculture or agroforestry techniques in the planning of marble quarries for advertising purposes can create a good opportunity on a public scale.
- When planting, pioneer plants should be used in the first year, and after a few years, climax species should be planted. For example, in the first year, a mixture of herbaceous plants (e.g., *Dactylis glomerata* (30%), *Bromus inermis* (25%), *Poa pratensis* (15%), *Onobrychis sativa* Lam (15%), *Melilotus officinalis* (15%)) can be sown in rows or hearth sowing to using 70-100 kg of seed per 1 ha, and a straw mulch can be applied to the seeded area.
- Woody and herbaceous species belonging to the legume family, which can be particularly useful for biological soil improvement due

to the nitrogen fixation of their roots and the suitability of the C/N ratio in their fallen leaves, should be preferred. For example, *Robinia pseudoacacia, Alnus* sp., *Onobrychis sativa, Vicia* sp., *Lotus* sp., etc. (Görcelioğlu, 2002).

- When planting, trees and shrubs should not be used as single species or long rows of one species, but in small groups of the same species and composition with other plants (deciduous and evergreen plant mixtures).
- When planting rootless cuttings (e.g., *Alnus* sp., *Populus* sp., *Salix* sp., *Vitis* sp., etc.), they can be planted in the ground by making large cracks or pits in marble surfaces or mirrors. In addition, rootless cuttings can also be used to create terraces on all types of embankments and excavations. For this purpose, rootless cuttings are placed in bundles in pits at least 15-20 cm deep so that half or 1/3 of them remain in the soil (Wells, 1994).
- As a general rule, planting will vary according to the weather conditions in the area. In general, the best time for planting is before the wettest season (Uzun, 2014). For example, for the Lake Region (Isparta, Burdur, Afyon, Konya, Antalya region and its surroundings), it should be carried out in 2 different periods, in spring (March and April) and autumn (September and October).
- Ecological solutions should be found for sheltering and feeding wild animals in the area. For example, holes of different sizes (hole diameter between 4 cm and 1.5 m) can be drilled in marble mirrors for bird nests depending on the species (Oğurlu et al., 2014). Or the plant species that provide food sources and shelter for wildlife.
- As a result of the planting done in biotechnical applications on the land, maintenance, and repair works (fertilization, mulching, irrigation, pruning, thinning and completion, pest control, etc.) works should be monitored between 1-5 years.
- During and after the landscape repair process, the area should be safe for people and wildlife. For the first 5 years, the area should be

completely enclosed with a wire fence to prevent human and animal access. It can be opened for controlled use for between 5-10 years. After 10 years or when the ecosystem has the potential to regenerate itself, the area can be fully opened for use. Warning and information boards should be placed in the area.

Thanks and Information Note

This e-book chapter complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

There is no conflict of interest. All authors contributed equally to the article.

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Prof. Dr. Atila GÜL		
E-mail	:	atilagul@sdu.edu.tr
Undergraduate 1	:	Istanbul University, Faculty of Forestry, Department of Forestry Engineering (1986).
Undergraduate 2	:	Anadolu University Education Faculty of Business Administration, Department of Business Administration (2020).
MSc:	:	Yıldız Technical University, Science Institute, Landscape Planning (1988).
PhD	:	Ege University, Science Institute, Field Crops (1998).
Associate Professor	:	UAK (Presidency of the Interuniversity Board) Landscape Architecture (2008).
Professional experience	:	Süleyman Demirel University, Faculty of Architecture, Department of Landscape Architecture (2014-……...), Süleyman Demirel University, Faculty of Forestry, Department of Landscape Architecture (1999- 2014), Researcher, Aegean Forestry Research Directorate, İzmir (1993-1999).

İskender Emre GÜL		
E-mail	:	iskenderemregul@gmail.com
Undergraduate	:	Süleyman Demirel University Civil Engineering (2020)
MSc:	:	Akdeniz University Graduate School of Natural and Applied Sciences Department of Civil Engineering (Ongoing)

Ecological Approaches in Urban Planning: An Appraisal of New Urbanism

Dr. Fatmagül BOLAT[1]

[1]İstanbul University-Cerrahpaşa, Vocational School of Forestry Valide Sultan Cad. No:2 Sarıyer, İstanbul/Türkiye
ORCID: 0000-0003-1714-3334
E-mail: fatmagul.bolat@iuc.edu.tr

Citation: Bolat, F. (2023). Ecological Approaches in Urban Planning: An Appraisal of New Urbanism. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches.** 2023, Chapter 2, 51-77. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

New urbanism (NU) is a planning and design movement that aims to encourage environmentally friendly habits, promoting environmental and economic sustainability and creating more livable cities through physical planning. The emergence of the movement is directly related to a reaction to prevailing forms of urbanism, especially in the United States (Łucka, 2018). Instead of automobile-dependent suburbs, the movement emerged with a number of aspirations such as re-evaluating declined urban areas within the city, catalysing human interactions and encouraging walking and community life by building narrower roadways, hiding garages and garbage cans in alleys, and improving pedestrian links between residential districts and business areas (Fulton, 1996). In urban planning and design, it has always been important to increase the efficiency of the variables such as accessibility, walkability, aesthetics, size, presence of green areas and proximity to food and beverages of areas that form an important part of the urban structure such as city squares (Dinç & Gül, 2022). Typical suburban plannings have led to these features to become the amenities for the few. NU was considered as an alternative to typical suburban planning in the United States (Day, 2003).The concept of new urbanism arose as a means of endorsing residential projects that feature a combination of multiple uses whether residential, business, cultural, institutional, or recreational (mixed-use) and are situated in close proximity to both amenities and public transportation. These projects are designed to be compact and pedestrian-friendly, with the goal of increasing opportunities for social interaction and promoting a sense of community and social control.

Additionally, the emphasis on surveillance and encouraging walking is intended to reduce crime rates (Cozens 2008). The NU movement gained popularity in the early 1990s (Gonzalez & Lejano, 2009) and was implemented in many areas, mainly in the USA and Canada. Although there have been criticisms that new urbanism practices are not successfully meet the initial goals, the movement continues to exist and tries to adjust the to the conditions of a rapidly changing era through the Congress of New Urbanism which is an organization that was founded in 1993 to promote the principles of new urbanism and to facilitate communication and cooperation between individuals and organizations involved in the movement (Marcuse, 2000). It provides a discussion platform and debate on new urbanism, and it also organizes conferences, workshops, and other events to promote the movement (Fulton, 1996).

This chapter presents the emergence, development and general framework of the new urbanism movement together with its history, reviews the criticisms of new urbanism and examines the principles of this movement through the Charter of New Urbanism developed by CNU. This chapter provides a summary of the historical development of urban planning movements in Turkey and evaluates the current planning and design movements based on their adherence to the principles of New Urbanism. For this purpose, the text of the Regional Plan for Istanbul for the years 2014-2023, the most populous city in Turkey, is taken into consideration. Finally, in the light of comparisons and general evaluations on the two texts, the contributions that the new urbanism movement may offer to today's cities is revealed.

2. Material and Method

Initially, a comprehensive review of relevant literature was undertaken to establish a strong basic understanding of New Urbanist principles. The review focused on academic articles and online resources related to New Urbanism, as well as the Charter of New Urbanism itself. The Charter of New Urbanism is a text that was reaffirmed by The Congress for the New Urbanism (CNU) held in South Carolina in May 1996 (Villiers, 1997).

For the comparison, the principles indicated in the Charter of New Urbanism and the urban planning policies and strategies outlined in the Istanbul Regional Plan 2014-2023 (İRP) published by the Istanbul Development Agency were examined.

Next, a text analysis on Voyant Tools (voyant-tools.org) was conducted on the Charter of New Urbanism to extract the most frequent keywords related to NU. Voyant is a web-based text analysis tool that allows users to visualize and explore textual data (Sampsel, 2018). Fourteen keywords were identified based on their frequency and relevance to the principles of NU.

Subsequently, a text analysis using Voyant Tools was conducted on the İRP to extract the most frequent words from the document. The Istanbul Regional Plan is a comprehensive urban planning document that outlines the city's development policies and strategies for the next decade. The analysis revealed the most frequent words used in the report.

Finally, the most frequent words from the Charter of New Urbanism and the frequencies of the same words in The Istanbul Regional Plan were compared to identify commonalities and differences between the two documents.

There is an order of magnitude in lexical variety between Charter and the regional plan. Charter consists of 1188 words while The Istanbul Regional Plan consists of 39475 words. In order to have a proportional comparison, the word values are calculated by multiplying the frequency values with the vocabulary density value that is provided by the Voyant Tool. These values are presented in a table and a graphic. The ranking of NU keywords in the Charter and the ranking of the same keywords in the İRP are compared in value according to the table. The analysis also focuses on the extent to which the principles of NU are reflected in the urban planning policies and strategies of Istanbul, and the potential for incorporating NU principles into the city's development plans.

3. The History and Emergence of New Urbanism

The new urbanism movement, which emerged towards the end of the twentieth century, emerged as a response to dissatisfaction with existing urban planning approaches. It aimed to create livable urban environments based on the criticisms that the spread of suburbs, especially in American cities, increased automobile dependency and that traditional urban planning approaches caused environmental concerns and deepened social inequalities. Hence, examining the historical context and roots of the new urbanism movement is important for understanding the movement.

3.1. Predecessors of New Urbanism

Before the emergence of the new urbanism movement, there were movements that aimed to design livable environments and can be characterized as precursors of the new urbanism movement. The first of these is Ebenezer Howard and the Garden City movement.

The Garden City movement, conceived by British urban planner Ebenezer Howard in the late 19th and early 20th centuries, aimed to create self-sufficient communities that harmoniously combined the best aspects of urban and rural living. Designed with a concentric pattern, Garden Cities featured public parks and green spaces at their core, promoting a healthier lifestyle for inhabitants. One of the primary objectives of this movement was to alleviate overcrowding and depopulate London by establishing satellite towns with utopian social characteristics (Fishman, 1998). Garden Cities emphasized a cooperative governance structure, balancing the need for democratic decision-making with the efficient management of resources. However, this approach occasionally led to dilemmas concerning the balance of power between local authorities and residents (March, 2004). Agriculture and gardening played an essential role in the Garden City concept, ensuring local food production and fostering a connection to nature. Overall, the Garden City movement sought to create sustainable, well-planned communities that provided a high quality of life for their residents.

As a prominent activist, Jane Jacobs' critique of modernist urban planning has also been highly influential in shaping contemporary planning practices, including the New Urbanism movement, as it also aims to create more sustainable, human-centered urban environments. In her 1961 book, “The Death and Life of Great American Cities”, Jacobs argued that the top-down, rationalist approach of modernist planning, with its emphasis on functional segregation and large-scale development, led to sterile, lifeless urban environments that lacked the vibrancy and diversity of traditional neighborhoods (Jacobs, 2011). In her book, she also criticized the reliance on cars and car-oriented design. She emphasized mixed-use, walkability, and human-scale design to preserve urban vitality (Basmajian, 2014). Although critics have argued that Jacobs' approaches have sometimes been criticized for being overly idealized and limited to the neighborhood scale or do not adequately address social and economic inequalities (Tavolari, 2019), her focus on vibrant and diverse urban environments continues to influence urban planning and design practices. Christopher Alexander's "A Pattern Language" published in 1977 was another influential idea that had a profound impact on the evolution of the New Urbanism movement (Duany et al. 2000).

In his book, Alexander analyzed the recurring patterns in urban space together with event patterns and the culture created by this combination as a component of the city (Gabriel & Quillien, 2019). Pattern language approach emphasized the importance of a human-centered approach, focusing on the human scale, walkability, mixed use and social interaction (Iwańczak & Lewicka 2020). In his book, Alexander advocated the idea of designing urban environments as spaces that can evolve and adapt over time, responding to changing needs and conditions (Alexander, 1977).

Even though it is not a urban planning movement itself, Rachel Carson's 1962 book "Silent Spring" spawned a grassroots environmental awareness and increased public understanding of environmental issues caused by human activity. International actions as the Brundtland Report (1987), the

Club of Rome's "Limits to Growth" report (Meadows et al., 1972), Stockholm Conference, also known as the United Nations Conference on the Environment and the United Nations Conference on Environment and Development (1992) are examples of how growing environmental awareness forced governments to take action. It can be stated that these developments played a role in the emergence of new urbanism indirectly.

3.2. Early Developments and Milestones in New Urbanism

The term "New Urbanism", which was first used in the mid-1980s, gained an organizational structure with the establishment of the Congress on New Urbanism in 1993 as a non-profit organization based in Chicago. the Congress for New Urbanism (CNU) has become an influential force within the movement. Key figures in the NU movement such as Andres Duany, Elizabeth Plater-Zyberk and Peter Calthorpe have also helped shape its development. There have also been influential projects and developments such as Seaside, Florida and Kentlands, Maryland that have helped to spread the principles of NU.

Over the years, the Congress for the New Urbanism (CNU) has worked with many organizations, both nationally and internationally, to promote the principles of NU and to foster more sustainable and livable communities. Some of these organizations are; American Planning Association (APA), U.S. Green Building Council (USGBC), Urban Land Institute (ULI), Smart Growth America (SGA), Institute of Transportation Engineers (ITE), Project for Public Spaces (PPS). CNU has also worked with numerous local and regional planning agencies, non-profit organizations and community groups to support the implementation of New Urbanist principles and projects at the grassroots level.

3.3. Principles of New Urbanism

New urbanism emphasizes walkability, connectivity, mixed use and diversity, mixed housing, quality architecture and urban design, traditional neighborhood structure, increased density, smart transportation, sustainability and quality of life (Heydari & Shojaeivand, 2017). The congress of New Urbanism, which still continues its activities today, has developed guiding principles for the planning and design of cities based on the notion that physical spaces have an impact on human welfare and happiness. These principles are addressed at three levels of scale (CNU, n.d.).

The principles at the regional scale emphasize the importance of the natural boundaries of the metropolitan area in relation to its agricultural hinterland and natural landscape. The principles proposed for this scale are to reuse existing urban areas rather than expanding outwards to the periphery, to avoid blurring boundaries, and to integrate new development into the existing pattern. It also recommends respecting the historic fabric and encouraging mixed uses to support a regional economy that benefits all income levels. Finally, it calls for a cooperative sharing of resources between municipalities within the region.

Neighborhood-scale principles emphasize the creation of identifiable, compact, pedestrian-friendly and mixed-use areas that promote social responsibility. Civic, institutional and commercial activities should be integrated into neighborhoods and access to school, work and other daily activities should be provided on foot or by bicycle. It advocates the interconnection of different areas through neighborhood parks and a diversity of housing types and prices to encourage social interaction.

The principles for block, street and building scale emphasize the importance of physically defining streets and public spaces for common use. Architectural projects are recommended to be integrated with their surroundings, accessible, safe and secure. Streets and squares should prioritize the safety and comfort of pedestrians, while automobiles should respect public space. Designs should encourage social interaction, foster a sense of community and democratic culture, and preserve historic buildings wherever possible.

3.4. New Urbanism Examples

Considered the first example of new urbanism, (Hamer, 2000) Seaside, Florida is a small town along the gulf coast. Robert Davis enlisted the help of new urbanism architects Andres Duany and Elizabeth Plater-Zyberk to create a gated community of traditional-style homes on the land he owned. The architects developed a plan in which all roads lead to the center on a radial plan. In the center of the town there are shops, restaurants, cultural and educational institutions, and a central green space and wide beach access, which becomes the main attraction for tourists during the peak season (CNUb, n.d). In designing the residences, Duany and Plater-Zyberk used a variety of architectural styles, including Victorian, Neoclassical and Postmodern, to give each street its own unique character. The houses have very little front yard space and walkways between backyards to encourage interaction between neighbors (CNUb, n.d). Preserving the natural landscape is an important aspect of the Seaside design. The preservation of the sand dunes on the beachfront as an ecological barrier makes it a pioneering example of environmentally sensitive construction practices.

Another example of New Urbanism is a settlement in Florida near Walt Disney World. Led by Disney CEO Michael Eisner and planned by Cooper, Robertson & Partners and Robert A.M. Stern, the town was designed using New Urbanism principles. Accordingly, the town includes extensive parks and green spaces. It is made up of eight villages, each specially planned. Celebration is a walkable community with unique architectural styles, diverse amenities offers a broad spectrum of educational and employment options. For its focus on traditional urban planning principles, the Urban Land Institute named Celebration as the "New Community of the Year" in 2001 (CNUc, n.d.).

Built in 1987, Kentlands, Maryland is widely regarded as one of the earliest examples of a New Urbanist development in the United States (Zurborg, 2023). It was designed by Andres Duany and Elizabeth Plater-Zyberk. The town was designed to have walkable, mixed-use neighborhoods, closely built housing units and a variety of historic architectural styles. Each neighborhood is designed to have its own unique character. Kentlands has a variety of housing types, ranging from single-family homes to apartment buildings. Each neighborhood has these different housing types together. Green spaces, lakes and wetlands are scattered throughout the neighborhoods (Tu, 1999).

3.5. New Urbanism Critics

New urbanism gained rapid recognition and implementation in the 1990s with projects implemented in many states throughout the USA (Garde, 2004). However, the movement has faced criticism over time regarding its ability to achieve its goals. For instance, although reducing car dependency is the primary objective, some argue that new urbanism projects do not have a positive impact in this regard because they are located in the urban periphery. Critics argue that new urbanist communities are generally composed of middle and upper classes which goes against the principle of diversity, a key principle of New Urbanism. This can lead to negative consequences such as gentrification, displacement of low-income residents and social segregation, undermining the egalitarian structure of these communities (Smith, 2002).

Although New Urbanism suggests that neighborhood-scale design can encourage a habit of walking, Rodriguez et al. (2006) found that residents of new urbanist neighborhoods did not show a significant change in physical activity rates compared to residents of traditional communities.

According to Dewolf (2002), New Urbanist settlements with their brick houses and white fences, create an artificial atmosphere that resembles a television set more than a real neighborhood. This appearance is thought to prevent the development of a sense of place and community that New Urbanism aims to foster. However, this is not the only criticism of the traditional design principles of New Urbanism. The architectural codes followed to create a town were seen as prescriptive and inflexible particularly in the early period.

In his study, Trudeau (2013) makes the case that while modern urbanism aids social and environmental sustainability in some limited ways, some types of its development unintentionally work against social and environmental sustainability aims.

New Urbanism has evolved over time in accordance with the changing social, economic, and environmental conditions. Feedback from implemented projects and criticism from various stakeholders have also contributed to its evolution. Since the movement's inception, there has been increasing environmental awareness and growing concerns about climate change. As a result, New Urbanism has incorporated sustainable design principles such as green building practices, renewable energy, water conservation, and rainwater management. In response to criticism that New Urbanism creates inequalities, the movement has taken initiatives towards social equality. These initiatives include affordable housing, mixed-income neighborhoods, and projects targeting underserved communities. While traditional and vernacular architecture was encouraged in the first period, New Urbanism has gradually embraced various architectural styles. In the recent period, the movement has also integrated technological developments such as smart city applications. Overall, New Urbanism strives to adapt to changing conditions and continuously develop by taking into account feedback on negative results.

3.6. Turkey's Urban Planning

The first planned cities in Turkey were built after the proclamation of the Republic in 1923. During this period, the government focused on modern urban designs to establish a modern and secular state (Erman, 1998). The new capital, Ankara, was designed by German architect Hermann Jansen in accordance with modernist urban planning principles. Major cities such as Istanbul and Izmir also initiated modernisation efforts, resulting in the construction of new public buildings, infrastructure, and transportation systems. However, increasing industrialisation following the Second World War led to a rapid migration from rural to urban areas (Bal, 2007). As the housing and infrastructure works developed to accommodate the rapidly increasing urban population were insufficient to meet the incoming migration, informal settlements called "Gecekondu" emerged on the peripheries of large cities. These squatter settlements created urban problems that have continued to persist to the present day and have been severe enough to influence the country's policies. Since the 1980s, Turkey has adopted neoliberal economic policies and has opened up to the global market. As a result, significant investments have been made in real estate, tourism, and infrastructure projects, giving rise to the era of big projects. Urban development and expansion have been uncontrolled and with little regard for sustainable principles. Gated communities, shopping centers, and apartment buildings have become common features of Turkish cities since the 1980s. Unfortunately, Turkish cities exhibit numerous negative characteristics, including high housing prices, inadequate infrastructure and transport services, unaesthetic designs, and environmental problems. Recently, municipalities have commenced investing in concepts such as energy efficiency, green space systems, metro networks, and sustainability as they have become recognized and demanded. However, to overcome these problems, holistic urban policies that are effective throughout the country are required.

With a population of more than 16 million people, Istanbul holds the distinction of being not only the largest city in Turkey but also the primary hub of the country's economic and cultural activity (Birinci, 2023). It is also one of the most historically and culturally rich cities in the world with a heritage that spans thousands of years. Istanbul's unplanned development parallel to the industrialization process has resulted in a significant number of unhealthy, decrepit neighborhoods (Özdemir Durak & Külahlıoğlu, 2017). In order to ensure the sustainable growth and development of İstanbul, it is important to have a comprehensive urban development plan in place.

The Istanbul Regional Plan 2014-2013, published by the Istanbul Development Agency, is a valuable resource for examining the planning approaches used in Istanbul (Akbulut & Çölgeçen, 2023). Encompassing a broad spectrum of topics, including land use, transportation, environmental conservation, economic progress, social welfare, and cultural heritage conservation, this plan lays out policy guidelines that serve as a blueprint for the city's growth and development. Designed to promote the well-being of its residents, the plan aims to facilitate sustainable and efficient urban expansion while ensuring that the city's unique identity is preserved for future generations.

4. Findings and Discussion

Within this section, a thorough examination of the research results is provided, honing in on the similarities and divergences evident in both texts and their probable implications for the forthcoming growth of Istanbul.

4.1. The Charter of the New Urbanism

The Charter of New Urbanism text is consisting of 1118 words in total. This text was uploaded into Voyant Tools and the word cloud created by Voyant Tools is shown in Figure 1. According to this analysis, the most frequent words are; urban, public, neighborhood, development and districts (Figure 2).

Figure1. Word Cloud of the Charter of the NU.

This corpus has 1 document with 1,188 total words and 513 unique word forms. Created now.

Vocabulary Density: 0.432

Readability Index: 17.317

Average Words Per Sentence: 36.0

Most **frequent words** in the corpus: urban (12); public (11); neighborhoods (10); development (10); districts (9)

Figure 2. Most Frequent words in The Charter of NU.

In order to provide a finer representation, essential keywords of new urbanism have been selected among the words with highest frequency. As a result, 14 words were chosen: “urban”, “public”, “neighborhoods”, “development”, “districts”, “community”, “design”, “towns”, “metropolis”, “metropolis, “economic”, “building”, “street”, “pedestrian” and “environmental”. The frequencies of these words are given in table 1.

4.2. The İstanbul Regional Plan 2014-2023

The İstanbul Regional Plan 2014-2023 is a text consisting of 39,475 words in total. This text was uploaded into Voyant Tools and the word cloud created by Voyant Tools is shown in Figure 3. The most frequent words in İstanbul Regional Plan are: İstanbul, objective, development, urban and social (Figure 4).

Figure 3. The word cloud of the Istanbul Region Plan 2014-2023.

This corpus has 1 document with 39,475 total words and 3,770 unique word forms. Created now.

Vocabulary Density: 0.096

Readability Index: 17.364

Average Words Per Sentence: 25.7

Most **frequent words** in the corpus: istanbul (511); objective (494); development (320); urban (286); social (201)

Figure 4. Most Frequent Words in the İstanbul Regional Plan.

4.3. Comparison

Table 1 presents the frequency and word values of selected keywords from the Charter of NU and the same words in the İstanbul Regional Plan (2014-2023), allowing for a comparison of their discursive content.

Table 1. Comparative frequencies of key words.

	Charter of NU			**İstanbul Regional plan (2014-2023)**		
Keywords	**Word frequency**	**Vocabulary density**	**Word Value**	**Word frequency**	**Word Value**	**Word Value**
Urban	12	0,432	**5,18**	286	0,096	**27,46**
Public	11	0,432	**4,75**	125	0,096	**12,00**
Neighborhoods	10	0,432	**4,32**	0	0,096	**0,00**
Development	10	0,432	**4,32**	320	0,096	**30,72**
Districts	9	0,432	**3,89**	0	0,096	**0,00**
Community	9	0,432	**3,89**	23	0,096	**2,21**
Design	8	0,432	**3,46**	41	0,096	**3,94**
Towns	7	0,432	**3,02**	0	0,096	**0,00**
Metropolis	7	0,432	**3,02**	0	0,096	**0,00**
Economic	7	0,432	**3,02**	148	0,096	**14,21**
Building	6	0,432	**2,59**	27	0,096	**2,59**
Street	5	0,432	**2,16**	0	0,096	**0,00**
Pedestrian	5	0,432	**2,16**	17	0,096	**1,63**
Environmental	4	0,432	**1,73**	37	0,096	**3,55**
		Average Word Value	**3,52**	**Average Word Value**		**7,29**

According to this comparison, both texts are focusing on the epithet "urban" which is an expected outcome regarding these texts are about urban planning and design. There are five words in the CNU text that are not mentioned in the İstanbul Regional Plan (2014-2023) which are; Neighborhoods, Districts, Towns, Metropolis and Street. Their absence in the İRP does not necessarily mean that there is a lack of consideration but it indicates that the plan may focuses more broadly on larger-scale urban development, infrastructure, or policy, rather than on the specifics of how neighborhoods, districts, towns, streets, or other urban design elements are planned and implemented.

The Charter of New Urbanism prioritizes walkability, mixed-use development, sustainability, and community building. It recognizes the importance of human-scale neighborhoods and streets, which are the not even mentioned once in the Istanbul Regional Plan.

The highly valued words "community," and "design" in the charter suggest a focus on creating livable, sustainable, and equitable urban environments that prioritize community building and public space. Interestingly, the word "environmental" has a value of 1.73 in the CNU text, which is lower than the average word value of 3.36 for all words in the text.. It may indicate that although environmental sustainability is one of the important goals of new urbanism, it may not be its main focus. The emphasis of the new urbanism movement may be on developing walkable, mixed-use and transit-oriented communities that are socially, economically and culturally dynamic, walkable, mixed-use and transit-oriented, that are economically sustainable and livable.

Upon analyzing the Istanbul Regional Plan 2014-2023 and the Charter of New Urbanism, it becomes evident that there are noteworthy differences in their approaches to urban planning and development. Notably, the Istanbul Regional Plan places greater emphasis on economic concepts than the Charter of New Urbanism does (Figure 5).

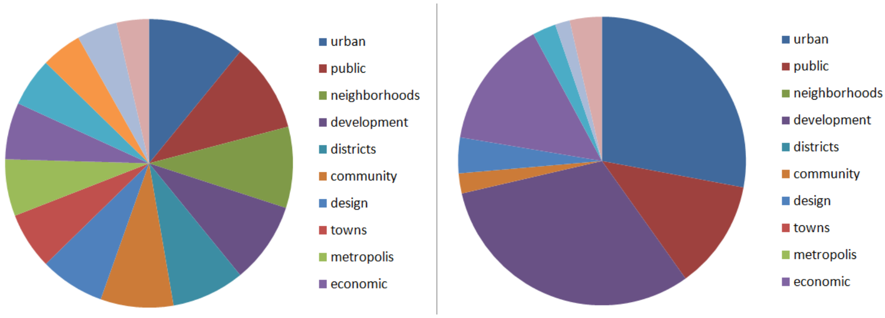

Figure 5. The graphic of the Comparison of the Charter of NU and İRP.

Despite these differences, the analysis also revealed some similarities between the two documents, particularly in their focus on public spaces. It indicates that both plans aim to prioritize the well-being and prosperity of city dwellers.

5. Conclusion and Suggestions

The emergence of the New Urbanism movement is related to the problems associated with American cities, which have been characterized by urban sprawl, automobile dependence, and social isolation. In the late 1990s, the New Urbanism movement gained traction, and applications were made in various parts of the USA. The movement established guiding principles and a general framework for implementing its ideas. These principles emphasized the importance of walkability, mixed-use development, human scale design, and sustainable practices. The central aim was to cultivate lively, inclusive, and ecologically sound urban environments that would facilitate social engagement and nurture a strong sense of community. However, over time, it is understood that the new urbanism movement has some shortcomings in terms of creating more livable cities in terms of its initial objectives. Despite aiming to reduce automobile use, many New Urbanism developments ended up promoting suburban development and automobile dependence. Many of these communities lacked the amenities and services that were promised, and some became privileged areas where those with greater financial means lived, leading to gentrification and displacement of lower-income residents. Strengthening social ties by putting the human scale at the center of urban development is an important step forward. However, although it has an environmental sensitivity, it has not sufficiently incorporated ecological principles. To be successful, physical planning must also address the economic, social, and other inequalities that contribute to urban problems.

As a result of today's multifaceted changes, solutions are sought in the context of eliminating or reducing the existing problems and negativities that should be approached with a new vision for the future of today's cities. Today, a process has evolved from "Information Society" to "Super Smart Society" and there is a rapid transition to the production of living and self-renewing smart cities and spaces. In this context, the importance of the urban planning and design process, which is suitable for new lifestyles, facilitates life, targets spatial quality and urban identity, protects spatial values, and is equipped with ecological and smart technologies, increases even more (Gül & Bostan 2018; Aydemir, Gül & Akın, 2020).

Despite its declining popularity, New Urbanism can still offer a fresh approach to city planning and design. The movement has learned from its mistakes and has updated its tenets to take into account the lessons learned from the problems encountered and the ecological and social sensitivities that have grown in recent years in urbanism.

The new urbanism approach can be particularly effective in restoring livability to areas within the city that have lost their quality. It can also help create dynamic, diverse and sustainable urban communities. But this has required a renewed approach; one that addresses the issues of ecological problems, equity, affordability and sustainability. It also required greater focus on promoting walkability, mixed-use development and human scale design.

The issues addressed in the development of Istanbul Regional Plan seem to focus on a more general sustainable development than the new urbanism movement, especially in terms of scale, and do not seem to take into account principles that would increase the connection between people and space, such as people and street scale, neighborhoods and social networks. It is worth noting that the Istanbul Regional Plan may benefit from incorporating some of the principles of NU to create more livable communities and sustainable development in the city.

Instead of focusing on devising new business districts and the development of high market neighborhoods along the fast-growing network, İstanbul's authorities might want to focus on reviving older neighborhoods and promoting inter-neighborhood connections where it is missing. At the same, the municipality should be wary of fostering gentrification by creating the type of arrangements based on beautifications and improved services that would only raise the level of rents and in effect, segregate.

Thanks and Information Note

This e-book chapter complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

The author contributed fully to the article. There is no conflict of interest.

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Dr. Fatmagül BOLAT		
E-mail	:	fatmagul.bolat@iuc.edu.tr
Undergraduate	:	Cukurova University, Faculty of Agriculture, Department of Landscape Architecture. 2003.
MSc:	:	Cukurova University, Institute of Natural and Applied Sciences, Department of Landscape Architecture, 2006
PhD	:	Istanbul University-Cerrahpasa, Institute of Graduate Studies, Department of Landscape Architecture, 2021
Professional experience	:	Lecturer Artvin Coruh University Faculty of Forest, Department of Landscape Architecture. (2008-2011) Research assistant: Isik University Faculty of Design and Architecture Department of Landscape Architecture. (2011-2012) Lecturer Cerrahpasa University Vocational School of Forestry (2018-……)

Exploring the Synergy between Urban Agriculture and Ecotherapy

Dr. Ahmet Erkan METİN [1]

[1]Uşak University, Banaz Vocational School, Department of Forestry, Uşak/Türkiye
ORCID: 0000-0002-1016-0927
E-mail: erkan.metin@usak.edu.tr

Dr. Hüseyin Berk TÜRKER [2]

[2]Usak University, Faculty of Agriculture, Department of Landscape Architecture, Usak/Türkiye.
ORCID: 0000-0002-8995-3259
E-mail: berk.turker@usak.edu.tr

Citation: Metin, A. E. & Türker, H. B. (2023). Exploring the Synergy between Urban Agriculture and Ecotherapy. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches.** 2023, Chapter: 3, 78-88. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

As cities continue to expand a trend in unplanned and densely constructed areas, people living in urban areas increasingly need access to nature due to the decreasing green areas. Singh (2017) stated that population growth, fossil fuel consumption, overconsumption of natural resources, and waste production have caused significant impacts on the environment. Environmental problems have emerged due to human activity's negative impacts on nature, ultimately negatively influencing people's lives (Çakır & Sancar, 2022). It is commonly known that an environment significantly impacts their physical, cognitive, and mental health. (Er et al., 2020). As a result, it is to consider the interplay between humans and the environment in urban planning strategies.

Urban designs that satisfy the interplay between humans and nature are crucial in ensuring individuals' healthy lives and the sustainability of nature. Sustainability integrates development, environment, and natural resources to achieve targeted socio-economic levels, thereby improving the quality of life (Tuğluer & Çakır, 2021). Environmental psychology theories, which concentrate on the interplay between humans and their surroundings, guide urban and landscape designs. Eco-therapeutic spaces are essential to connect humans and nature, particularly in industrialized cities where construction is rampant.

The primary goal of this study is to elucidate the importance of Urban Agriculture (UA) concerning Ecotherapy (ET) for maintaining a healthy psychological structure for individuals and a sustainable environment. Moreover, the study offers suggestions for the widespread implementation of UA practices in cities. Consequently, the study aims to evaluate the concepts of ET and UA and explain their interaction.

2. Material and Method

In this study, the importance of urban agriculture practices in the context of ET has been emphasized. The concepts of ET and UA have been presented through literature reviews conducted in line with the aim of the study. Recommendations have been made regarding healthy living and sustainable nature in the context of these concepts.

3. Findings

3.1. Ecotherapy

It is known that the environment in which individuals are involved, the entities, objects, designs, and arrangements affect their emotions, thoughts, and behaviors. This effect has been studied mainly in recent years in environmental psychology, architecture, landscape architecture, psychology, and ecology literature. The concept of ecopsychology also addresses ecology and psychology together, arguing that many psychological and physical disorders, particularly stress, arise from human alienation from nature (Greenway, 2009; Hablemitoğlu, 2015). Hilmann (1995) states that Ecopsychology aims to reconnect people psychologically with nature, understand the interaction between the mind and the environment, and protect mental health and nature through sustainable behavior (Weaver, 2015; Metin & Gül, 2022). It is known that the concept of "Ecotherapy" emerged, and studies started in this field by discovering the healing effects of nature-human interaction in the research on the effects of environmental conditions on human psychology (Hilary et al., 2017). The concept of ET is known as the application area of ecopsychology. ET is one of the ecosystem services offered by nature and is based on ecopsychology theories (Summers & Vivian, 2018). Clinebell (1996) states that the foundation of Ecotherapy practices is based on three interactive ecological cycles (Kara & Oruç, 2020). The cycles can be listed as follows:

Acceptance: Internal acceptance and nourishment with the healing presence of nature and the universe

Realization: Reconnecting oneself with nature

Action: Doing something for nature.

ET can generally be defined as outdoor activities that people engage in for their physical and psychological health. While people practice ET for their physical and psychological health, they also support the preservation and sustainability of natural environments. ET includes wild therapy, green exercise programs, horticulture therapy, animal-assisted interventions, environmental conservation, nature and art, and farming practices (Russel, 2001; Linden & Grut, 2002; Prety et al., 2005 Chalquist, 2013; Hilary et al., 2017; Wordpress, 2017; Ak, 2021). ET can be conducted in many places in urban settlements, such as parks, university campuses, urban forests, and botanical gardens. These can be used as areas for ET purposes. The importance of ET has increased even more in today's conditions where rapid and intense urbanization is observed. Cities have both natural and artificial environments and offer social and cultural opportunities for people; on the other hand, they create unhealthy living conditions. The ecological balance is disrupted in rapidly urbanizing living areas, negatively affecting individuals' physical and psychological health. In this context, people need to engage in nature activities. This need coincides with the purpose of the emergence of ecotherapy. In this regard, UA practices are considered areas where urban people can easily connect with nature.

3.2. Urban agriculture

UA has become a sustainable farming method in urban areas. Its purpose is to address the challenges of feeding city dwellers while supplying food products. Mougeot (2000) defines UA as an industry that involves producing, distributing, and marketing food and non-food-related products utilizing urban and peri-urban resources. Smith et al. (1996) characterize urban agriculture as "metropolitan-intensive agriculture." UA aims to sustainably provide fresh food to urban dwellers by utilizing the natural and human resources of the city. As well as its socio-economic and economic advantages (Orsini et al., 2013; Bryld, 2003), and ecological benefits (Doherty, 2015). UA can play a vital role in maintaining the cities' ecological and socio-economic systems. Furthermore, UA produces more environmentally friendly food, using less water, energy, and chemicals than conventional farming. Bolat & Deneri (2022) highlighted the potential of urban agriculture in enhancing the immune system of cities, thereby contributing to the development of resilient cities. UA encourages local food production, reduces food miles, and contributes to a healthier lifestyle and a more environmentally friendly food supply chain.

The psychological benefits of UA are also significant:

• UA promotes interaction with nature and has anti-stress properties. Urban dwellers who use it can lessen stress and enhance their mental health.

• UA gives individuals a chance to get first-hand knowledge of cultivating their food, which may boost self-esteem and confidence.

• UA promotes social ties.

• UA activities can motivate people for a healthy lifestyle.

3.3. Relationship between Urban Agriculture and Ecotherapy

In order to attain mental, emotional, and physical well-being, it is commonly accepted that the link between UA and ET entails engaging with nature. ET includes activities like going outside, enjoying nature, and spending time with soil, plants, and animals. It emphasizes the importance of always being in contact with nature and avoiding distancing oneself from it to benefit human health.

Natural areas are frequently far from city centers or even outside the boundaries of urban regions in heavily populated metropolitan areas. Participating in ET activities in such places can be challenging for individuals regarding time, transportation, and cost. UA areas should be considered readily accessible places for ET activities in cities. These areas can contribute to both personal and environmental health, allowing city dwellers to connect easily with nature without excessive effort in terms of time, cost, or transportation.

Therefore, the relationship between UA and ET is seen as one that can easily facilitate the connection of urban individuals with the natural world while also contributing to their mental, emotional, and physical well-being and the sustainability of the environment. Additionally, it is known that green areas in cities positively affect the health of urban individuals due to the urban climate (Önder & Polat, 2012; Metin & Çağlak, 2022). Consequently, UA areas should promote the relationship with ET could lead to multifaceted positive effects in all aspects of life.

4. Conclusion

Urban areas are widely acknowledged as vital habitats for their denizens, affording them dwelling places where they allocate most of their time (Kara & Oruç, 2020). However, a pressing challenge that impacts the well-being of urban residents pertains to the availability of green spaces that enable a harmonious integration of urban existence with the natural world. To this end, this study examined the correlation between UA and ET. UA plays a significant role in the city's network of green areas. ET aims to reconnect people with nature and foster a feeling of environmental responsibility, consequently encouraging a favorable impact on their psychological and emotional well-being. Urban residents would benefit from a more sustainable and livable urban environment with the help of such integration. Overall, this study's findings underscore the importance of integrating UA and ET practices into urban spaces' planning and design. Both practices encourage a relationship between humans and nature regarding the connection between UA and ET. Engaging in UA can support mental and emotional health as part of ecotherapy treatment. Incorporating UA into ecotherapy can demonstrate the potential benefits of interacting with nature on individual and environmental health. UA helps expand green spaces in cities and it can provide a stress-reducing effect and contribute to a healthier mood. Cultivating plants can calm individuals, promoting a sense of peace and tranquility. UA can also instill confidence and success, potentially reducing depression by increasing individuals' focus. Those who understand the benefits of UA can produce healthier, more affordable food by creating additional land and preventing soil and water pollution by avoiding chemical use during production. Overall, the benefits of UA align with the objectives of ecotherapy. UA is considered a viable and easily accessible method of benefiting from the therapeutic effects of nature in cities within the scope of ecotherapy. Therefore, it is of great importance to integrate UA areas into urban planning and landscape design.

Thanks and Information Note

This e-book chapter complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

There is no conflict of interest. All authors contributed equally to the article.

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Dr. Ahmet Erkan METİN		
E-mail	:	erkan.metin@usak.edu.tr
Undergraduate	:	Karadeniz Technical University, Faculty of Forestry, Department of Forestry Engineering.
MSc	:	Atatürk University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture.
PhD	:	Süleyman Demirel University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture.
Professional experience	:	Uşak University, Banaz Vocational School, Department of Forestry (2013-…)

Dr. Hüseyin Berk TÜRKER		
E-mail	:	berk.turker@usak.edu.tr
Undergraduate	:	Akdeniz University Faculty of Agriculture, Department of Landscape Architecture.
MSc	:	Ege University Graduate School of Natural and Applied Sciences, Department of Landscape Architecture.
PhD	:	Süleyman Demirel University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture.
Professional experience	:	Uşak University, Faculty of Architecture and Design, City and Regional Planning Department (2013-…)

Ecology and Landscape Planning: Evolution in the World and Türkiye

Prof. Dr. Şükran ŞAHİN[1]

[1]Ankara University, Faculty of Agriculture, Department of Landscape Architecture, Ankara/Türkiye.
ORCID: 0000-0002-3730-2534
E-mail: sukran.sahin@ankara.edu.tr

Citation: Şahin, Ş. (2023). Ecology and Landscape Planning: Evolution in the World and Türkiye. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches.** 2023, Chapter: 4, 89-122. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

Spatial planning can be called as ecological spatial planning when the process carried out in a "nature-based" manner. When such an action is carried out based on landscape knowledge, then the process is called landscape planning. The landscape knowledge in question is first and foremost nature-based. Within the scope of landscape knowledge, the concept of nature-base can be expressed within the context of the mechanisms that form/characterize a landscape. Those mechanisms can be identified by landscape structure, function, and change. The concept of landscape is about the whole that its components form it together, rather than the singular expressions of the components that compose it. In other words, any landscape component can be included within the scope of landscape knowledge, when it is explained in the context of the whole. Then, landscape knowledge can be conceptualized as the spatial and temporal expression of ongoing interactions in a certain area. Such a landscape-based spatial planning approach is called as landscape planning, and it is critically significant as the most fundamental basis for securing the benefit of "healthy natural environment for all" expected from spatial development decisions.

According to the modernist spatial planning approach, which is still influential today, space is an object to be shaped for social purposes. Therefore, urban space has a value only within the scope of a certain social project (Işık, 1993). It would not be wrong to say that such a human-centered planning approach did not provide an answer to the problems it promised to solve within the framework of the worldview dominated by modernism, and even added many more problems and carried the world to the environmental crises of today. It is not possible to say that this approach which has been started to be abandoned since the first half of the 20th century, found a response all over the world. First and foremost, the worrying aspect of modernist planning approach from the perspective of ecology is its tendency to see nature and its elements as "the other". What is most surprising is that such marginalization still goes unnoticed by the legally authorized individuals and institutions for spatial planning in developing or undeveloped countries. The most obvious proof of this explanation is the absence or inadequacy of actions in national laws and regulations to ensure the implementation of landscape planning. It is possible to say that there is almost obvious resistance to the ecological planning approach (landscape planning) mentioned in this section. For example, while Türkiye is considered among the G20 countries in the world, which focuses, inter-alia, sustainable development, health, climate change (G20, 2023), it is surprising that the landscape plans in question have not yet been legally included in the spatial planning process. Evidence and consequences of this discourse can be traced from the practices of urbanism, architecture and even landscape architecture that interfere with nature. Of course, there are successful practices of landscape planning in the developed world. However, if landscape planning does not find widespread execution in the world, the fragmented practices will not be able to protect the fragile world from global environmental problems. Therefore, the most fundamental problem is that the ecological perspective and the concept of landscape planning, design and management, which form the basis of the existence of the profession of landscape architecture, have not fully taken their place in legislation and practice in many parts of the world and in Türkiye, despite many well-intentioned partial steps. From the perspective of landscape knowledge, the ecological approach is mainly based on the science of landscape ecology. Landscape architecture is the discipline that has established its ecological knowledge and competencies in its educational structures in the world via worldwide program accreditation documents (IFLA Europe 2017; ASLA LAAB, 2021). However, today, still in many countries including Türkiye, the landscape is considered after the city has been planned with a modernist approach and its building architectural development has been decided, even constructed. From the ecological point of view, landscape is not a scientific basis to be evaluated in the last instance, on the contrary, it is a preliminary action area in spatial planning efforts.

In this part of the book, the reasons why ecological planning, more comprehensively landscape planning, are the basis for spatial planning and the information base it will provide is intended to be explained. Then, explanations are provided on the development process of landscape planning in the world and in Türkiye. In conclusion, emphasis is placed upon the necessity and importance of landscape planning as a preliminary action area in spatial planning processes.

2. Landscape and Ecology

German geographer Alexander von Humbolt (1769-1859) defined the landscape as the total character of a region. Landscape ecology is “a branch of science that deals with the complex cause-effect relationships between the environmental conditions prevailing in any part of the landscape and living communities as a whole" (Odum and Barrett, 2008). In other words, landscape ecology is the field of scientific endeavor that examines the structure, function and change of the landscape within the framework of an ecological view (Koç and Şahin 1999; Şahin, 2001a,b). This definition, as visualized in Figure 1, also reveals the differences in the focus and evaluations of landscape architects and other disciplines in their view of the same landscape. And precisely indicates that three forming mechanisms (structure, function, and change) are interconnected (Dilek et al, 2008).

The concept of landscape should be understood as an integrated expression of the following words (adapted from Şahin 2009; Şahin et al. 2014):

*"**1. Dynamism and continuity**: The European Landscape Convention defines landscape as "an area whose characteristics, as perceived by humans, are the result of the interaction and activity of human and/or natural factors". However, this perception does not represent a snapshot but a dynamic, constantly evolving and changing space.*

***2. Perception and reality:** The landscape as perceived by people is shaped by natural and cultural processes. The rhythm of the landscape (Thayer, 1994) emerges from the continuum of processes that make up the perceived landscape (landscape structure) (Figure 2). The structure of an ecosystem (or landscape) is the physical expression of its organizational pattern. Process, on the other hand, includes all activities within the scope of the organization pattern (Capra, 1996).*

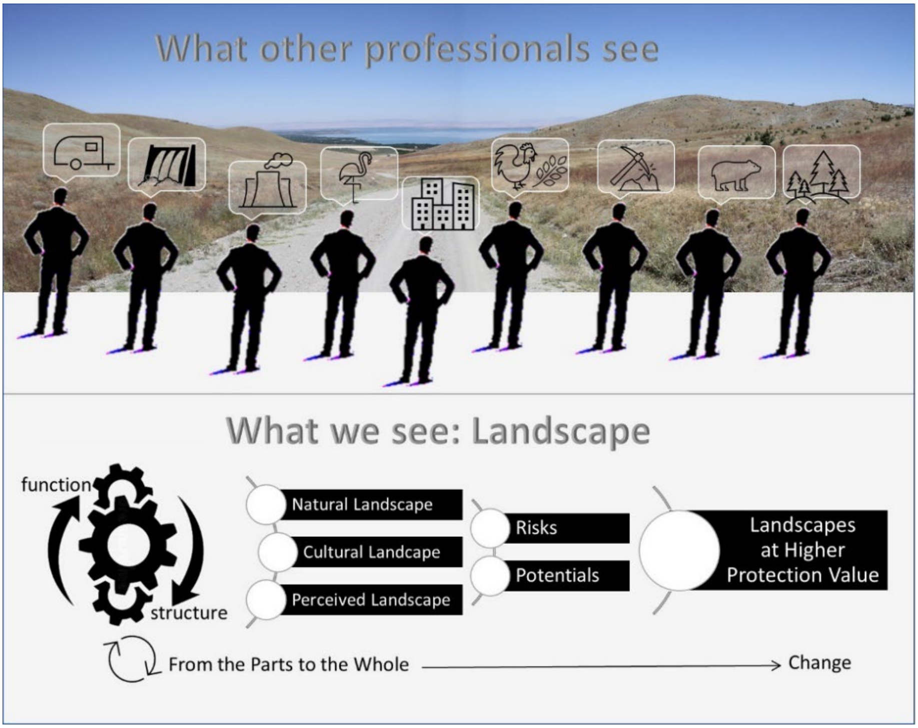

Figure 1. The meaning of landscape for the landscape architects and the other disciplines.

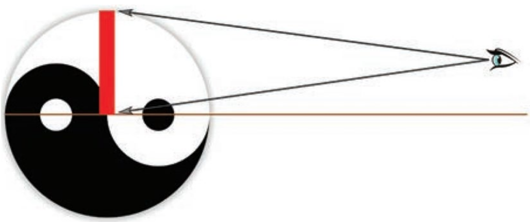

Figure 2. Harmony of the landscape.

Thayer (1994) defines the perceived landscape as "surface values" and the processes on which this landscape depends as "core value". When these two are in harmony, the system is in balance.

3. Change: *Landscapes are changing constantly. The environmental conditions that exist today are the result of events from the past. It is important to realize that landscape change can take place over a long period of time, which cannot be expressed in the lifetime of a human being, and that there are conditions in which this change can occur immediately.*

4. Scale and hierarchy: *Landscape hierarchically covers local, regional, national and global scales. This hierarchy is significant in terms of landscape characters and its dynamics. For example, while a species tends to decline in a local scale study, the opposite may be the case in a higher scale assessment covering the same area. Or, while resources are recorded as being in good condition at the local scale in terms of water reserves, when evaluated at a higher scale within the scope of the mechanisms that make up that landscape, it may be understood that the supply of the same water resources is at risk.*

5. Interaction*: The interaction between landscape components determines the mechanisms that shape that landscape. For example, two areas with the same degree of soil erosion in existing national data records may have very different values and importance due to the interaction among their landscape components and processes such as vegetation quality, biomass process, hydrogeological landscape structure, slope-related water movements (natural drainage pattern), etc.*

6. Authenticity: *Each landscape is different from each other in terms of its constituent elements and processes. Although there are spatial repetitions of different landscape types (valleys, waterfalls, wetlands, etc.) in an area,* *the landscape that emerges as a result of the interaction of its elements is unique to its location.*

*7. **Boundaries and multilayeredness**: At each stage of the spatial hierarchy, the landscape has different spatial boundaries in terms of structure, function and change characteristics, and thus has a multi-layered structure. For example, while the watershed boundary should be considered in defining the landscape within the scope of water process, it may be necessary to work in different spatial boundaries in analyzing habitat value, biomass process, biodiversity, visual quality, cultural landscape value, etc."*

3. Ecological Planning and Landscape Planning Nexus

Landscape is shaped by the composition of its constituent elements and the processes driven by the mutual interaction of these elements. A change in a single element can change the entire landscape. Landscape is a concept that can be understood with a holistic approach. In contrast to the totalistic approach, the holistic approach argues that the existing structure cannot be understood completely by analyzing individual elements and therefore suggests that systems should be analyzed as a whole. In this context, each element should be considered within the framework of its interaction with other elements within the whole in landscape assessments. In other words, in order to define a landscape, it is necessary to express each of its constituent elements in the context of the whole (Şahin et al., 2013).

Human influence in shaping a landscape is undeniable. Therefore, the landscape ecologist is not only interested in natural processes, but also in cultural landscapes, in other words, in human communities and their habitats. From this perspective, ecological planning and landscape planning can be considered equivalent concepts.

In order to understand human interaction with nature, or to understand societies, cultures, and settlements, it is first necessary to understand nature. For this, it is misleading to look at its constituent parts in the conventional way. It is essential to analyze and understand the interaction between these constituent parts. At this point, the most critical question is how humans, who tend to look at nature in a fragmentary way, can analyze these interactions in the whole. Aldo Leopold, considered the father of deep ecology, emphasized the need to "think like a mountain" to understand nature (Türksoy, 2001). To think like a mountain is to put oneself in its place. On the other hand, such empathy will not be enough; one will also need to question his/her own decisions through the eyes of the object in question. Ecological thinking is a field of mental activity that explores the nature-human interaction on such a ground.

For many years, the emphasis on landscape as a criterion in land use planning and management has been on landscape valuation, which makes one area more valuable than another within the framework of land use decisions. Landscape assessment, on the other hand, emerged after the 1980s as a tool that includes landscape character classification and definition, which differentiates one area from another. The end product of landscape classification (or characterization) is a judgement-independent map of landscape character types and/or areas, together with an analysis of the most important key processes that shape that character. The process also identifies forces of change, such as land use changes and pressures from development types. The main products of the landscape character judgment phase are the development of landscape strategies, the assignment of a status to landscapes, guidelines for landscape capacity assessment and, as a final product, the landscape plan (Şahin et al., 2013).

3. A Brief History

The history of ecological planning can be found in the literature of the West which is the developing face of the post-industrial world. There is a certain need for further clarification on the place of nature, especially in the context of archaeological periods and the dynamics of planned urbanization in the post-industrial era of the eastern part of the world. The first half of the 1960s was the time when environmental problems began to crystallize in the developed West. This was followed by national and international legal sanctions for environmental control, sensitive to the limits of intervention in nature. At the same time, ecological discourse and ecological planning began to take their place in practice. Of course, scientific studies on ecological planning go back much further. In this context, Ian Lennox McHarg (1920-2001) is perhaps the most famous landscape planner who left his mark on history with his book "Design with Nature" published in 1969. Of course, many others have played a role in the development of the systematic and inclusive ecological planning approach that McHarg (1969) put forward. McHarg was brought to the University of Pennsylvania in 1954 by Dean Prof. G. Holmes Perkins to re-establish the Department of Landscape Architecture (Steiner, 2004). Later, Prof. Holmes, an architect and planner educated at Harvard University, came to Ankara in 1955 with the support of the UN Technical

Assistance Unit. During his one-year stay in Türkiye, Prof. Holmes conducted studies that would form the basis for the establishment of the Faculty of Architecture at the Middle East Technical University in Ankara. In the comprehensive report prepared by Prof. Holmes, the most noteworthy issue is his suggestion that building architecture, urbanism and landscape architecture programs should be included together and within the scope of joint education within the Faculty of Architecture (Yorgancıoğlu, 2010). However, only building architecture and urbanism departments were established in Middle East technical University. Perhaps this decision is one of the reasons why landscape architecture, and therefore ecological planning, is not included in spatial planning processes in Türkiye as defined in this study. Moreover, Prof. Holmes was an academic who realized the joint education of these three disciplines during his tenure at Harvard University, then University of Pennsylvania, School of Fine Arts (Yorgancıoğlu, 2010). Harvard University, as the school where McHarg graduated in 1949 (Whitaker and Steiner, 2019) and where the first landscape architecture courses were given by Frederick Olmsted Jr. at the beginning of 1900s (Bayındır Eren, 2014), is one of the universities in the world that has developed the most concepts in ecological planning in the historical process.

McHarg, together with Lewis Mumford, changed the understanding of regional planning in the USA and defined landscape planning as a pre-action field of the spatial planning process. It is exciting to notice the traces of the influences of Patrick Geddes (1854-1932), the first person in Europe to call himself a landscape architect, and his thoughts on nature and culture on the young Mumford and then McHarg. Cohen (2019), in his book of "Ecohumanism and the Ecological Culture", explains how ecology changed the modernist approach and the contributions of Olmstead, Ebenezer Howard, Geddes, Mumford, MacKaye, Glikson and McHarg on that, respectively and interactively. Cohen (2019) reports that McHarg developed his ecological planning approach between 1930 and 1950. This discourse is already evident in McHarg's biography written during his lifetime (McHarg, 1996) and the subsequent updates of this biography by Frederick Steiner (2019), a member of McHarg's school. McHarg proposed an ecology-based method for landscape architecture and interpreted nature as an interactive process that reveals opportunities and limitations for human use. (McHarg, 1967). Ecological planning becomes a tool for uncovering "interacting and dynamic natural systems that have inherent possibilities and constraints for human use" under what McHarg defines as ecological determinism. In his famous book "Design with Nature" published in 1969, McHarg argues that 'understanding natural process is central to all environmental issues and should be incorporated into all considerations of land use" (Misra, 2022). McHarg's book "Design with Nature", which celebrated its 50th anniversary in 2019, deserves high praise. It is a book that is also the main source of inspiration for the academic life of the author of this Section. It can be stated that McHarg included ecological processes in his spatial planning works within the scope of the ecosystem inventory, which he analyzed according to the cause-and-effect relationship, and also four main values attributes to natural processes listed below (Belknap and Furtado, 1967).

1. Attributes or properties inherent to a landscape. Areas of wilderness, scenic beauty, scientific value, and educational value would be included.
2. Landscape productivity, which would include agriculture, forestry, extractive minerals and recreation.
3. Contribution to the continuity of ecological balance, which might include water storage and drought, and erosion control.
4. Potential damages (negative value) as a result of natural processes or improper use of resources.

During the years when McHarg was developing his ecological planning approach, Prof. Philip H. Lewis Jr. in the State of Wisconsin, USA, focused on landscape pattern/structural character and defined landscape connectivity with the concept of "Environmental Corridor" (Belknap and Furtado, 1967). Philip H. Lewis Jr. received a bachelor's degree in landscape architecture in 1950 from the University of Illinois (Wisconsin State Journal, 2017), then earned a master's degree in landscape architecture from Harvard Graduate School of Design (JSTOR, 1953). His approach was reflected and implemented in Wisconsin State laws in USA. Before Lewis, in the first half of the 1900s, landscape connectivity was reflected in Olmsted's Park System concept, which found widespread application in the USA. In both approaches, landscape connectivity is planned in terms of perceptible structural features. Today, this connectivity can also be expressed in different terms. Ecological and landscape planning point of view, the ideal is to establish connectivity based on character-function/pattern-process approach (Şahin et al., 2014; Doğan, 2012).

In addition to McHarg and Lewis, in Canada Angus G. Hills developed an ecological planning process for the land use capacity and suitability of ecological units (Belknap and Furtado, 1967) in 1961 and 1974 (Ndubusi, 2002). The approach, also known as the "Hills Ecosystem/Physiographic Unit Classification", was applied in Canada. Hills' classification involves identifying top-down ecological/physiographic units at different scales and hierarchical structures and developing land use suitability decisions based on the smallest ecological units. Then, these land use decisions are carried to upper scales of sub-regional and regional by reclassifying and reunifying the ecological units. This type of land classification content can be compared with the nowadays terms of landscape character areas and landscape types present in the European discourse and in Turkey following the Council of Europe Landscape Convention in 2000.

A landscape planning process based on also ecological units, however integrated with ecological processes and was developed by Buchwald (1964, 1966, 1973) and his colleagues, as reported by Köseoğlu (1975, 1982), in central Europe, at the Institute for Landscape Planning and Nature Conservation at the Technical University of Hannover parallel to the historical development of ecological planning approaches in the USA and Canada.

As a final remark, it may be remarked that there is a certain need for studies that will reveal the interaction between above mentioned developments in ecological and landscape planning in the western world. All ecological approaches in history which were pointed out in this study have, of course, differences in terms of planning methodology. Among the pioneering studies, the most prominent emphasis and scope on ecological processes (landscape functions) was put forward by McHarg. On the other hand, following the pioneers, Bastian's (1998, 2000) work in Germany is a response to the weakness in the landscape function focus. However, there is a need for research on the extent to which this approach has been implemented in practice.

3.1. Advancements in Türkiye

At the first place, it would not be wrong to state that the ecological approach, which is addressed in this article within the scope of spatial planning processes and legislation in our country has still not taken its place in practice despite the exciting developments in recent years, until today, in the first quarter of the 21st century. The McHarg approach, which was first developed in the world between 1930-1950 based on ecological processes has been defined by many planners only by means of overlapping method and the approach has not been fully implemented. Within the scope of scientific studies, the system approach, which McHarg, a landscape architect, defined as an ecological process and which would reveal the interactions of landscape elements with each other, did not take place properly until the second half of the 1990s. Scientific researches were mostly limited to the analysis and evaluation of system elements, or ecological functions were considered as values that limit or enable use, and the intrinsic value of nature was ignored. Therefore, ecology has been analyzed with a human-centered and fragmented approach. Capra (1996) described the inadequacy of the fragmentary approach in analyzing the system by stating that "the systems engineer must be able to predict the emergent properties of the system, which are properties that the system has but the parts do not". In this context, it can be stated that the ecological approach involves the expression of each landscape element in the context of the whole, in other words, the examination of the interaction between elements. Capra (1996) reports that while such a systems analysis approach, also referred to as strategic thinking, had a significant impact on management and engineering in the 1950s and 60s, its impact on biology, on the contrary, was almost neglected (until 1996, when his book "The Web of Life" was published). Perhaps this may be one of the reasons for the delay in reflecting the ecological approach or thinking, including biological processes, in planning processes. Considering that the ecological planning approach mentioned in this study is based on landscape ecology, starting from the year of 1968, when landscape architecture education formed at Ankara University in Türkiye, to 1980 can be considered as the period when the academic infrastructure on ecological planning was developed. Around this period of time, Prof. Dr. Mehmet Köseoğlu, Prof. Dr. Türker Altan, Prof. Dr. İlçin Aslanboğa and Prof. Dr. Hayran Çelem, who did their PhD studies at the Institute of Landscape Planning and Nature Conservation at the Technical University of Hannover in Germany and brought the German school of ecological planning to Türkiye. Prof. Dr. Günel Akdoğan, whose research on landscape planning was published in 1967, as well as İsmet Gürses and İsmet Olcay can be mentioned among pioneering people on ecological planning. However, the need for more detailed studies on the antecedents of ecological planning in the academic sense in Türkiye is clear. Young Dr. Hayran Çelem as research assistant at the Department of Landscape Architecture, who had a PhD in the above mentioned German school in 1975, helped to translate German sources on landscape ecology into Turkish. At the same Department, landscape ecology and rural planning courses were continued by Prof. Dr. Nizamettin Koç who had conducted post-doctoral research at the Institute of Landscape Planning and Nature Conservation at the Technical University of Hannover in Germany too between 1969-1970, transferred his knowledge of landscape ecology to the ecological planning approach in his textbook on rural landscape planning (Koç, 1972; Koç and Şahin, 1999). The ecological planning approach explained in Koç's book, according to Köseoğlu, was developed by Buchwald (1964, 1966, 1969) together with other faculty members, research assistants and students at the Technical University of Hannover. This approach is based on the identification of ecological units (now called landscape units in landscape planning) and the possibilities and constraints they present for human uses within the context of their natural potential and resilience. While developing appropriate uses for ecological units, it is aimed to protect the natural ecological latent capacity of the planning area and the ecosystem. The criticism that can be made for this method within the scope of ecological planning is its human-oriented planning process. However, it seems that this method has been the basis for the development of ecological planning by the first generation of academic environment in

Türkiye. On the other hand, at the end of the 1970s, the Ian Lennox McHarg ecological planning school was introduced at Ankara University by Prof. Dr. Nur Sözen's. So that, McHarg school began to shape ecological planning alongside the Buchwald (German) school. It should also be noted that, in Prof. Koç's lecture notes, landscape ecology is defined as "an interdisciplinary branch of science that studies and investigates the structure and function of ecosystems or a specific part of an ecosystem from a geographical and ecological point of view". The understanding based on this definition can be counted among the factors that facilitate the inclusion of studies based on landscape function as well as landscape structure in ecological planning in Türkiye.

Until the first half of the 1990s, it is possible to categorize the methods developed and applied in Türkiye for the use, development, and protection of natural resources under two main topics (adapted from Şahin 1996).

1. Use Suitability Analysis: It is based on the determination of the importance of each environmental element in terms of each land use type, and relative scoring the environmental factor's sub-components in terms of their suitability for different land use types. Although the degree of importance of environmental factors in terms of land use categories was taken into consideration, the interaction among the factors was ignored in the practices in Türkiye. Most importantly, key ecological processes (water cycle, matter-energy flow, etc.) were not considered for the sustainability of the natural system. As such, it can be stated that the method was applied with a human-oriented approach in Türkiye and was therefore not ecological.

2. Risk Analysis: It is based on the determination of risk levels according to the severity of the impact of land uses on environment and the sensitivity of the environment to the land uses. The method was predominantly used for the studies to determine the risks arising from existing land uses. It can be stated that the biotope mapping technique, which reveals the structure of the landscape, was predominantly used in the method, but key ecological processes were neglected in the applications.

Şahin (1996) developed "Strategic Planning Approach and Holistic Landscape Assessment Method" in her PhD thesis entitled "A Research on Determination and Assessment of Landscape Potential of Dikmen Valley" under the supervision of Prof. Dr. Yalçın Memlük, which made McHarg's ecological planning approach more understandable in Türkiye. The study, conducted at Ankara University, was the first scientific study in which ecological processes can be included in spatial planning. It is also worth to mention here that Prof. Memlük, who was acquainted with the German school at Hannover University, produced information in his doctoral study on the subject that attracts attention as landscape metrics in scientific circles today is a pioneering step too for Türkiye.

Şahin (1996), in her PhD thesis study, presented a method on how ecological processes can be assessed in the spatial planning process, on the basis of the Ian McHarg school and the landscape structure-function-change approach defined by Forman and Godron (1986) (Şahin, 2001). In the following years, especially after Türkiye signed the Council of Europe Landscape Convention and enacted it into law, landscape planning gained some institutional strength, and the studies of Uzun et al. (2010) and Şahin et al. (2014) based on landscape structure-function-change gave a new direction and momentum to ecological planning. Şahin et al.'s (2014) work entitled "National Technical Guideline for Landscape Character Analysis and Assessment at Regional and Subregional Scale", which is the final output of a project period of 8 years in total from project preparation to the final report, a landscape planning (landscape character analysis and assessment) process was developed (Figure 3a,b). Şahin and Kurum's (2002) concept of "landscapes with higher (protection) value" based on integrated landscape function values was reflected into the process. In Türkiye, the ecological planning approach based on the landscape function and function-based change is being studied in the scientific environment within the scope of landscape planning, especially after second half of 2010. The studies conducted by Yenil (2010), Çorbacı (2014), Uzun et al. (2015), Demir and Demirel (2016, 2018), Güneş (2017), Doğan (2017), Alparslan (2017), Aysu (2018) and Yılmaz (2021) can be named among the main ones, although not limited to the given list.

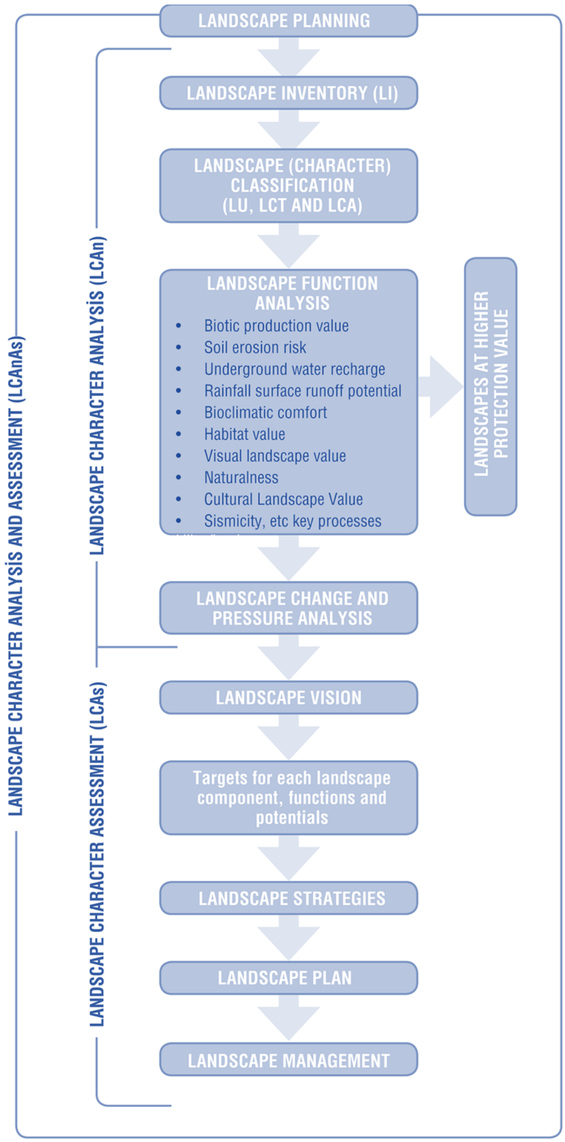

Figure 3a. Landscape Character Analysis and Assessment (LCAnAs) (Şahin et al. 2014).

LC: Landscape Units, LCT: Landscape Character Types, LCA: Landscape Character Areass

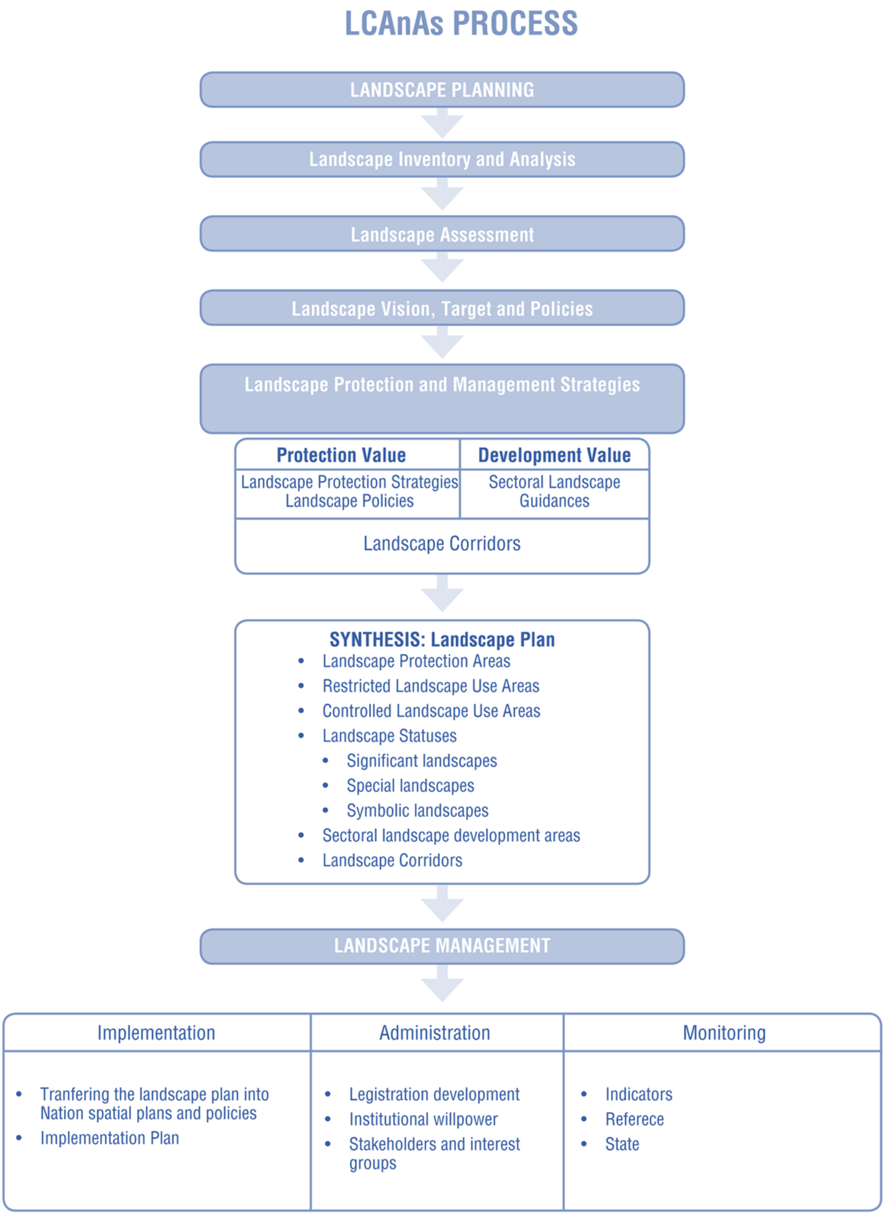

Figure 3b. Landscape Character Analysis and Assessment (LCAnAs) (Şahin et al. 2014).

4. Conclusion and Suggestions

Ecological planning is an approach that mainly refers to the natural landscape characteristics of the area being studied in the spatial planning process. Landscape planning is a field of action that is based on primarily landscape ecology science and the analysis of the mechanisms that shape the landscape. In this approach, biotic and abiotic elements are analyzed in the context of the structure, function and change of the landscape. It can be predicted that landscape modelling studies based on landscape structure-function-change analysis in an holistic way, will take place more in ecological planning in parallel with scientific and technological advances in the future.

While modernism tended to dominate nature, the classical economic views that developed during this period treated nature with a utilitarian approach. Today, a fundamental change in the understanding of planning and design is required. The essence of this change in terms of ecological concerns is to perceive that nature has an intrinsic value. The reflection of this perception into planning and design creates a field of action that considers ecological values, components, and processes holistically in temporal and spatial dimensions (Şahin 2003). Holism is essential in nature. It is about understanding the interactions within the whole rather than understanding the individual parts and ongoing events in nature.

The isolation of an area, whether rural or urban, from the surrounding systems in the whole ecosystem does not create ecologically sustainable systems. The ecological approach in land use land use decisions is now a generally accepted practice. The basis of the ecological approach in planning is the developments and transformations that emerged in the 1960s, which brought to the agenda the concepts of “environmental concern” until the 1980s and “quality of life”, “sustainability” and finally “landscape character” after 1980.

Ecological planning or landscape planning approaches, which comprehensively came to the agenda with McHarg's famous book “Design with Nature”, have undoubtedly emerged as a result of direct or indirect interactions with each other in the historical progress. In this progress, of course, many names other than those mentioned in this Section have contributed. Undoubtedly, a systematically structured and comprehensive chronological study on the historical development of ecological planning would be beneficial.

Thanks and Information Note

This e-book chapter complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

The author contributed fully to the article. There is no conflict of interest.

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Prof. Dr. Şükran Şahin		
E-mail	:	sukran.sahin@ankara.edu.tr
Undergraduate	:	Ankara University, Faculty of Agriculture, Department of Landscape Architecture, 1986
MSc	:	Ankara University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture, 1989
Postgraduate	:	The International Center for Advanced Mediterranean Agronomic Studies in Zaragoza, CIHEAM, 1993
PhD	:	Ankara University, Graduate School of Natural and Applied Sciences, Department of Landscape Architecture, 1996
Professional experience	:	Faculty Member at Ankara University since 13.04.1987

Effects of Ecological Factors on Urban Growth in Cities: Example of Artvin Central District

Ass. Prof. Dr. Manolya ÖZDEMİR DURAK [1]

[1]Artvin Çoruh University, Faculty of Art and Design, Department of Landscape Architecture, Artvin/Türkiye.
ORCID: 0000-0002-9103-3435
E-mail: manolyaozdemir@artvin.edu.tr

Citation: Özdemir Durak, M. (2023). Effects of Ecological Factors on Urban Growth in Cities: Example of Artvin Central District. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches**. 2023, Chapter: 5, 123-155. ISBN: 978-625-367-073-3. Iksad Publications

1. Introduction

A large number of industrial facilities established with the industrial revolution throughout the world, and residential areas located near them, and urban spaces have grown rapidly and continue to grow. The rapid increase in urban growth has brought along many environmental problems (Hacıoğlu Deniz, 2009). Urban growth with various environmental effects is the spatial and functional expansion of cities as a result of the growth of population, economy, infrastructure and built environment. Urban growth may occur due to different factors such as population increase in urban areas, migration from rural settlements to urban areas and/or changes in rural land uses (Aydın, 2015).

Factors related to the close environment relations of urban space, factors related to urban and regional planning policies, factors related to individual preferences, economic factors, especially ecological factors such as slope, topographic structure, natural disaster risk, soil structure, climate characteristics, which have effects on urban growth, It can be listed as basically six factors, including socio-economic and political factors (Aydın, 2015). Related professionals such as local and regional administrators, city planners, landscape architects, urban designers are involved in the management of urban growth while contributing to the creation of laws and regulations that ensure that the needs of the citizens are met as well as sustainable economic development. In addition to the positive effects of urban growth, such as the creation of new economic opportunities in the city, easy access to services and facilities, and improvement in living conditions, the increase in population density as a result of overcrowding, deterioration of urban ecological conditions (air quality, water quality, etc.), intensive use of vehicles. There are also negative effects such as traffic congestion and social inequality due to income distribution. Minimizing these negative effects can be achieved by planning urban growth depending on the existing ecological factors of the cities. In this process, the evaluation of ecological factors that have effects on urban growth minimizes the negative effects of urban growth and ensures the healthy execution of the urbanization process and sustainability in cities.

1.1 Urban Growth

Urban growth is a concept that expresses the increase in the spatial size, population density and diversity of uses (Vlahov & Galea, 2002). Urban growth is one of the current research topics due to the migration of the rapidly increasing population in the world to cities due to various reasons, rapid urbanization and its consequences. Urban growth is one of the issues emphasized in the "Urban Sustainable Development Framework" of the United Nations. According to the framework, "measuring and evaluating the policies, infrastructure, socio-economic factors, resource use, emissions and other processes that contribute to and benefit from the metabolism, well-being and quality of life of cities is one of the important steps in creating a sustainable urban environment." (Pınarcıoğlu & Kanbak, 2020).

In this context, in recent years, there are studies in the literature that deal with urban growth in terms of population growth, social welfare, economy, spatial growth, demographic structure, infrastructure, climate change, air pollution, depletion of natural resources and sustainability (Whang et al., 2023; Li et. al., 2022; Lavenus & Diemer, 2022 ; Smith & Johnson, 2021; Liu et al., 2022). There are studies that deal with urbanization and urban growth in various aspects, as well as studies on urban growth forecasts (Kuru & Yüzer, 2021; Song & Li, 2020; Sarkar & Lakshmana, 2022; Dhanaraj & Jain, 2022; Makido et al., 2020; Modiri et al., 2023). Population-oriented ones among these studies deal with urban growth in terms of population growth. For example, Zhang et al. (2022), in their study on urbanization, examined the urbanization level of the counties in China and revealed that the urbanization level of the counties is a factor affecting urbanization. As a result of the comparison of the censuses and the regression analysis, the steep and harsh natural structure, distance from the central cities and high altitudes were the most important factors as an obstacle to urbanization. However, Zhang et al. (2022), urban growth is used with the meaning of the increase in the population living in the cities, so urban growth is handled with a population growth aspect, since urbanization is made with urban population growth data in the analyzes related to urbanization. However, urban growth is a population accumulation process that leads to an increase in the number of cities in parallel with industrialization and economic development, and to the spatial growth of existing cities under the influence of relevant factors, and causes city-specific changes in human behavior and relations in society (Şevket, 2005).

In regions where rapid urban growth takes place, many planning institutions have to make decisions based on unsubstantiated assumptions and incomplete information, since long-term and systematic information about urban spaces is not available (Cash et al. 2003). From this point of view, evaluations of ecological factors in urban space are as important as the analysis of other urban growth factors in terms of proper planning of urban growth. In addition, as urbanization is a rapidly developing process throughout the world, environmental, ecological and social concerns are increasing as a result of urbanization.

The speed and intensity of urbanization is effective in changing land uses. It is important to investigate the factors that cause land use change in order to understand the change process, to estimate the speed, intensity and path of the land change in the urban area (Aydın, 20015). Ecological factors can be shown among the most important factors affecting land use change in the urbanization process.

2. Material and Method

The main material of the study is Artvin Central District with its sloping and steep land structure, crowded population compared to other districts and high density building stock. Study; It has been shaped by on-site observations and research based on the literature on the subject. In this study, ecological factors and urban growth models that are effective on urban growth for the study area were examined and in this direction, the ecological factors effective in urban development and the urban growth model of the area were evaluated for Artvin Central District, which was chosen as the study area. In the light of the information and findings obtained, evaluations were made and urban growth proposals were put forward for the study area.

3. Findings and Discussion

In this section, the ecological characteristics and population change of the study area were determined, urban growth systems were examined and the ecological factors affecting the urban growth of Artvin Central District were revealed.

3.1. Ecological Characteristics of the Study Area and Population Change

In this section, the urban ecological features that have an impact on the urban growth of the study area are explained. After explaining the urban ecological features, the population change, which is one of the conditions of urban growth, is examined.

The study area, Artvin Central District, is located in the northeast of Turkey, in the Black Sea Region, within the Coruh Basin, between 40 54' 57 north latitudes and 41 30' 51" east longitudes. The lowest elevation in the area is 125 m, the highest point is 3195 m and the average height is 1402.11 m. The area of the study area is 7,436 km². Turkey's fastest flowing river forms a deep valley in the study area. The district is surrounded by Şavşat in the east, Murgul in the west, Yusufeli in the south and Borçka in the north (Figure 1).

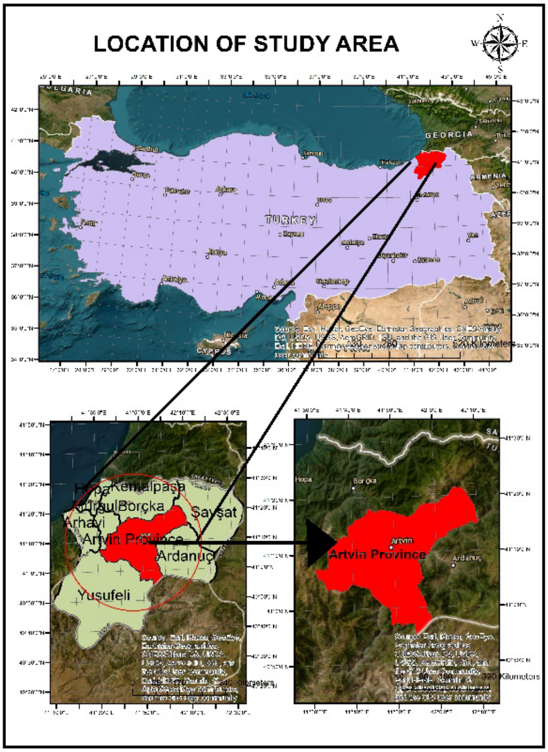

Figure 1. Location of study area (Original, 2023).

Artvin Province, which is the center of the study area, is very rich in terms of natural and cultural values. While there is a protected area with an area of 400 km² in Artvin, Hatila Valley National Park (169 km²) and Kafkasör Plateau and Urban Forest (0.08 km²) are in Artvin Central District. In Artvin Central District, there are administrative units of various state institutions such as hospital, population directorate, regional directorates of institutions affiliated to the relevant ministries, since it is a center determined by administrative borders. From this point of view, it can be said that the study area is the most dense district in terms of population and building stock, which are accepted as criteria for urbanization.

Topographic and Geological Structure of the Study Area

The topographic structure of the study area is quite active. The Çoruh River and its tributaries, especially Fabrika and Hatila Stream, form deep valleys in the rugged area.

Alacadağ (2844 m) in the north-northwest direction, Otlu Mountain (2800 m) extending in the north-east-southwest direction, Cerattepe (1700 m) extending in the northwest-southeast direction are among the most important mountains (Artvin Governorship, 2015).

General Soil Characteristics and Land Uses of the Study Area

There are six soil types in Artvin, namely brown and non-calcareous brown forest soil, red soils, yellow podzolic soils, high mountain meadow soils, alluvial and colluvial soils. According to the land use capability classes related to soil properties, the most common of the 8 capability classes (46.5%) is VII. class tillage is unsuitable for agriculture (Bolat, 2020).

In terms of Land Use Capability Subclasses (ATS), slope and erosion damage, stoniness, drainage disorder or flood damage, slope and erosion damage, soil insufficiency (stony, salinity and alkalinity), slope and erosion damage, soil insufficiency (stony, salinity and alkalinity)) and there are 4 subclasses (Özdemir Durak, 2022). Current land uses in the study area garden (dry), garden (irrigated), heathland, heath-pasture, pasture, dry farming (fallow), dry farming (fallow)-pasture, dry farming (fallow)-forest, forest, forest-heath, forest-dry farming (fallow), irrigated farming, vineyard (irrigated), hazelnut-dry farming (fallow), bare rocks and water surfaces consist of 17 uses. The most common of these is the forest use type (Özdemir Durak, 2022).

Land Cover of the Study Area

According to the land cover map created by Özdemir Durak (2022) with Corine 2018 data, in the study area; discontinuous city structure, industrial or commercial areas, highways, railways and related areas, mineral extraction areas, construction areas, non-irrigated arable land, orchards, mixed agricultural areas, agricultural areas with natural vegetation, broad-leaved forests, coniferous forests. There are 18 land cover classes: mixed forests, natural meadows, vegetation change areas, bare cliffs, sparse vegetation areas, waterways and water bodies. The most common of these are broad-leaved forests, coniferous forests, and mixed forests.

Climate of the Study Area

In Artvin, a wide variety of climate types are seen, including Black Sea Climate on the coast, Continental Climate in the interior and higher parts, and even Mediterranean Climate in places. According to the Köppen climate types classification made by the General Directorate of Meteorology, the Central District is generally in the type of climate with warm summers, hot and dry winters (Meteoroloji Genel Müdürlüğü, 2010).

Vegetation of the Study Area

The study area is very rich in terms of vegetation. Artvin is located in the Euxine sub-flora of the European-Siberian Floristic Region. In the Euro-Siberian floristic region, as a result of the destruction of vegetation caused by human influence in the coastal areas, the forests have been replaced by the shrub and bush (pseudo-maquis) belt. In this region, broad-leaved forests (beech, chestnut, hornbeam, oak, linden, ash) between 300-800 meters, mixed forests (beech, hornbeam, oak, linden and fir, spruce, larch, yellow pine) between 800-1200 meters, Conifers (fir, yellow pine and spruce) are seen between 1200-2200 meters and alpine meadows belt is seen from 2200 meters (Bolat, 2020).

Hydrological Structure of the Study Area

The largest river within the boundaries of the study area is the Coruh River. After the Yusufeli Dam, which is located within the boundaries of the study area and has started to hold water in Turkey, but is not yet operational, the highest dam is Deriner Dam, which is 2 km away from the center of Artvin. Among the important surface waters related to the hydrological structure of the study area, the streams are Çoruh River, Hatila Stream and Fabrika Stream.

Population Change of the Study Area

Urban growth is shaped by the economic developments that occur in line with the effect of ecological factors and, accordingly, the population change. Many dams, HEPPs and road constructions connected to them are planned, in progress and completed on the Çoruh River and its tributaries, some of which are located in Artvin, with the highest flow rate in Turkey. From this point of view, it is possible to say that the construction and energy sectors are among the most important sectors for the city's economy.

In addition to the aforementioned economic investments, the establishment of a university in Artvin can be listed among the factors that cause population growth in the Merkez District and the associated urban growth. According to the address-based population registration system data of the

Turkish Statistical Institute, the population in Artvin Central District was 25.002 in 1965, while it was 34.537 in 2022 (last official record). As Özdemir Durak (2022) stated in his study, the population increase has also occurred as internal migration in the form of migration from rural areas to district centers.

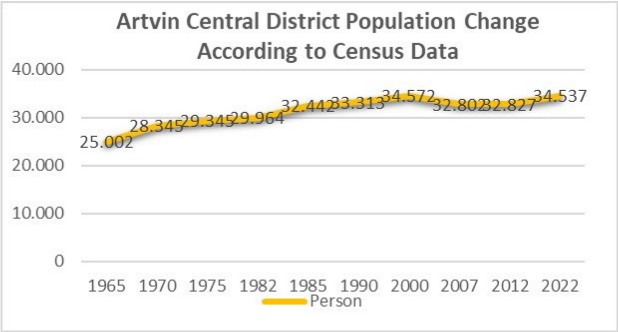

Figure 2. Population change in Artvin Central District between 1965 and 2022 (Original, 2023).

Özdemir Durak (2022) revealed that there was an increase of 31.77% in the class of land cover settlement areas between 1984-2021 according to Corine 2018 data in Artvin Central District and its immediate surroundings. In this context, considering the previously examined population indicator, it is possible to say that urbanization has increased in Artvin Central District.

3.2 Urban Growth Systems and Ecological Factors Effective in Urban Growth of Artvin Central District

In this section, first the urban growth systems are explained and then the ecological factors that are effective in the urban growth of Artvin Center are evaluated in line with the described urban growth systems.

Urban Growth Systems

Aru (1998) states that urban growth takes place in six forms: linear, radial, concentric, saddle, arc and miscellaneous. In radial, concentric and saddle-shaped growth, the formal structure is complementary to each other. Linear growth (Figure 3) spreads in many directions in line with the topographic structure features and reveals the radial growth form. As the process progresses, these developments lead to the formation of a concentric settlement (Figure 4) with the formation of transportation axes (Sinmaz & Özdemir, 2016).

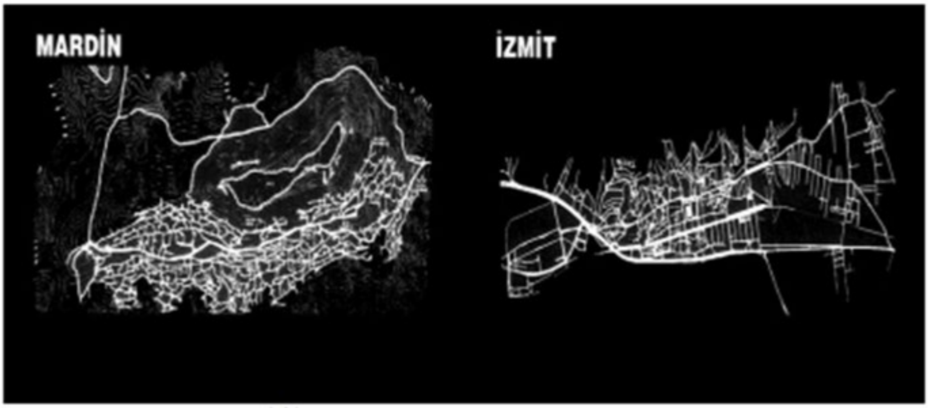

Figure 3. Linear Urban Growth (Sinmaz & Özdemir, 2016).

Topographic features and hydrological structures of cities are among the main ecological factors that affect urban growth. Linear urban growth is generally formed by the effect of topography factor. The Mardin City Suriçi settlement is shown as an example of linear urban growth. The city of Mardin was founded in the 12th century on the southern slope of the hill where the Mardin Castle is located. In the Suriçi region, within the constraints of the topography, the city is located in a linear fashion for 2.5-

3 km and approximately 500 m. It grew in width in the east-west direction. Similarly, the city of Izmit, which grows linearly, is a coastal city that was established in the area under the influence of the hydrological structure and continued its growth along the water element (Sinmaz & Özdemir, 2016).

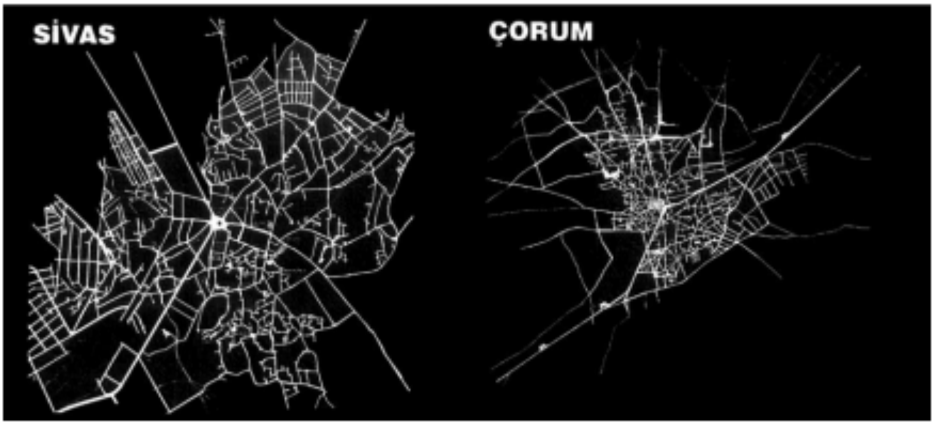

Figure 4. Radial City Form (Sinmaz & Özdemir, 2016).

Urban growth in radial form refers to the urbanization that spreads along the transportation axes in the form of rays from the center. In the city of Sivas, where the slope is low, the urban growth took place in a distinctive radial system between its western slopes and Kızılırmak. The first settlements were formed on the east side of the radial structure, in the section up to the Kızılırmak river. Afterwards, the developing urban growth progressed in all directions (Sinmaz & Özdemir, 2016).

The city of Erzurum, which was established in and around a castle from the Roman period, showed a concentric growth by being influenced by the topographic structure of the city (Figure 5). With the rise of the castle, the ring roads developed and the city grew in the west direction. The old city, on the other hand, does not show any urban growth characteristics in terms of formal structure, except for the core of the city (Aru, 1998). The city of Siirt was established on the western slope of the Şeyhşemu and Rasinnebah hills, which dominate the Botan valley. It was established near the plateau of the Southeast Taurus Mountains. Along with the safety factor, which was effective in the urban growth of this small Anatolian city, ecological factors for its climatic and morphological structure were effective. The eastern border of the city is determined by a deep cleft formed by the Botan valley, which shows a very distinctive morphological structure. The city has grown in the west direction. Since the dominant ecological factor affecting the growth of the city is the morphological structure and the city has a very rugged morphology, the urban growth has taken place in a concentric manner (Sinmaz & Özdemir, 2016).

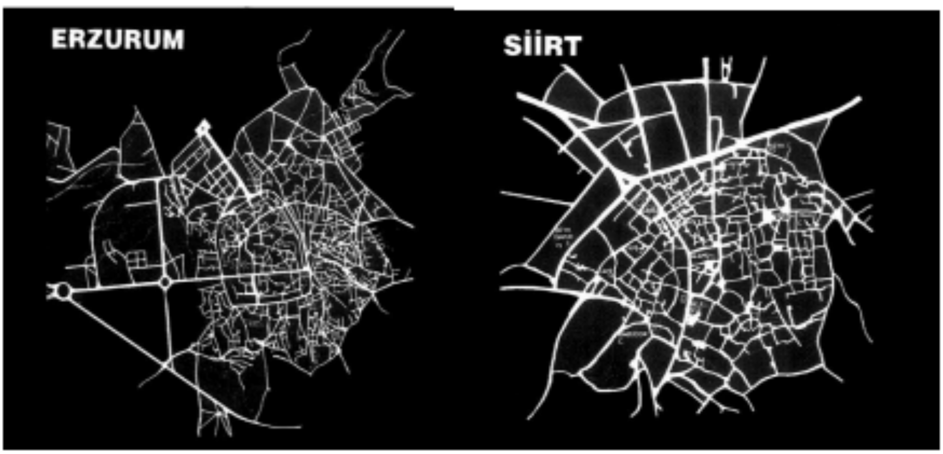

Figure 5. Concentric (Erzurum) and Spring (Siirt) Urban Form (Sınmaz & Özdemir, 2016).

Ecological Factors Influencing the Urban Growth of Artvin Center

Determining the factors affecting urban growth and planning urban growth in line with these factors is the sure way to create sustainable and high-prosperity urban spaces. The planned and controlled growth form in question is "smart growth". The city center of Portland, Oregon, is cited as the two best cities representing smart urban growth (Sınmaz & Özdemir). In the Oregon city plan, the city is divided into 10 sub-regions (Figure 6) Portland Central city, Oregon, has rich natural resources and a mild climate. The characteristics of ecological factors in urban growth have been the hydrological structure due to the climate and the river in the city (Portland Goverment, 2020). In the cases of Portland province and Oregon city center, the main features are the use of high-density mixed areas and minimizing the use of car addiction (Sınmaz & Özdemir, 2016).

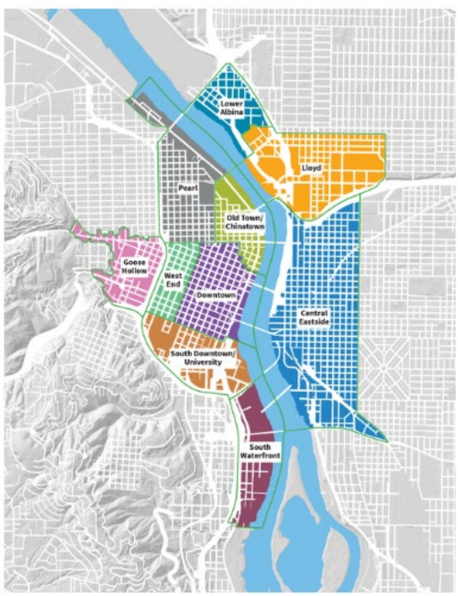

Figure 3. Portland Oregon City Plan (Portland Gov., 2020).

The effects of location, geological structure and landforms on urban growth

There are steep mountains throughout the Artvin Province. The extensions of the Eastern Black Sea Mountains, extending parallel to the Black Sea coast, within the provincial borders; It extends to the border under the name of Kaçkar, Altıparmak, Kükürtlü, Iskaristi Mountains. There are many mountains and high peaks on this mountain range (Artvin Valililiği). The main ones of these mountains are Kaçkar Mountain located on the borders of Arvin-Rize and Erzurum, Kükürt Mountain located on the Artvin-Rize provincial border and an extension of the Eastern Black Sea Mountains, Karçal mountain ranges to the east of Borçka District, and Yalnızçam and Çadır Mountains located in Ardanuç District. (Artvin İl Kültür ve Turizm Müdürlüğü). The city is surrounded by the high topography created by these mountains. Artvin Central District is a city center that develops from the Çoruh River valley floor to the high slopes. Urbanization, which starts from the valley floor where the Çoruh River carries alluvium and rises sharply with 11 bends, grows towards the Hatila Valley in the north direction and in the direction of Cerattepe in the northeast direction at high altitudes (Figure 7).

Figure 7. Çoruh River valley floor and general view of urban growth towards higher elevations in Artvin Center (Original, 2023).

The city center of Artvin was formed by the movements of the earth's crust, erosion, transport and deposition that took place in morphologically different geological periods. This morphological structure is the main obstacle for transportation in urban growth. Transportation within the city and its surroundings is not easily provided. In fact, even from the settlements (Dere Mahallesi) at the bottom of the Çoruh Valley, transportation is provided by 7 tunnels and 2 bridges at a distance of 45 km to reach the Black Sea coastal road. As a result, the city of Artvin is a city with limited transportation opportunities with its steep morphological structure and this situation has a negative impact on urban growth (Figure 8).

Figure 8. An example of the topographic structure of the study area that restricts access. (Original, 2023).

Transportation constraints not only have a negative impact on urban growth in the study area, but also create major obstacles in terms of the use of urban space. It is very difficult for users to reach urban uses on foot as well as by car. Sidewalks and disabled ramps required for pedestrian use in the city do not exist at all in many areas, and where they do exist, they are not up to standards and are unsafe to use (Figure 9).

Figure 9. Example of a sidewalk not suitable for pedestrian use in the study area (Original, 2023).

The effect of climatic conditions

The observation data of Artvin Central Meteorology Station, which was established in 1948 and makes regular measurements, can be used to investigate the climatic characteristics of the city environment. As a result of the calculations made in line with these data, it is possible to say that the meteorological events that developed in the Black Sea regime determine the climatic characteristics of Artvin Center. According to the water balance calculations made with the long-term data of the relevant meteorology station on the city and its surroundings, there is a water deficit in the soil between July and September due to the lack of precipitation. The highest runoff is observed in February and during the non-vegetation period. From this point of view, the water need in the dry period can be met from the ground water in the region. The bottom of the alluvial fill of Artvin Province and the accumulation cones around it are rich in groundwater. Due to the geological structure of the mountainous areas, which facilitates infiltration during the rainy season, the ground water can be fed continuously. However, due to the surface water resources used for dam lakes and HEPPs in a long time, the problem of water insufficiency may arise in the face of the increase in irrigation and urban needs in the future. Temperature is also an important factor in urban life. When the long-term temperature data are examined, while the annual average temperature was 11.9 °C in 1949, it is 12.3 °C in 2022 °C. The average temperature was measured as 2.7 °C, the coldest in January, and 20.8 °C, the hottest in August. According to these values, it is understood that the summers are warm and the winters are cold in Artvin. In conclusion, in

Artvin, the precipitation and temperature elements of the climate provide very favorable conditions for human life, activities and agricultural production. This allows for various agricultural productions around the city. In addition, moderate winds blowing in the city center, which has the effect of the Bosphorus, provide air circulation over the city. However, the vertical growth of the city and the high-rise construction affect the air currents. In addition, since it is located in a region surrounded by high mountains, the air currents in the city weaken under high pressure conditions. Urban air can be polluted as the air flow with the wind is not sufficient in these conditions and the city still cannot fully switch to natural gas for heating. Pollution is increasing in the Çayağzı neighborhood due to the fact that it is established in the city center and on the valley floor due to intense construction. In order to disperse the polluted air in order to prevent air pollution, ventilation corridors to be formed with plant species that will absorb the polluted air particles located in the direction of the prevailing winds opening from the city core to the environment should be planned.

Effect of Vegetation and Soils

According to the evaluations of the General Directorate of Meteorology regarding the climate; Artvin Central district and its surroundings show a semi-humid character (Meteoroloji Genel Müdürlüğü). Climatic conditions provided an advantage in terms of being rich in plant species diversity in the study area. It is known that approximately 13% of the entire flora of Turkey, which has approximately 10 000 species, is located in Artvin (Artvin Valiliği, 2015). The general vegetation of the area consists of forest, shrub and meadow vegetation. According to the data obtained from the 1/25 000 scale Artvin Province forest management plan between 2001-2010, the stand types that are common in the forest areas in the study area are Spruce, Scots Pine, Beech, Oak and Hornbeam (Bolat, 2020). Therefore, according to the prevailing humidity and temperature conditions, the natural vegetation of the Artvin region is at low altitudes, pseudo-maquis (300-800 m) at higher altitudes, Forest (500-2100 m), swamp, mountain steppe (900-1500 m), subalpine (1900-2200 m).), alpine (2100-3000 m), humid stream (0-1800 m) (Eminağaoğlu, 2015). However, the natural vegetation in Artvin has been destroyed by anthropogenic effects. The destruction of vegetation first started at the Coruh River valley floor and progressed towards the slopes. Along with the dam constructions, the roads connected to them have affected the forests and these forests have been replaced by small trees and bushes. The fact that the Artvin region has been a residential area for centuries, the destruction of natural vegetation as a result of the cuts made to provide housing, fuel and agricultural land, has caused the destruction of vegetation. has changed. Re-establishment of forests on the slopes, even if the base is not on the land, urban climate. In fact, due to this destruction, the soil, which could not be held by plant roots during periods of heavy rainfall, became active and landslides where loss of life and property occurred. The fertile soils of the study area encouraged the people living in the region for agricultural production, but the morphology of the area was not suitable for creating large agricultural lands, causing landslides. For this reason, agricultural production in the city could not be an effective economic factor in urban growth and could not go beyond producing products only for the local people and the domestic market. Some of the alluvial soils in the stream beds in the area are lost due to the construction of various structures, while these structures face risks such as landslides and floods. The soils on the slopes and mountainous areas where the dam roads are built are considered suitable for re-establishing and benefiting from the natural vegetation (Figure 10).

Figure 10. Destruction of dam roads on land and vegetation and afforestation studies (Original, 2023).

4. Conclusion and Suggestions

Artvin Central District is a city center with very limited transportation and connection with the environment in terms of its highly active topographic structure and geographical location (Figure 11).

Figure 11. General topographic structure of Artvin Central District (Original, 2023).

Artvin Center is the most populated district of the city and the density of buildings, pedestrians and vehicles are quite high here. For this reason, public transportation as well as transportation to the city constitutes a negative factor on urban growth and the quality of urban space. Structures built on lands formed by high retaining walls due to their topographic situations carry urban growth to a complex and unhealthy dimension (Figure 12).

Figure 12. Buildings located on high retaining walls (Original, 2023).

Settlements on high retaining walls built by urban growth, in addition to their negative effects on urban space, pave the way for slope and erosion damage, stoniness, drainage disorder or flood damage in terms of soil and rock structure and land use capability subclasses. Especially the selection of areas with high landslide sensitivity such as İskebe (Yeni Mahalle) District as new settlements and the development of urban growth in this direction increases the risk of landslides in the area. Gardening (dry/irrigated) and agriculture (dry/irrigated) are present not only in rural settlements but also in urban settlements in the area where current land uses are quite diverse. This situation can be explained by the continuation of the use of gardens and agriculture at the residential scale in some old houses in the area where there is intense construction, and it has a small positive effect on the density of buildings in the city. Mineral extraction areas seen in the land cover of the study area have a very negative effect on urban growth and welfare of the city. Especially the concrete plant and quarry located at the entrance of the city negatively affect the appearance of the city from an aesthetic point of view (Figure 13).

Figure 13. Concrete batching plant and quarry at the entrance of the Central District (Original, 2023).

The mild climate of the study area has been a factor increasing the diversity of vegetation. In general, climatic conditions provide a suitable environment for urban growth in the area and do not require special precautions. Vegetation in the study area is destroyed due to the construction of forest trenches for agricultural production, the construction of dams, HEPPs and related roads. Although afforestation works are carried out to repair the destruction, the destruction cannot be completely eliminated due to factors such as the limited diversity of species used in these studies and the loss of land due to road construction. Due to its hydrological structure, the location of settlements near stream beds increases the risks of flood and flood damage, especially in the months when temperatures increase and snow melts, due to the inconvenience of the topography to meet the housing need for population growth, which is observed when the population data of 1965-2022 is examined.

When the study area is considered in line with urban growth systems, the ecological factor for its morphological structure, which is effective on urban growth, has been effective. Its southern border is determined by a deep valley that shows a very distinctive morphological structure and forms the border with Yusufeli District. The city has grown in the southwest direction. Since the dominant ecological factor affecting the growth of the city is the morphological structure and the city has a very rugged morphology, the urban growth in the study area took place in a concentric manner.

In the urban growth of Portland, which is given as an example within the framework of ecological factors and urban growth models that are effective in urban growth and similar to Artvin with its rich natural resources, dividing the city into sub-sections in line with the ecological factors of the city is a method that can be applied for Artvin. Artvin also has a mild climate, rich natural resources and a large river in the city, similar to Portland city center. From this point of view, planning urban growth in Artvin by dividing urban uses into sub-sections according to geographical features, as in the example of Portland city center, and targeting the least use of vehicles in the city will provide the highest benefit from the existing ecological factors of the city, as well as positively affect the sustainability of urban growth and urban welfare. In this direction, the planning of new settlements for Artvin Center on the banks of the Çoruh River in the north east-south west direction will also have a positive effect on transportation in and around the city, which has a hilly structure in terms of morphological features. The use of cable cars as a means of public transportation in the city and in the proposed new settlement area will reduce the density of urban vehicles. As another transportation alternative, tour boats used for touristic purposes between the Center, which came into service in 2022 on the Borcka dam lake, and Borcka District, can be used for public transportation. Because Yusufeli Dam's water retention and Yusufeli Dam, whose water is the most upstream, will hold the water level of Deriner Dam and Borçka Dam lakes in the study area, and Yusufeli Dam will determine the water level of the lakes and will not fall below a certain level, so it will be suitable for boat use. As a result, the study area should be developed in the form of the new city plan, the southwest bank of the Coruh River, Artvin Çoruh University, the new settlement area (northeast bank of the Çoruh River), the middle quarter, the old city settlement, rural settlements and rural areas, similar to the Portland city center plan. This urban growth plan will create a by-pass effect on the urban growth of Artvin Center, which has been compressed and distorted under the influence of various ecological factors such as hydrology, soil structure, especially its morphological structure, and will reduce the destruction in the natural environment of the city, also will provide much healthier and more comfortable urban spaces for the users.

Thanks and Information Note

This e-book chapter complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

The author contributed fully to the article. There is no conflict of interest.

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Dr. Manolya ÖZDEMİR DURAK		
E-mail	:	manolyaozdemir@artvin.edu.tr
Undergraduate	:	Istanbul University, Faculty of Forestry, Department of Landscape Architecture
MSc:	:	İstanbul Technical University, Faculty of Architecture, Landscape Architecture Department
PhD	:	Istanbul University-Cerrahpasa, Institute of Graduate Studies, Department of Landscape Architecture
Professional experience	:	Faculty Member at Artvin Çoruh University since 2013

Sustainable Agriculture for Sustainable Cities

Assist. Prof. Dr. Nurdoğan TOPAL [1]

[1]Uşak University, Faculty of Agriculture, Department of Field Crops,
1 Eylül Yerleşkesi, Uşak/Türkiye.
ORCID: 0000-0002-3466-1005
E-mail: nurdoğan.topal@usak.edu.tr

Citation: Topal, N. (2023). Sustainable Agriculture for Sustainable Cities. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches.** 2023, Chapter: 6, 156-188. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

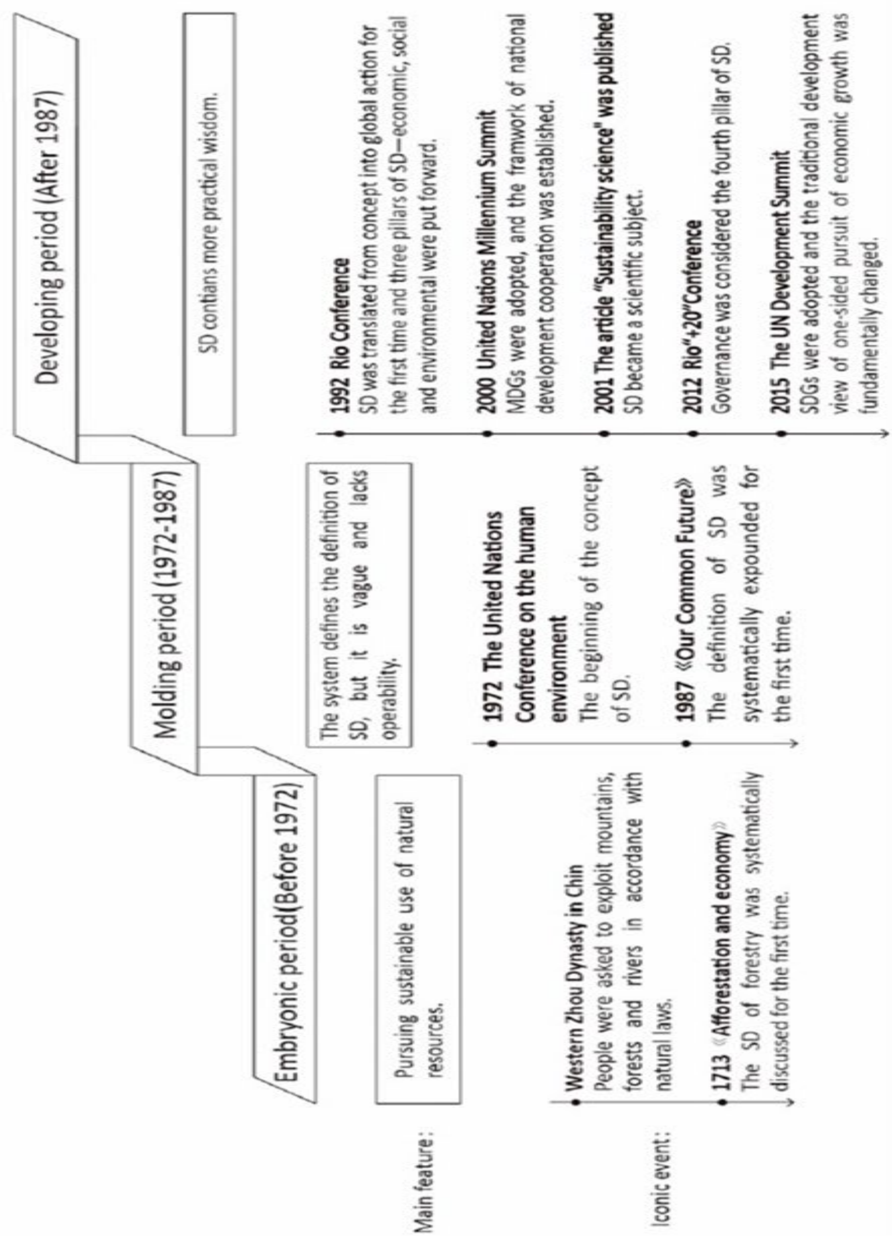
The Latin word sustinare, which combines the meanings sub (bottom-up) and tenre (to hold), is the source of the English word sustainability. It means "to sustain", "to sustain", "to support", or "to support". maybe most poignantly, "restrict," or "endure." Early modern literature made extensive use of the phrase, which originated in French and became the verb "to continue" in English. John Evelyn's important treatise on forestry can be found in Sylva (1664), for instance. According to the Oxford English Dictionary, the term "sustainable" first appeared in a dictionary of economics in 1965 under the heading "sustainable growth." Early in the 1970s, the noun "sustainability" was introduced to English. The emergence of these neologisms is a significant sign that the verb had evolved around the 20th century's end into a recognizable idea. The comparable etymology of the German words *Nachhaltig* and *Nachhaltigkeit*, which were both first used in Hans Carl von Carlowitz's book on the support of forestry in the 18th century, is also significant (Caradonna, 2014).

A proverb states that "Forests precede civilization; deserts follow." Ancient societies frequently fell into ruins once their territories had been cleared of trees. In fact, the term "sustainable" was first used in the 1700s in response to concerns over deforestation. In Germany, massive volumes of wood were needed to fuel the furnaces during the smelting of ores to create metals. The overharvesting of timber in German forests had such a negative impact that the mining sector was in danger. The first book on forest management was written in 1713 by Hans Carl von Carlowitz, a mining administrator, in response to the situation. Here, he discussed techniques for using woodlands sustainably. According to Carlowitz, sustainably maintained forests might provide wood resources perpetually. Despite Carlowitz's early use of the phrase, which didn't become widely used until the 1980s. (Thiele, 2016).

Since the 1980s, when the concept of sustainability first entered academic discourse, it has undergone a meaningful change (Portney, 2015). In the 1980s and 1990s, it recognized a crucial topic with global implications and brought together a group of actors, maybe for the first time, including governments, community organizations, academics, and industry. It wasn't that they disagreed (or frequently had no idea what the term meant technically). Frontier work in the name of sustainability gave political inaction, policy change, and innovation a substantial boost, notably in the run-up to the 1992 UN Conference on Environment and Development (UNCED) in Rio (Scoones, 2007). To balance the needs of agriculture and human survival, the ancient concept of sustainability and simplicity first emerged during the age of agricultural economics. The population grew quickly as the Industrial Revolution got under way, and productivity was expanding. The resources of nature are being exploited by humankind, and more garbage and toxins are being released into the environment. Rapid and ongoing environmental changes brought on by humans have made it harder to sustain global life support systems. By the way, the survival of humans was seriously threatened by these developments. The Eight Great Pollution Events of the early 20th century are the most well-known example. The Donora Smog tragedy in 1948 sickened approximately 6,000 people in 5 days, the Belgian Meuse Valley Fog disaster in 1930 harmed thousands of citizens and killed more than 60 people in one week, and the Great Smog in London in 1952 killed more than 4000 people in 4 days. At the same time, Humankind was dealing with a deteriorating range of issues, including food insecurity, an energy crisis, environmental pollution, a worsening "ecological crisis", sluggish economic growth, and rising local social unrest. These kinds of issues have made it necessary for mankind to reconsider its place in the ecosystem and look for new avenues for long-term survival and development. According to some researchers, the evolution and development of sustainability theory can be split into three phases: the embryonic stage (before to 1972), the formation stage (1972–1987), and the developmental stage (since 1988) (Figure 1) (Shi et al., 2019).

The concept of sustainability encompasses urban planning, agriculture, health care, and other fields. It is related to a variety of ideas. Whatever its context, it unquestionably has an impact on the economy, society, and environment. Because of this, sustainability comes in a wide variety.

Figure 1. Depicts the Sustainable Development (SD) theory's evolution stages and symbolic occurrences (Shi et al., 2019).



2. Types of Sustainability

One widely embraced definition of "sustainability" revolves around three interconnected pillars, components, or perspectives that encompass economic, social, and environmental factors. These pillars collectively strive to achieve targets or objectives that promote sustainability. Sustainability is positioned at the crossroads of society, the environment, and the economy in this triple definition, which is frequently but not always presented in this way (see Figure 2) (Purvis et al., 2019).

Every society consists of four components: economic, social, environmental and institutional. Each is a dynamic, complex, self-organizing, and self-developing unit, which adds up to a very complex regional system. Each of the four subsystems must continue to be able to exist and develop, and their links between one another must result in a continuous co-evolution for this system to remain viable (Spangenberg, 2005).

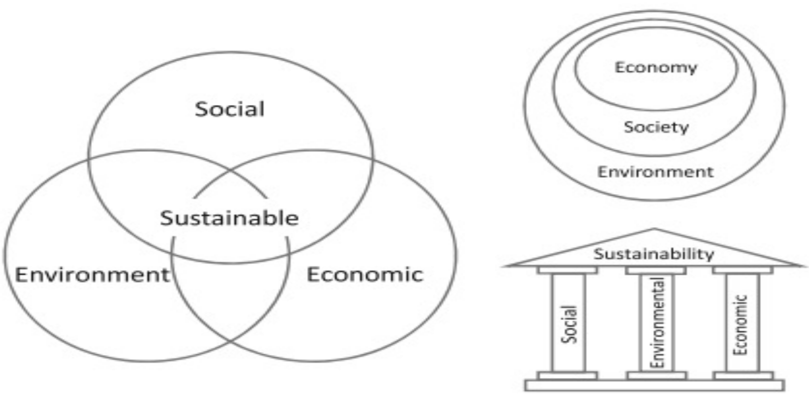


Figure 2. Left, typical representation of sustainability as three intersecting circles. Right, alternative depictions: literal 'pillars' and a concentric circles approach (Purvis et al., 2019).

2.1. Sustainability of Economy

These days, the necessity of employing sustainable economic methods is not really contested. Even people who care solely about business and not the future of the globe understand that the resources of healthy ecosystems (fresh water, clean air, robust biodiversity, fertile soil) and the stability of society are essential for corporate survival. The issue is simple. It is frequently less expensive to buy a product with a negative environmental impact than a comparable product with a positive impact. greater environmental costs may not necessarily translate into greater prices for consumers. Yes, this is the case because companies rarely have to pay for their global operations. Many of these consequences are difficult to quantify accurately or allocate appropriately to specific enterprises, thus their costs have been left out of business accounting. Can these externalized costs, however, be quantified and allocated? What if we could reach a point where the product with the lowest price also has the lowest impact on society and the environment? Sustainability theorists have been advocating this for a long time. For a very long time, "real cost accounting" has been the goal of the move Chouinard et al.,2011).

The trade-off between current and future consumption is the main emphasis of the economic view of sustainability. Economic thinkers of the late 19th century, like Malthus, who understood that population expansion was related to food production, were confronted with this issue. But technical advancement prevented the hunger and calamity predicted by Malthus from happening. Natural capital (labor and land) was replaced by created capital (machines). Therefore, the key to sustainability is determining whether generated and natural capital are complementary or replacement assets. Many economists think that we can keep up with present consumption and that technological advancement will meet future generations' requirements (Elliott, 2005).

The parallels and distinctions between the notions of sustainability and the Circular Economy are still unclear, despite the phrases gaining more and more popularity among academics, business leaders, and legislators. Because the relationships between the concepts are not explicitly stated in the literature, their conceptual boundaries are becoming muddled, which limits how effectively the techniques may be used in study and practice. (Geissdoerfer et al., 2017).

Neo-classical economics concludes that consumption can be maintained even if production depends on a natural resource that is running out owing to substitution and technological advancement. There is a level of consumption that can be maintained indefinitely if production depends on a necessary, renewable resource. The amount of consumption that can be sustained declines due to pollution. Recycling garbage is insufficient to sustain consumption when production depends on a finite resource, barring the possibility of 100% recycling. If resource productivity is high enough and resource growth potential surpasses the total of the discount rate less the rate of exogenous technological progress, sustainable economic development is achievable. Additionally, the potential for sustainable economic development is influenced by the initial levels of environmental quality (a composite of pollution and natural resources) and manufactured capital. The utility of the resource supply itself will be impacted, and optimal extraction and consumption will be reduced. According to ecological economics, the quantity of output that can be sustained is constrained by the limited availability of substitutes, the impossibility of fully recycling trash, and the finite solar energy supply. This life support function restricts economic expansion since the functions of the environment (production factor, consumer good, and waste sink) are linked. Development is seen as an evolutionary process in ecological economics, with ongoing feedback between the economy and environment. Welfare involves environmental compatibility and the explicit (collective) development of policy involving the conservation of species, ecosystems, and natural resources. Welfare is not simply the total of discounted individual preferences (Klaassen & Opschoor, 1991).

The circular economy has become recognized as a viable approach to more efficient resource utilization. The circular economy is viewed favorably by organizations in the public, private, and civic sectors as a technology-focused idea that can increase economic benefits while reducing environmental strain, and, increasingly, by academia. Concerns have been made, nevertheless, about some allegedly "sustainable" circular economy activities that have negative effects on the environment and society (Velenturf & Purnell, 2021).

Circular, green, and bioeconomy are all aspects of sustainable economy. In a study by D'Amato et al. (2017), the concepts of circular economy, green economy, and bioeconomy can be consubstantiated by a single ideal to reconcile economic, environmental, and social aims. This is true despite conflicting assumptions and operationalization methodologies.

As a consequence of the literature assessment, the Green Economy is built on the Circular Economy and Bioeconomy principles (such as nature-based solutions) on challenges relating to environmental sustainability. In contrast to the Green Economy, which embraces the supporting role of all natural processes, the Circular Economy and Bioeconomy are more resource-oriented. In terms of the social component, the Green Economy There is a growing dispute in the bioeconomic literature about local processes in terms of biosecurity and rural policies, even though some aspects are more inclusive at the local level (such as eco-tourism and education). Researchers have once more argued for the clarity and mutual integration of these sustainability strategies, not their substitutability, by contrasting the many sustainability strategies supported by these principles.

2.2. Sustainability of Environment

The word "environmental" is frequently related with some sort of human impact on natural systems in both understanding and usage. It can be distinguished from the term "ecological," which can be defined as the idea of interdependence of elements within a system, by the context in which it is used. Ecological sustainability, according to this definition, is "meeting human needs without compromising the health of ecosystems." This seems improper because, according to popular belief, the term "ecological" denotes a wider context than merely the human experience. Environmental sustainability can be more precisely described as a state of equilibrium, resilience, and interconnectedness that enables human society to meet its needs without depleting its supporting ecosystems' capacity to continue regenerating the services required to meet those needs or by our actions reducing biological diversity (Morelli, 2011). Through indicators like planetary boundaries, life cycles, and sustainable development targets, we can classify environmental sustainability (Dong & Hauschild, 2017).

The identity I = PAT (pollution = (population) x (production/person) x (pollution/production) was examined and the components of sustainability were further analyzed in a study using the Ehrlich-Holdren framework, in which "Population, Welfare, and Technology" are examined separately. formulas that are dynamic (Goodland & Daly, 1996).

According to a different study, the issues of population number and increase, resource consumption and depletion, and environmental degradation should be dealt with concurrently and globally. Population control is required but not sufficient in and of itself to resolve the environmental catastrophe, as has been argued in this context. According to the study, "Environment" should be widely understood to cover elements like the epidemiological environment, the human behavioral environment, and the physical environment of urban ghettos (Holdren, 2018). According to a different study, industrial and organizational psychologists are in a unique position to support global economies' and organizations' efforts to reduce, mitigate, and neutralize their environmental impacts and adapt to environmental sustainability (Ones & Dilchert, 2012).

Islam (2015) reported that inequality negatively impacts environmental outcomes through a variety of channels, including household, community, national, and international channels, in a study that presents evidence of a negative correlation between income inequality and environmental quality. Only these channels overlap, according to the study, and thus can strengthen the effect of inequality. It has been revealed that one of the other dimensions of inequality, especially gender inequality, negatively affects environmental quality. He stated that the concept of the Environmental Kuznets Curve (EKC) does not help to explain the negative relationship between inequality and environmental quality, and that reducing inequality will have an important role in ensuring environmental sustainability.

Culture is considered to play a significant role in the relationship between income and environment in another study looking at the correlation between the World Economic Forum Environmental Sustainability Index scores and the four aspects of national culture developed and quantified by Hofstede (1983). A considerable multidimensional relationship between cultural and environmental sustainability metrics has been established. When cultural variables are incorporated into the model, the Environmental Kuznets Curve (EKC) phenomenon's limited relevance is demonstrated in this article (Park et al., 2007).

Decades of scientific observation demonstrate that, despite initiatives like international accords, national policies, and environmental legislation, the world is not any closer to achieving environmental sustainability and, in many ways, things are growing worse. It has been discovered through a systematic review of the literature that the failure of environmental policies to produce the desired results is caused by economic, political, and communication factors, which is discussed in this study as an important factor contributing to this situation. In the same study, it was emphasized that the failure to effectively communicate the objectives of environmental policies to important stakeholders and the inconsistency between the goals of environmental policies and those emphasizing economic development were the primary causes of the failure of environmental sustainability (Howes et al., 2017).

Environmental sustainability is now a crucial component of planning and reporting on urban performance. Studies on environmental sustainability are now being used as a guide for people responsible for building and administering cities due to population pressure, proximity to resource restrictions, existing or anticipated external environmental impacts, and a heightened sense of global responsibility (Baynes & Wiedmann, 2012).

2.3. Sustainability of Social

Urban sustainability is a topic that has been debated for as long as cities have existed. Urban inequality's ability to fuel divisive social tensions has long been a source of worry, from Plato's Athens to Marx's Manchester. However, some of the problems that led to these worries have changed and evolved over time. Nevertheless, some issues are more enduring than others. For instance, the ongoing argument over the design and viability of cities was fueled by the advent of capitalist urbanism. Naturally, post-apocalyptic city images continue to influence popular culture. Take the movie Children of Men by Alfonso Cuarón. Cuarón creates a story around the biological and consequently social breakdown of humanity in this instance. With London serving as the major setting, urban society is portrayed as fractured, consisting of random acts of violence and feuding nationalist sects. Therefore, urbanism has always been the focus of sustainability concerns whether it is shown in political theory or in media. Maintaining growing populations and their activities is an ongoing issue in a number of areas (such as employment, cultural connections, etc.). However, many of these conflicts have only lately been recognized as sustainability problems in and of themselves (Davidson, 2010).

Ghahramanpouri et al. (2013) consulted works from the urban planning, urban design, urban sociology, and urban policy fields that were released between 1993 and 2012. The study stressed the importance of social equality, meeting human needs, wellbeing, quality of life, social interaction, cohesion, and inclusion, feeling of community, and sense of place in defining and evaluating social sustainability. A study of research conducted in various urban units demonstrates that earlier efforts for urban social sustainability placed a greater emphasis on concerns pertaining to the local community. The investigation came to the conclusion that discussions of issues related to place were scarce. Due to this, it has been noted that there is a void in the academic literature about the urban social sustainability of urban places. The social component of sustainable development, sometimes known as "social sustainability," has gained more attention in recent years. Colantonio (2010) noted in his study that there is no agreement on the definition of social sustainability, which makes it challenging to come up with a general definition because the concept is approached from various working perspectives and according to criteria that are discipline-specific. Additionally, he added, rising "soft" and less quantifiable ideas like happiness, social cohesiveness, and a feeling of place are increasingly supplanting or replacing old "hard" themes of social sustainability like employment and poverty reduction.

3. Sustainability of Cities

Cities have developed into improbable but essential areas for human survival. The most significant efforts at human adaptability and sustainability are currently taking place in these places. They offer a potential point of concentration for the future flourishing of life on this planet. But in order for this to happen in a way that is more than haphazard, we need to radically rethink the way urban development is done. 'Business as ‘usual' or even 'business with a new rhetoric' won't cut it given how serious the problems are. It is crucial to adopt new ideas, especially the reconciliation of theory and practice. Although it seems easy, the task is challenging. We require a paradigm shift away from the current narrow emphasis on productivity based on growth and high-tech "solutions." We require an alternative paradigm that can address the issue of bridging internationally debatable concepts and cutting-edge perspectives on sustainability with locally relevant practices (James, 2014).

Government initiatives to reduce poverty and social exclusion are increasingly using a multifaceted strategy that incorporates partnerships for collaboration and capacity building within the community. This suggests more extensive community input as well as participation from nonprofit organizations, official institutions, and the commercial sector in the democratic administration of local affairs. Although these are well-established theoretical notions, putting localized social policy into practice and evaluating the results are notoriously challenging, especially in historic metropolitan locations where the management of heritage value and democratic decision-making may conflict (Landorf, 2011).

More than half of the world's population will reside in cities in ten years. According to the United Nations (UN), this will put cities in danger of social unrest, environmental deterioration, and the breakdown of essential services. As a remedy for these unfavorable urban trends, the economic, social, and environmental planning methods of civilizations that include "urban sustainability" have been suggested. The concept of "urban sustainability" has several different historical roots (Basiago, 1998).

Sustainability is often understood to have social, economic, political, and environmental aspects. The justifications for employing a natural capital strategy are accompanied by examples of natural capital. When making decisions that have an impact on sustainability, such as those involving land use, transportation infrastructure, and fiscal policies, indicators help communities assess current conditions and trends, promote informed discussion among diverse groups within the community, provide input into the policy process, and help communities identify significant tradeoffs they may face (Olewiler, 2006).

Rapid growth is threatening the viability of cities and the quality of city life. Social instability brought on by mass urbanization can compromise a city's potential to be both environmentally and economically viable. A new sustainability paradigm is required, one that provides stronger incentives for reducing consumption, conserving energy, and protecting the environment while simultaneously raising levels of public wellbeing. Future cities should be socially varied environments where social and economic activities coexist and where neighborhoods serve as the focal point for communities. To enable their residents to be socioeconomically creative and productive, they must be developed or modified (Riffat et al., 2016).

The relationship between urban form and social sustainability has been investigated, and it has been said that the two main dimensions of social sustainability are fair access and the sustainability of the society itself (Dempsey et al., 2011). This study aims to address this inequality through detailed research and definition of the concept of social sustainability in the urban context.

It was argued in a different study that urban social sustainability is a multidimensional concept that includes six main dimensions of social interaction, sense of place, social participation, security, social equality, and neighborhood satisfaction to develop a comprehensive measurement scale to evaluate urban social sustainability at the neighborhood level. The study used factor analysis to investigate the urban social sustainability scale's validity, reliability, and dimensionality. Additionally, by examining the impact of design quality, one of the least researched aspects of urban form, on several social sustainability dimensions, the application of the urban social sustainability scale has been proven. The study offers fresh proof of the significance of raising neighborhood design quality as well as the relationship between it and many aspects of social sustainability as well as overall social sustainability (Larimian & Sadeghi, 2021).

One of the key concerns defining the interaction between humans and ecology is urbanization. Utilizing the right sustainability indicators, one must quantify the degree to which urban growth is sustainable or not. The context-specific definition and interpretation of the idea of sustainability, which varies from nation to country and according to the socioeconomic strata of society, are generally unknown. Two major challenges (internal: the problem inherent in the indicators due to development methodologies, external: lack of data, policy laxity or government reluctance to implement indicators, lack of consensus on what constitutes standard indicators, and lack of compliance) were identified in a study that aims to address this challenge by identifying the main problems encountered in the development and implementation of sustainability indicators in the urban context and proposing solutions. Food production and consumption entail basic biological functions that cannot be fully controlled by or for the benefit of capital. Food systems, and the effects they have on people's health and wellbeing, naturally interact with (and shape) locations and spaces, in part because of this. Despite being globally distributed, food still has specific spatial configuration aspects. Therefore, it is not unexpected that food security and sustainability have been important governance problems for more than 200 years in advanced economies (Marsden & Sonnino, 2012). Quantifying the link between food and globalized cities has recently piqued the interest of urban planners in general and economists in particular. According to Rhys-Taylor (2016), food plays a crucial role in almost every aspect of urban life, from the spatialization of socioeconomic class to the creation of air pollution to the manipulation of financial markets. Urban and peri-urban agriculture may harm the urban ecosystem or provide an ecological function. Urbanists and landscape architects have supported urban agriculture and food systems over the past 20 years while paying little attention to the harm that is being done to the ecology. The current state of affairs necessitates a fresh model that takes into account trade-offs between ecosystem benefits and disservices, due to rising urbanization, environmental degradation, population development, and changes in food systems. Edible urbanism 5.0, which we define as "a sustainable planned network of edible food components and structures, within the urban ecosystem, to manage and design the provisioning of ecosystem services" (Russo & Cirella, 2019), is a supportive component in achieving these goals, which include ending hunger and all forms of malnutrition by 2030 and feeding up to ten billion people.

4. Sustainability of Agriculture

Since the 1987 release of the Brundtland Report, the concept of sustainable agriculture has gained popularity. However, the definition of sustainable agriculture is exceedingly imprecise, making its use and application very challenging (Velten et al., 2015).

Economic issues brought on by conventional agriculture include higher costs of energy-based inputs, lower farm earnings, and agricultural overproduction. Additionally, it has led to ecological issues like low biological diversity, water and soil contamination, and soil erosion. These economic and environmental issues can be resolved by implementing integrated agricultural production methods that require less fertilizer, pesticide, and cultivation input. Such systems require an in-depth knowledge of the interactions that exist between their four primary components—fertilizers, insecticides, cultivation practices, and rotations—and how these interactions affect crop yields and farm income (Edwards, 1989).

Agriculture that is sustainable generates a lot of food without consuming too many resources or harming the environment. Agriculture creates methods for growing crops and rearing livestock that are self-sustaining, just like nature, by adhering to the laws of nature. Indistinguishable from prosperous rural communities, fulfilling lives for families on the farms, and healthful food for all, sustainable agriculture is also the agriculture of social values (Earles & Williams, 2005).

But as a set of approved practices or a model farm economy, sustainable agriculture is still in its infancy in the first decade of the twenty-first century. Making greater use of the biophysical and human resources that are now accessible is the fundamental problem for sustainable agriculture. Reduce the amount of external inputs used, maximize the use of internal resources, or employ a mix of the two to achieve this. As dependencies on external systems are kept to a reasonable level, this assures the efficient and effective use of resources and guarantees that any enhancements will last. The goal of sustainable agriculture is to use a variety of insect, nutrient, agroforestry, soil, and water management methods in an integrated manner. Wastes or byproducts from one part or business are used as inputs in another.

Instead of aiming for a certain end state, improving sustainability is a process that advances farming systems along a trajectory toward reaching multiple socially chosen sustainability goals. Four widely accepted objectives characterize agricultural sustainability: (NRC, 2010)

• Contribute to the production of biofuels while meeting human requirements for food, fiber, and feed.

• Improve the base of resources and the quality of the environment.

• Maintain the agricultural sector's economic viability.

• Improving the standard of living for farmers, farmworkers, and society at large.

4.1. Urban Farming

Four primary obstacles stand in the way of feeding the world's expanding population: a lack of natural resources, changing demography, climate change, and rising waste. Utilizing cutting-edge technologies to boost productivity, sustainability, and agriculture is motivated by these difficulties. In comparison to conventional farming, urban farming has a number of benefits, including increased productivity, enhanced sustainability, and the potential to supply fresh food all year long. With their capacity to facilitate controlled release of nutrients and pesticides, improved seed health, substrates with better water retention capability, more efficient recycling of agricultural waste, and precise plant health monitoring, novel materials are key to accelerating the evolution of urban farming. In urban farms, materials science promotes environmental sustainability and increases harvest yields (Xi et al., 2022).

The rapid expansion of the global economy, the share of the GNP that goes to industrial and service industries, and the number of workers employed in these sectors have all contributed to urbanization. Globally speaking, agriculture has been able to meet urban population needs, even those for food that is more energy-, land-, water-, and greenhouse gas-intensive.

However, hundreds of millions of metropolitan residents are malnourished. Therefore, the main questions in the relationship between agriculture and urbanization are whether the expanding and changing needs for agricultural products from growing urban populations can be sustained while both supporting agricultural success and lowering rural and urban poverty. In addition, it is necessary to lessen greenhouse gas emissions and strengthen urban and agricultural development's ability to withstand the effects of climate change (Satterthwaite et al., 2010).

Year of 2007 saw a significant development in the course of world history. For the first time, cities now house more than half of the world's population. In many developing nations, the process of urbanization is also accompanied by rising urban poverty, pollution, food insecurity, and malnutrition, particularly for children, pregnant women, and nursing mothers, as well as rising unemployment. Urban agriculture offers a chance to improve the local economy, social integration, food supply, health conditions, and environmental sustainability as a whole. Urban agriculture exists in many different farming systems around the world. Around 25% to 30% of people live in cities and work in the agro-food industry. Due to the growing urban population and rural-urban migration, urban agriculture will be more widely recognized for its advantages and services (Orsini et al., 2013).

Urban farming has emerged as a response to rising urban food demand, unsustainable conventional agricultural methods, and shrinking arable land. Vertical farming, indoor farming, hydroponics, aeroponics, aquaculture, and aquaponics are examples of urban farming techniques. To achieve their full potential and benefits, these strategies must be combined with technical advancements as they cannot revolutionize farming on their own (Ng & Mahkeswaran, 2021).

Urban areas can access fresh, regional food thanks to urban agriculture. However, consumers' good perceptions of urban farming and their acceptance of urban farms in their neighborhoods are necessary for urban agriculture to be successfully integrated into urban environments. The success of urban agriculture is based on residents' good perceptions of the area, and this view has a significant impact on residents' willingness to accept farming in their immediate vicinity (Grebitus et al., 2020).

By supporting urban farming and increasing urban greenery, numerous urban cities throughout the world are attempting to increase sustainability. It is possible to achieve environmental, social, and economic sustainability for buildings in urban cities by adding green roofs with urban farming because it can improve community functions, help mitigate environmental issues, and help develop urban food systems (Hui, 2011).

4.2. Sustainable Urban Farming

A comprehensive system model that considers the energy and material consumption in vegetable production processes as well as the economic and environmental performance of urban farming systems was utilized in a study on the case of vertical farming in Singapore. The net present value of various urban farming system configurations, as well as cradle-to-door CO_2 emissions, water consumption, and land use, were assessed using the multidimensional assessment model.

Through optimization, the study's farming modules' ideal crop mix and accompanying cultivation set points (such as temperature, humidity, irradiance, illumination time, and CO2 concentration) were identified. They looked at alternative farming methods that used grid-to-grid solar photovoltaic (PV) energy, glass-enclosed and windowless building designs, and food waste composting instead of traditional chemical fertilizers. The findings suggested that combined plant-factory farming systems with solar photovoltaics and fertilizer made from beer residues could be a viable and sustainable farming option for Singapore, a tropical megacity (Li et al., 2020).

In a different study, municipalities are community-focused to ensure the sustainability of Urban Agriculture (UA) continuous investment in initiatives and care. The study explores the challenges and opportunities of sustainable urban farming as an integrated environmental management strategy for improving informal settlements in three case studies in Durban, South Africa. It has become clear that guided processes need to be supported. The study found that in order to manage the food-water connection and strengthen local community structures and groups like cooperatives (including women's groups), policy makers must foster an environment that encourages academics, non-governmental organizations (NGOs), and the private sector to develop water-efficient solutions.

This study, conducted in Malaysia, aimed to look at the finest urban farming techniques appropriate for the urban setting, environment, and culture of the locals. A survey of urban farmers at a chosen community garden in Subang Jaya, Selangor, was used to collect data for the study.

Investigations about the gardening practices and the physical characteristics of the gardens were conducted in the interim. 131 urban farmers from 22 community gardens in Subang Jaya were included in the study sample. It was found that the majority of people's gardens were planted on the ground or in the ground, and that the lower income group's members (83.2%) were those with low monthly family incomes. Urban farmers are most motivated by the social and health benefits. The research demonstrates that the social and health benefits are the main drivers of urban agriculture practitioners. Additionally, it has been noted that the local government has undertaken a number of significant projects, including green initiatives and a cooperative gardening program at community garden locations within the administrative border, to encourage citizens to grow their own food. The availability of resources and good agricultural methods are best practices. If the local government allocates more funds for additional garden area and urban farming, urban farmers may experience increased financial gains (Othman et al., 2018).
The integration of the city and the countryside is regarded as a crucial issue in the development of urban agricultural-recreational areas/activities, according to a study done in Gaziantep, Turkey. For people of Gaziantep, such urban-rural locations and activities are becoming more and more important for recreation. This circumstance, which significantly enhances the local fruit and vegetable output, demonstrates the present leisure model of urban agriculture-recreational activities in Gaziantep. Jobs with a particular focus on agriculture, animal husbandry, and local agritourism have lately been formed as a result of the rising demand for this kind of

urban-rural interaction. Consequently, a concept is evolving wherein families in highly urbanized areas can directly experience rural life, provide leisure activities, and support their lifestyles with a novel concept, wherein urban parks and urban peripheries can be the engine of a self-sufficient city (İnceruh, 2012).

Urban farming is becoming more and more significant in both industrialized and developing nations that are dealing with serious environmental and social issues. Since the 1950s, Turkey has experienced some environmental, social, and economic problems in urban areas as a result of erratic industrialization and urbanization processes. Community gardening, one of the urban agricultural methods, was considered in this study as a strategy for sustainable urban development in Turkey's Izmir Metropolitan area. With the help of two case study locations in Bornova and Buca, the potential of already-existing community gardens was examined in relation to the social, economic, and environmental characteristics of the area. A mixed method approach combines diagramming, interviewing, and historical research. Interviews show that community gardens foster a link between both family members and with other gardeners, which furthers their positive effects. My study's findings show that community gardens contribute to the social and cultural sustainability of an area.

In the same manner, it's crucial to acknowledge that community garden participants save a sizable amount on their grocery expenses when we take their socioeconomic status into account (particularly in the case of the Bornova community garden). This suggests that Izmir's community gardens could potentially contribute to economic sustainability (Vardi Topal, 2015).

5. Conclusion and Suggestions

Sustainability increases its importance as a concept that is used in a very broad sense. Although it is divided into main groups such as social, economic and environmental, it has many sub-concepts that belong to these groups and resemble a tangle of relations. The concept of food safety, which expresses the risk of access to food, and the concept of safe food, which expresses the quality of food, are more important in terms of sustainable agriculture and urbanism. The fact that the population of the city has increased compared to the countryside as of 2007 further increases the importance of the understanding of sustainable urbanism. First of all, the access risk of the people living in these cities to food, and then the quality of the food and their sustainability are possible with agricultural sustainability and more specifically with sustainable urban agriculture. Considering that a large part of the world's population, which is estimated to exceed 9 billion in 2050, will live in settlements called cities, it is obvious that sustainable urbanism and agriculture will be considered more sensitively.

Thanks and Information Note

This e-book chapter complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

The author contributed fully to the article. There is no conflict of interest.

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Asisst. Dr. Nurdoğan TOPAL		
E-mail	:	nurdoğan.topal@usak.edu.tr
Undergraduate	:	University of Ondokuz Mayis, Agriculture Faculty, Field Crops Department (2001)
MSc:	:	University of Ondokuz Mayis, Graduate School of Natural and Applied Sciences, Field Crops Department (2005)
PhD	:	University of Ondokuz Mayis, Graduate School of Natural and Applied Sciences, Field Crops Department (2011)
Professional experience	:	Faculty Member at Uşak University

Wood-Based Circular Bioeconomy in the Building Sector: Impacts, Opportunities and Innovations

Mehtap KOÇ [1]

[1] Istanbul University-Cerrahpaşa, Faculty of Forestry, Department of Forestry Economics, Bahçeköy Campus, Istanbul/Türkiye.
ORCID: 0000-0003-4763-7108
E-mail: mehtap.koc@iuc.edu.tr

Citation: Koç, M. (2023). Wood-Based Circular Bioeconomy in the Building Sector: Impacts, Opportunities and Innovations. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches**. 2023, Chapter: 7, 189-217. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

The building sector is one of the largest industries in the world, responsible for a significant amount of resource consumption and environmental impact. The planetary boundaries, which represent the limits of the Earth's capacity to support human activities, are being exceeded in several areas, including climate change and biodiversity loss. Therefore, it is crucial to focus firstly on this environmental impact of the building sector with the information on how this impact is measurable.

The concept of wood-based circular bioeconomy has emerged as a potential solution for sustainable building. This concept is closely related to other concepts such as green economy, bioeconomy, circular economy, and sustainable development, which not only have significant interconnections with each other but also have important implications for the evaluation of the wood-based circular bioeconomy. Therefore, defining these related concepts and exploring their linkages is essential before delving into the specifics of wood-based circular bioeconomy in the building sector.

Innovations are the primary driving forces behind the transition to a wood-based circular bioeconomy and their evolving networks and main substitute strategies in the building sector must be understood. This book section provides five main sub-topics: the overview of the building sector and its impact on the environment (1.1), the definition of wood-based circular bioeconomy (1.2), the innovations of wood-based circular bioeconomy in the building sector (1.3), various innovation examples from the building sector (1.4) and finally, a conclusion (1.5).

2. Overview of the building sector and its impact on the environment

The two impact classes that are commonly associated with the environmental impact of buildings are embodied impact and operational impact (Heeren et al., 2015; Tirelli & Besana, 2023). Embodied impact refers to the environmental impact associated with the production, transportation, and construction of building materials, while operational impact refers to the environmental impact associated with the ongoing use and maintenance of a building.

The building sector is one of the largest energy consumers and emitters of greenhouse gases globally. According to the International Energy Agency (IEA), Buildings are responsible for 30% of global final energy consumption representing an increase from 115 EJ[1] in 2010 to almost 135 EJ in 2021 and 27% of total energy sector emissions, with 8% being direct emissions from buildings, 19% being indirect emissions from the production of electricity and heat used in buildings, and an additional 6% related to the manufacture of cement, steel, and aluminum used for building construction. In 2021, direct and indirect emissions from building operations rebounded to about 10 Gt[2], which was approximately 2% higher than in 2019 and 5% higher than in 2020. In 2021, energy demand in buildings increased by almost 4% compared to 2020 (or 3% compared to 2019), with electricity accounting for about 35% of building energy use,

[1] EJ, Exajoule is equal to one quintillion (10^{18}) joules and is used specifically to measure very large amounts of energy. For example, global energy consumption is typically measured in exajoules.
[2] Gt, gigaton, which is a unit used to measure greenhouse gas (GHG) emissions. One gigaton is equal to one billion metric tons.

and space cooling seeing the largest increase in demand. Fossil fuel use still increased by 0.7% annually since 2010 (IEA, 2022).

Buildings consume large amounts of energy and contribute significantly to the carbon footprint, as they rely heavily on fossil fuels for heating, cooling, and lighting. The embodied carbon in building materials and construction processes is also a significant contributor to the sector's carbon footprint. Buildings responsible for consuming almost %50 by weight of all extracted materials (Orfanidou et al., 2023).

According to projections, floor area will expand by 20% by 2030, which is higher than the total built floor area of North America. The majority of this growth, about 80%, is expected to take place in emerging and developing economies. As the global population and urbanization continue to grow, the impact of the building sector on the environment is expected to increase unless significant measures are taken to improve energy and material efficiency and shift to renewable energy and fossil substitute sources. But decarbonization of the buildings sector has seen a negative rebound since 2020, resulting in a growing gap between observed performance and desired pathway (UNEP, 2022).

The number of actors measuring the environmental impacts of the building sector and sharing potential future scenarios is increasing, resulting in a growing body of knowledge. However, the information is still limited and Tirelli & Besana (2023) identify drivers for change in the net zero building sector, including economic, legislative and technological factors, and highlight barriers to progress in areas such as economics, legislation, technology, socio-cultural attitudes, professional practices and geography.

Impact measurement is carried out at various scales, including global, national, local, operational or product levels. Nowadays, the most common quantitative techniques used for sustainable measurement are Life Cycle Assessment (LCA) and Material Flow Analysis (MFA), Life Cycle Cost and Input-Output (IO) models and their integrated versions of other related methods (Verstraeten-Jochemsen et al., 2018). These techniques enable a comprehensive analysis of the environmental footprint of the building sector, from raw material extraction to the end of a building's life. The use of these methods is essential for developing sustainable strategies and identifying the most effective interventions to mitigate the environmental impact of the building sector. According to Van Stijn et al. (2021) MFA generally focuses on assessing the quality of resource flows, such as virgin, renewable and recycled materials, as well as the resource consumption of building components. However, life cycle assessment is considered the most well-defined method for analyzing environmental impacts. In addition to the quantitative methodologies, Verstraeten-Jochemsen (2018) offers some qualitative methodologies such as project self-assessment, circular quick scan and expert opinion on societal benefits, impact assessment methodologies for building components based on their Technology Readiness Level (TRL).

The Building sector has led to increased interest on the environmental impacts both embodied and operational, particularly from a life cycle perspective. Currently, there is a significant focus on the potential of the building sector to transition towards a circular bioeconomy, given the environmental impact associated with all life cycle stages of the sector.

This is particularly important as the construction industry is a major contributor to global resource consumption and waste generation. Orfanidou et all, (2022) provides a comprehensive illustration and explanation of the stages involved in building LCA, as outlined in EN15978:2011[3].

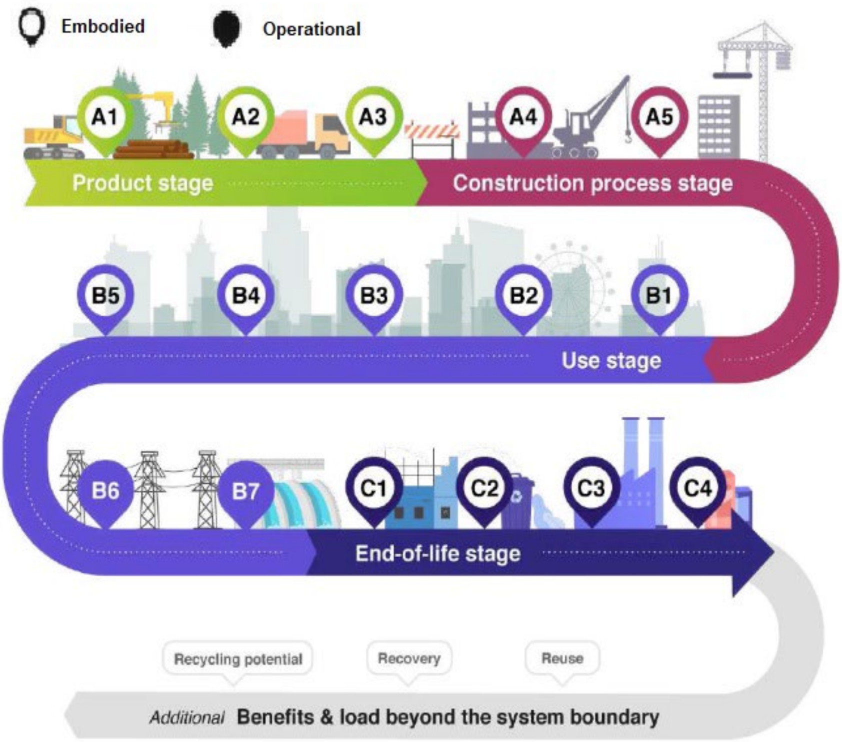

Figure 1. Building life cycle stages based on EN15978:2011 (Orfanidou et al., 2023).

This approach, which includes sub-stages A1-A5 (raw material supply, transportation, manufacturing, product transportation and construction),

[3] EN15978:2011 is a European Standard titled "Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method".

B1-B5 (use stage including application, maintenance, repair and replacement) and C1-C4 (end-of-life stage including demolition, waste transport, and processing), is crucial in providing a complete picture of the environmental impacts of buildings throughout their lifecycle (Figure 1).

Finding ways to reduce the environmental impact of the sector, identifying these different life cycle stages of the building sector is important for comparing different alternatives with LCA research. Comparison of wood building products or construction options with others according to these stages shows that the visible environmental impact can be reduced with wooden alternatives (Orfanidou et all, 2022).

3. Definition of wood-based circular bioeconomy

Circular economy, circular bioeconomy and wood-based circular bioeconomy concepts are interrelated and complementary, as they all focus on sustainability and reducing negative environmental impacts while creating value. Before defining wood-based circular bioeconomy, there is a need to explain each concept separately.

Today, in literature there are many definitions of the circular economy (Kirchherr et al., 2017). One of the most recognized definitions is offered by the Ellen MacArthur Foundation (2016) which states that a circular economy is "restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles ". Another definition comes from the EU Action Plan for the Circular Economy, which defines a circular economy as "maintaining the value of products and materials for as long as possible, minimizing waste and resource use, and keeping resources within the economy by reusing them." (EU, 2018)

The concept of circular economy has been shaped by various academic contributions, including the second law of thermodynamics, waste management policies, extended producer responsibility, industrial ecology and general systems theory. The early stages of the circular economy used technological innovations to turn waste into valuable inputs for other processes. However, political developments such as the Rio Declaration and the 2030 Agenda for Sustainable Development have emphasized the importance of transitioning to circularity for successfully achieving the SDGs[4]. Although reusing or remanufacturing materials and reducing material consumption remain uncommon, the shift towards a more comprehensive approach to circularity is a positive step towards a more sustainable future. According to Aggestam & Giurca (2022) academic contributions such as "Limits to Growth" and "Overshoot," have provided a foundation for the development of the circular economy. More recent contributions such as the "Cradle-to-Cradle" design and the "Performance Economy" have further advanced the circular economy approach.

According to the European Commission: "The bioeconomy covers all sectors and systems that based on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks land and marine

[4] Sustainable Development Goals, which are a set of 17 global goals adopted by the United Nations in 2015 to achieve a more sustainable and equitable future for all people and the planet by 2030.

ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries, and aquaculture); all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy, and services", (European Commission, 2018). The definition and delimitations of the bioeconomy depend on the stakeholders involved, and there are different visions of the bioeconomy that reflect different priorities. These visions include biotechnology vision, bio-resource vision and bio-ecology vision and they are associated with different actors (Bugge et al., 2016).

The focus of the circular economy is on resources of all types, including both biological and non-biological resources such as metals, minerals and fossil fuels. Circular bioeconomy, on the other hand, is a subset of the circular economy that specifically focuses on biological resources, such as biomass, organic waste, and other renewable resources derived from living organisms. The circular bioeconomy aims to capture carbon in the technosphere over the long term and provides additional options to support the decarbonization of the economy, particularly in hard-to-decarbonize sectors such as petrochemicals. The utilization of renewable carbon as a core structural molecule opens up new avenues for various sectors to meet net-zero emission targets (Tan & Lamers, 2021).

Circular bioeconomy is defined as a subset of the bioeconomy that goes beyond the objectives of the circular economy. Solar radiation, CO_2 and water used in agriculture, forestry and marine/fishery all contribute to the biomass flow. It is subsequently processed into food/feed, bioenergy/biofuels, chemicals/materials, and eventually bio-based products. By-products and biowaste are utilized again in cascading and organic recycling to form the circular bioeconomy. In a sustainable circular bioeconomy, the goal is to keep biobased products and by-products in use for as long as possible, maximizing their value and minimizing waste. Recovering energy from them should only be considered as a last resort before sending them to landfills, as it is not a sustainable option in the long run. Instead, cascading use and organic recycling should be prioritized to keep the materials circulating within the economy (Carus & Dammer, 2018).

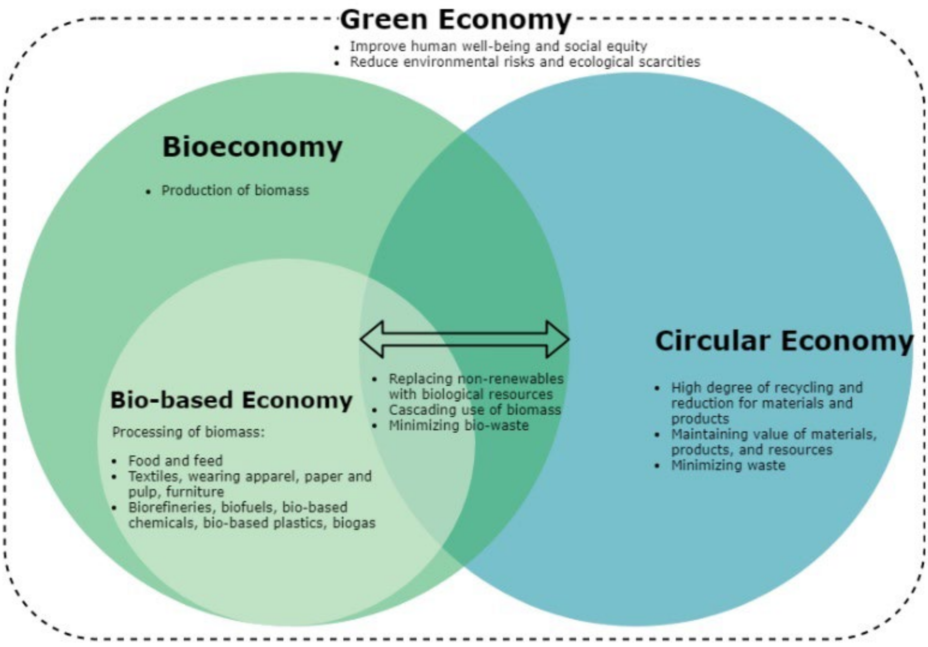

Figure 2. Relations between bioeconomy, bio-based economy, green economy, and circular economy (Kardung et al., 2021).

Kardung's (2021) work illustrates (figure 2) the relationships among green economy, bioeconomy, circular economy and bio-based economy, highlighting their interconnectedness and mutual influence. As commonly stated in literature, the green economy is an umbrella concept that promotes low-carbon, resource-efficient, and socially inclusive growth (Loiseau et al., 2016; D'Amato et al., 2017; Birner, 2018; Kardung et al., 2021) and it encompasses various sub-concepts such as circular economy, bioeconomy, and biobased economy. From the figure, it can be seen that the wood-based circular bioeconomy is located at the intersection of both circular economy and bio-based economy, indicating that it draws upon the principles and practices of both concepts.

Under the condition of extraction from sustainable forest management, wood as a raw material is an important input for the circular bioeconomy due to its high substitution effect (potential to replace many fossil-based products) and it does not compete with agricultural fibers in the food sector. Cascading use of wood, which involves maximizing the value of wood by using it for multiple purposes before final disposal, has the potential to further enhance the sustainability of the wood-based circular bioeconomy (Mantau, 2015; Campbell-Johnston et al., 2020; Besserer et al., 2021). There are various circular strategies to reduce the consumption of natural resources and materials and minimize waste production. This strategies hierarchy, known as R0-9 (Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover), and according to Potting (2017), their contribution to circularity, is expressed in terms of high circularity strategies and low circularity strategies.

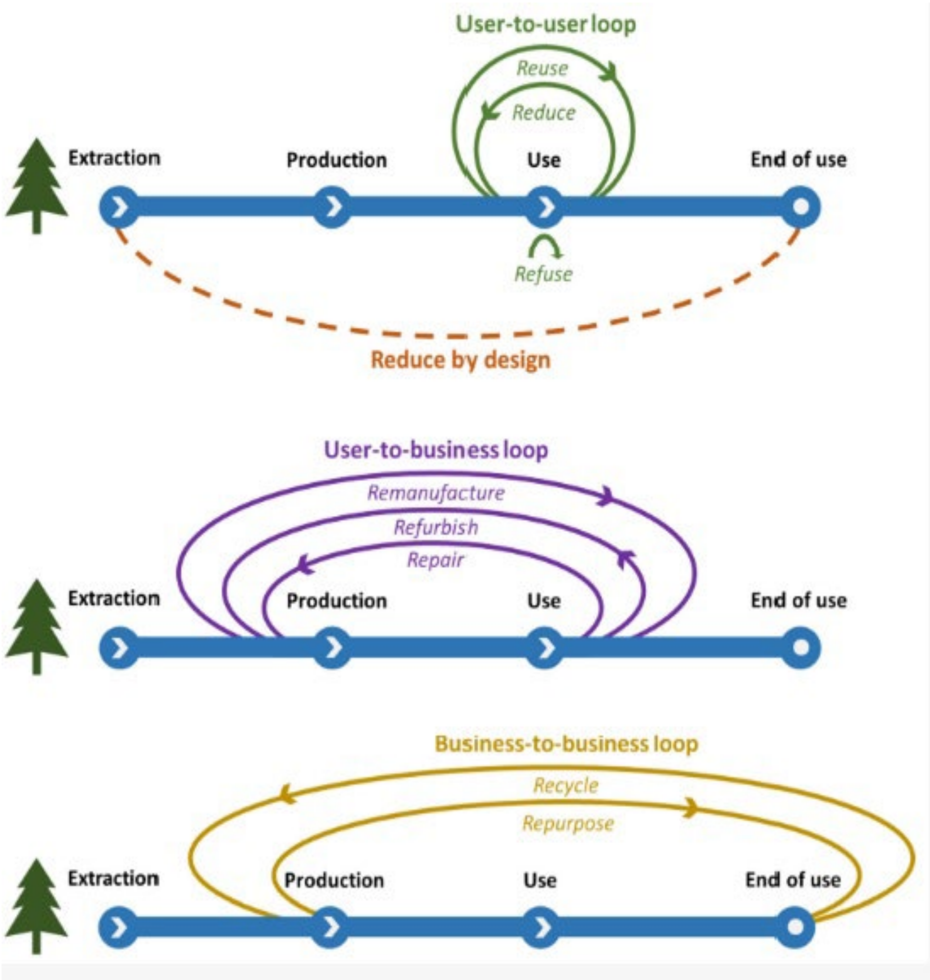

Figure 3. Circular economy model, covering value retention loops and guiding principles (Aggestam & Giurca 2022).

Aggestam & Giurca (2022) provide a guideline, characterized in Figure 3 as three value retention loops of wood material and highlight that circularity can be achieved within the respective loops like user-to-user, user-to-business, and business-to-business. Their study also focuses on the value chain analysis of wood from extraction to end of use in five sectors one of which is the construction in building sector. The circular bioeconomy involves both new and existing sectors, and understanding industrial life cycles is important for managing the transformation process and preserving value through innovation (Lewandowski, 2018). From this point, a wood-based circular bioeconomy has the potential to revolutionize the building sector. Innovation in this area is crucial for achieving climate target and can help the building sector transition toward a more sustainable and environmentally-friendly future.

4. Wood-based circular bioeconomy innovations in the building sector

Wood is a renewable resource that can be grown and harvested sustainably, making it a more environmentally friendly and biodegradable alternative to traditional building materials such as concrete, steel and some fossil-based insulation materials. The use of wood in building construction is not a new concept but with the advent of product, process, operation and social innovations this potential of a wood-based circular bioeconomy in the building sector extends beyond just reducing carbon emissions and waste. It can also provide economic benefits by creating new jobs and promoting local, sustainable forestry practices. Also, wood buildings provide solutions for sustainable urbanization and a circular bio-based economy (Toppinen et al., 2018). To drive the wood-based circular bioeconomy transition across various sectors, integration across value and supply chains, knowledge, education, awareness, certification, quality standards and labeling, policy frameworks, and innovation and technological development are cross-cutting factors (Aggestam & Giurca, 2022). The

New European Bauhaus (European Commission, 2020) initiative of the EU acknowledges the potential of wood as a sustainable and adaptable building material that can contribute to a more sustainable and circular economy. This initiative presents an exciting opportunity to integrate design, sustainability, and innovation.

Wood building systems, construction materials and wood composites have perceived as the most innovative products in the forest sector since the year 2000 in several EU countries (Stern et al., 2018), besides country-specific cultural differences (Viholainen et al., 2021) research for Slovak consumers address the need for marketing strategies for wood buildings should consider requirements such as construction type, fire safety, housing costs, quality, thermal insulation properties, and lifetime (Loučanová & Olšiaková, 2020). According to Hassegawa (2022), the adoption of wood construction systems varies greatly across different countries and regions. The Nordic countries have seen stronger development in this area while developing countries still consider wood as an old-fashioned construction material.

In the context of circular bioeconomy transformation of the building sector, a network of innovators and recipients, including User to User (U2U), User to Business (U2B), and Business to Business (B2B) collaborations, can lead to the emergence of various types of innovation. (Aggestam & Giurca, 2022) also define these networks as value retention loops and gives some circular approaches specifically for building construction in Table 1.

Table 1. Value retention loops and some circular approaches for the building sector (Aggestam & Giurca, 2022).

User-to-User
• Design for wood in place longer. • Changing the mindset of people about different (and longer) ownership. • Make new housing models more available for consumers, such as housing co-operatives.
User-to-Business
• Design for combined manufacture and assembly and disassembly. • Keep wood life-cycle phases in mind and need to from sustainably managed forests. • Change the construction sector's business models to recover systems, components, and materials. • Systemic developments for sorting, separation and recovery to recycle as efficiently as possible at end-of-life.
Business-to-Business
• New approaches to value chain management to integrate sustainable thinking into supply chains. • Enhance efforts to decrease emissions, implement efficiency in material design, and eliminate material waste at the design stage. • Integrate smart design, considering system design, construction techniques and building service technologies and re-assembly wooden buildings. More efficient use of side products. • Stronger collaboration between business ecosystems (e.g., municipalities, architects, designers, builders and end-users).

Before review about some existing innovations in the building sector such as Oslo Manual grouping such as product, process, marketing and organizational (OECD, 2018) and between some of them social innovation, table 2 provides some quick scan value creating strategies (refuse, rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, recover) for wood and wood related products and services in the building sector.

Table 2. Value Creating Strategies (9R) In Circular Bioeconomy and examples for wood in Building Sector.

R0-9 Strategies	Explanation for Wood Materials in Building Sector	Examples
Reduce	Refusing to use non-sustainable or non-certified wood products. Reducing the amount of virgin wood used, efficient use of materials.	Promoting the use of certified wood products. Designing buildings with smaller wood framing, using engineered wood products.
Reuse	Finding new uses for wood materials that would otherwise be discarded.	Salvaging and reusing wood from demolished buildings or repurposing wood scraps as firewood or mulch.
Refurbish/ Remanufacture	Repairing or upgrading wood components to extend their useful life.	Refurbishing wood floors or wood paneling to give them a new look.
Repurpose	Using wood materials for a different purpose than originally intended.	Using reclaimed wood from old buildings to create new furniture or decorative features.
Redistribute	Donating or selling wood materials that are still useful but no longer needed.	Donating excess wood materials to charitable organizations or selling them through marketplaces.
Re-manage	Managing wood waste in a more sustainable manner, such as through composting or recycling.	Implementing a wood waste management plan that includes sorting and recycling wood waste materials on the construction site.
Rethink	Challenging assumptions and changing behavior to reduce wood waste in the building sector.	Encouraging the use of sustainably sourced wood products.
Recover	Extracting value from wood waste materials through processes such as composting or anaerobic digestion.	Composting wood waste from construction sites to create soil amendments for landscaping.
Recycle	Turning waste wood materials into new products.	Recycling wood waste to create wood pellets or wood chips for biomass energy production.

5. Innovation examples in the building sector

In building sector well known product innovations are Engineered Wood Products (EWP) and some examples are edge-glued panels (EGP), glued-laminated timber (Glulam), cross-laminated timber (CLT), laminated veneer lumber (LVL), laminated veneer products (LVP), high-pressure laminated veneers (HPLV), low/medium/high density fiberboards (LDF/MDF/HDF), parallel strand lumber (PSL), oriented strand boards (OSB), laminated strand/scrimbed lumber (LSL) and wood plastic composites (WPC) (Klarić & Obučina, 2020). EWP enables high-rise construction and prefabricated building project innovations.

In building sector besides EWP, biocomposites and bioplastics made from wood can be a different group of product innovations. Wood-based bioplastics are being explored as a sustainable alternative to glass in windows and can offer improved thermal insulation and reduced weight compared to traditional glass, while also being biodegradable and renewable. Transparent Wood (TW) is also an innovative and energy-efficient alternative to glass in building construction and Wang et al. (2018) highlight it by discussing its potential, current production limitations and the benefits of a new fiber-based method for large-scale production with excellent thermal insulation properties. There are also some other wood-based insulation materials, like wood foam are an eco-friendly and renewable alternative to non-renewable thermal insulation materials, offering benefits such as lower embodied energy and high hygroscopicity for better humidity control in building applications (Palumbo et al., 2018). Verkerk et al. (2022) give market status and enabling factors for some innovative wood products for promoting the circular bioeconomy.

Process innovations happening in production process for example in figure 4, CLT involves using smaller, lower-grade pieces of wood that would otherwise be considered waste, making it a more sustainable option than traditional building materials. However, besides product process innovations, advanced wood construction techniques are another example of process innovations in the building sector. These techniques aim to improve the efficiency and sustainability of the construction process by using innovative methods and technologies to reduce waste, increase speed, and lower costs.

Figure 4. Cross-Laminated Timber (CLT) Panels Detail and Examples of Usage in Construction.

Wood construction processes can vary and there are different methods used in the building sector. On-site building refers to constructing a building from the ground up on the actual site where it will stand.

Prefabrication, on the other hand, involves the construction of parts of a building in a factory or workshop, and then transporting these prefabricated elements to the building site for assembly. The different construction processes, such as on-site building, prefabricated, or modular, can trigger the need for product, process and organizational innovations to optimize the construction process, reduce waste and increase efficiency.

Post-and-beam construction and light-frame construction are two different building techniques that use different types of structural framing.

Innovation in building structural systems has led to advancements in both post-and-beam and light-frame construction methods as seen in figure 5. For example, there are now EWPs available that allow for longer spans and greater load-bearing capacities in light-frame construction. In post-and-beam construction, new connection systems and material options have expanded the design possibilities while still maintaining the traditional look and feel. Both of them can also allow the integrated use of wood and other materials like concrete, glass. Post-and-beam construction is often used in high-end residential and commercial buildings, where a traditional or rustic look is desired. Light-frame construction, on the other hand, uses prefabricated wood or metal framing members to create the structural framework of the building, including walls, floors, and roofs. In light-frame construction, the walls themselves provide the structural support, and the framing members are typically smaller in size and spaced closer together than in post-and-beam construction. This method is more economical and faster to construct than post-and-beam construction and is commonly used in residential and low-rise commercial buildings.

Light-frame construction

Post-and-beam construction

Figure 5. Construction structural systems

Building Information Modelling (BIM) can be classified as both an operational and process innovation, has been recognized, particularly in the processes of design, performance assessment, visualization, management, and, more recently, operations and maintenance. With the Internet of Things (IoT), and data analytics technological development solving implementation barriers in wood construction projects (Gharaibeh et al., 2022), specifically BIM for wood-based modular residential buildings (Alwisy et al., 2019).

The University of British Columbia's Brock Commons dormitory in Vancouver (Figure 6), is a prime example of the wood building sector's collaborative design and decision-making approaches. The dormitory, standing at an impressive 53 meters high, is the tallest mass timber building in the world, built for 400 students. An excellent example of how product, process, organizational and marketing innovations can work together to achieve sustainable and innovative outcomes in the building sector. In terms of process innovation, the project utilized advanced construction techniques to efficiently and safely build the timber building. As for organizational innovation, the project utilized a collaborative design and decision-making approach that involved all stakeholders in the wooden building process, including end-users. By incorporating marketing innovation, particularly social marketing, into the dormitory project, the decision-making process can include not only the needs and preferences of the building's occupants and environmental sustainability but also address the social impact and benefits for the community at large. Social marketing can help promote social change by leveraging marketing principles to encourage people to adopt behaviours or attitudes that are beneficial to society as a whole.

Figure 6. The University of British Columbia's Brock Commons dormitory in Vancouver.

Social innovation examples in the building sector include new approaches to community engagement and participation in the building process, such as co-design and co-build projects. There are also innovative approaches to social housing that use wood-based circular bioeconomy practices to address affordable housing and social exclusion. Additionally, new approaches to education and training can equip the building sector workforce with the skills and knowledge needed to embrace circular bioeconomy practices. Some social innovations, in holistic view, use wooden buildings as main criteria for sustainable business models. For example, "Ecobnb" which started as a European Project and offers a platform for booking eco-friendly accommodations, which may include wooden buildings that are designed to be energy-efficient and environmentally friendly (Ecobnb, 2023). Community-based reuse is a type of social innovation. Instead of disposing of building materials, they can be repurposed for community-based projects. For example, the ReBuilding Exchange (2023) in Chicago collects donated building materials and uses them to train local residents in construction skills, while also providing affordable materials to community members.

6. Conclusion

The building sector presents both opportunities and limitations for reducing environmental impact, with innovations in sustainable materials and circular approaches to design having the potential to make a significant contribution towards achieving climate goals. The building sector is complex and interconnected and plays a significant role in driving the transition towards a circular bioeconomy. However, the rate of transformation in the industry is often slow due to various factors such as the complexity of the sector, regulatory and legislative barriers, and resistance to change within the industry itself. While the wood-based circular bioeconomy presents a range of possibilities, there are also certain limitations that can impact the speed of transition. These include the need for sustainable forest management practices to ensure the availability of wood resources for the long-term, as well as the certification and standardization of wood building components to ensure quality and safety. Knowledge sharing is also crucial as stakeholders need to be informed about the benefits and possibilities of wood-based circular bioeconomy practices. Furthermore, consumer attitudes towards sustainable building practices can also influence the pace of transition. Overcoming these limitations will require collective action and collaboration between policymakers, industry leaders, and consumers, as well as increased investment in research and innovation.

Thanks and Information Note

This e-book chapter complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

The author contributed fully to the article. There is no conflict of interest.

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Mehtap Koç		
E-mail	:	mehtap.koc@iuc.edu.tr
Undergraduate-1	:	İstanbul University, Faculty of Forestry, Forest Industry Engineering (2007)
Undergraduate-2	:	İstanbul University, Faculty of Forestry, Forest Engineering (2007)
Undergraduate-3	:	Anadolu University, Open Education Faculty, Business Administration (2018)
MSc	:	İstanbul University, Institute of Science, Department of Forestry Economics (2016)
PhD	:	İstanbul University-Cerrahpaşa, Institute of Graduate Studies, Department of Forestry Economics (ongoing)
Professional experience	:	Faculty Member at İstanbul University-Cerrahpaşa-Faculty of Forestry

Demolition Stories and the Role of Architects

Dr. Ezgi NİZAMOĞLU [1]

[1]Usak University, Faculty of Architecture and Design, Department of Architecture, Usak/Türkiye.
ORCID: 0000-0003-2592-3293
E-mail: ezgi.nizamoglu@usak.edu.tr

Citation: Nizamoğlu, E. (2023). Demolition Stories and the Role of Architects. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches**. 2023, Chapter: 8, 218-233. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

Buildings are dismantled/demolished due to reasons such as completing the useful life of the buildings, losing their function by not meeting the user's needs, becoming unusable due to damage after disasters such as fire and earthquake, and decisions to eliminate building/building groups.

In the resources researched, there are various definitions of the concept of dismantling/demolition. While demolition is the process of separating the building products from the building without damaging them for recycling and reuse, demolition is the process of voluntarily destroying the building (Shami, 2006). Deconstruction is a method that is employee-oriented and uses very little mechanical equipment, allowing the recycling of disassembled products and non-reusable products. Building demolition, on the other hand, is a process that reduces the reusability of building products and increases the amount of waste that needs to be destroyed by bringing the building to the ground, in contrast to dismantling (Tingley & Davison, 2011).

The decision to demolish a building is rarely straightforward. There are many actors involved in a demolition debate, each with its own interests and conflicting agendas. The familiar dichotomy between preservation and demolition as two clear courts of "for" vs. "against" is an oversimplification of the nuanced processes around demolition and redevelopment.

In this context, within the scope of the study, the reasons for the demolition of the building, the actors involved in the demolition discussion of the building, and the role of the architects in this process were examined.

2. Material and Method

In this article, first, the reasons for the demolition are analyzed. The analysis is based on the type of obsolescence, specific reasons for demolition, and the actors involved in the demolition discussion of the buildings. Then the role of the architect in the demolition process in some unique case studies in the United States is investigated and suggestions for architects to follow in this process are determined.

3. Findings and Discussion

The main reason for building to demolish is the obsolescence of the buildings. And the reasons for the obsolescence are classified as obsolescence by site, and obsolescence by the program.

3.1. Obsolescence by site

The obsolescence by site can be classified as devaluation, upsizing, and expendable.

3.1.1. Devaluation

The progressive depreciation and demolition of building stock, when long-term inactivity and lack of care result in collapsing physical envelopes and decaying streetscapes, frequently highlights city-wide trends of urban disinvestment that impact many American communities. To create room for future construction that never materializes, foreclosed homes that have been turned over to banks and lenders are frequently destroyed, creating a series of gaps in the urban environment (Yoshida, 2016).

3.1.2. Upsizing

An existing building is often demolished and then replaced with a higher-density construction. Usually linked to a rise in the site's real estate value, which gives the developer a financial incentive to build more rentable apartments. Just 22% of the 227 demolished buildings in North America in 2004 were destroyed because they were "no longer appropriate for intended use," according to a study for Forintek Canada Inc on the reported life lengths of these structures. Larger replicas of themselves were used to replace most of these cases (O'Connor, 2004).

3.1.3. Expendable

A disposable attitude towards an architecture that favors buildings with relatively short lifespans designed to be superseded. Typically, prevalent in cultural contexts centered around notions of impermanence, or volatile building climates marked by frequent changes to codes and standards. For instance, a single-family home in Japan has a 22-year lifespan. This is caused by several things, including constantly revised seismic rules, a propensity to utilize lighter, more readily disassembled construction materials, and expensive land taxes (Alexander, 2021).

3.2. Obsolescence by program

The program of a structure is one of the best indicators of how long it will last. From the politically driven to the blatantly utilitarian, the ability of a structure to carry out its intended purpose over time can give rise to a range of drastically varied explanations for why it could lose its worth.

Reasons for obsolescence by program can be classified as economic, functional, personal, iconic, and communal.

3.2.1. Personal

Changes in real estate value which can be seen as fluctuations in land value as the result of large-scale changes to the surrounding neighborhood context and pressure for redevelopment, and vacancy which can be seen as deterioration of physical fabric resulting from prolonged periods of vacancy and/or neglect. At some point, it becomes cheaper to rebuild than to repair, even if it is in a good neighborhood and the land it sits on is still valuable can be described as personal reasons (Odell, 2019).

3.2.2. Communal

Lack of funding for systemic maintenance, in particular of the building's shared facilities: corridors, elevators, mechanical systems, etc. makes the building not functional. And the building's fate is dictated by top-down political agendas and real-estate pressures far beyond the control of the residents, who often have little to no voice in demolition debates, and government policy determines that. These can be described as communal reasons (Shah& Kumar, 2005).

3.2.3. Economic

Under-performing architectural or mechanical systems that cannot keep up with current code requirements, or the building's evolving functions, building elements such as elevators, HVAC systems, asbestos insulation, etc. can be difficult and costly to replace or remove, making it more economical to demolish the entire building. Inflexible architectural layouts are difficult to adapt to keep up with the fleeting trends and demands of commercial office and retail interiors. Factors such as lack of rentable square footage or insufficient window displays were some of the main factors behind the demolition of many late 19th-century department stores in New York and Chicago. Fluctuations in land value as the result of larger scale changes to the surrounding neighborhood context create pressure for redevelopment. These can be described as economic reasons (Longstreth, 2006).

3.2.4. Iconic

Preservation practices often foreground the historic value of a building: tied to its relationship to important events, places, and people. As historical records are updated, and re-written, new building typologies are added to the list, while others are removed. Icons serve as the public face of the institutions they house, from private companies to political or religious organizations. As such, architectural value is constantly reassigned throughout the building's lifetime with shifts in ownership, political climates, and public perception. Architectural value is often derived in part from the building's association with a famous architect or architectural movement, and in part from its reception by the public. The fleeting nature of cultural and aesthetic trends leads to a constant reassessment of what society choose to preserve and demolish. These can be described as iconic reasons (Bianco, 2017).

3.2.5. Functional

Institutional buildings like schools and hospitals often have highly specific floor plans that relate to their daily operations. This can lead to inflexible layouts that are difficult to adapt as the practices and spatial requirements of these institutions evolve. Under-performing architectural or mechanical systems that cannot keep up with current code requirements, or the building's evolving functions. Building elements such as elevators, HVAC systems, asbestos insulation, etc. can be difficult and costly to replace or remove, making it more economical to demolish the entire building. These can be described as functional reasons (Schultmann & Kohler 2011).

3.3. Case Studies of architects' intervention in demolition stories

3.3.1. A Way, Away

A vacant piece of land and a nearby structure at 3721 Washington Boulevard that had been razed in April 2017 were both brought to life by the project. Chicago-based artists Amanda Williams and Andres L. Hernandez worked on the project with architecture students and locals. Over several months, the multi-phase project came to fruition, starting with the painting of the building gold before demolition, then modifying the topographical contours of the landscape, and lastly regenerating the green space. Building demolition materials that were saved have been given new life through community design initiatives. The artists asked citizens to pause and consider the life cycle of the urban landscape by choreographing the process in this way. The title of the project, which is supposed to symbolize the cycle of loss and transition that defines the built environment, is inspired by traditional blues music themes about hope and unrequited love. The 2017 production of A Way, Away (Listen While I Speak) ran from April through October. It was located across the street from the Pulitzer Arts Foundation at 3713–3721 Washington Boulevard in St. Louis, Missouri (Hernandez & Williams,2017).

The workflow of the project consists of 5 phases which are marking, subtracting, translating, shaping, and healing. In the marking phase, local architecture students and residents get involved in painting the wall with gold color as a way of rebranding the material. Then, after the building comes down subtracting phase is starting. In this phase, artists and volunteers assemble the pieces they decided to take to the next phase. The next phase is translating in which the building is returned to its material parts, and the bricks are cleaned, sorted, and stacked, to be given to local community groups for design projects. Then in the shaping phase, a green clearing is created by shaping the land and planting grasses of varying shades and opening the site to new possibilities. The last phase is healing. In this phase, four local projects were chosen to receive the bricks from the original building. These projects act as small structures across the city, retaining the memory of the previous function and continuing their storied life in a new form (Figure 1).

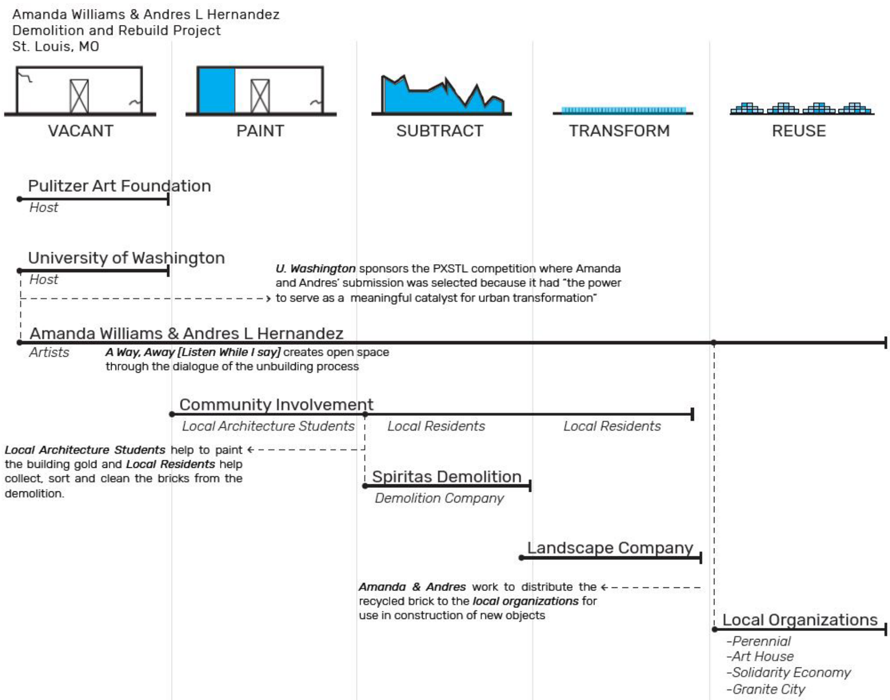

Figure 1. Workflow of A Way, Away project (Emily Cannon, 2018).

3.3.2. Stony Island Arts Bank

The bank at 68th and Stony Island, designed by William Gibbons Uffendell, was formerly a thriving neighborhood saving and loan. The renovated Stony Island Arts Bank now offers 17,000 square feet of space on Chicago's South Side for cutting-edge contemporary art and archive practices. Stony Island offers a variety of events, such as Arts Bank Cinema, a free weekly screening and discussion of films by and about black people, as well as exhibitions curated by and in collaboration with local artists (Gates, 2019).

The workflow of this project consists of 3 phases which are fundraising, renovating, and engaging. In the first phase of the project, the architect Theaster Gates removes the valuable pieces of marble in the building and engraves them with his stamp to take to Art Basel to sell for fundraising. Money from the bond sales is used for renovating the building. Then in the renovation phase, Illinois Historic Preservation Agency, Rebuild Foundation, and Fitzgerald Associates collaborate to help streamline the design and renovation process of Stony Island State Savings Bank. Then in the engagement phase, the architect and his Rebuild Foundation work together to select the Local Organizations to become permanent tenants and the temporary installations that use the building (Figure 2).

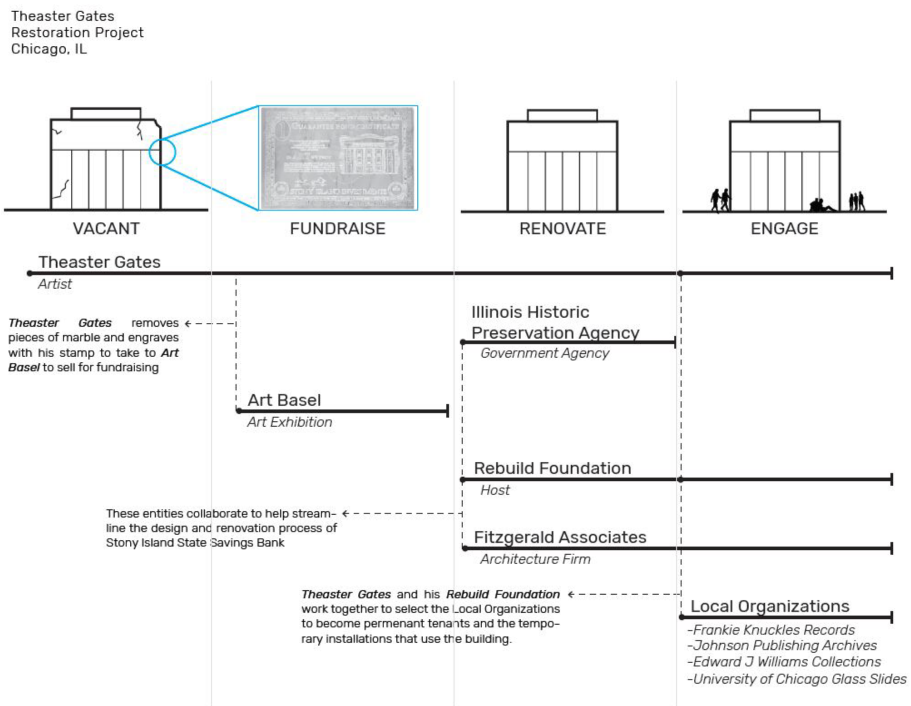

Figure 2. Workflow of Stony Island Arts Bank project (Emily Cannon, 2018)

3.3.3. Holding Pattern

The 2011 Young Architects Program project from Interboro Partner is called Holding Pattern. It is about recycling and developing ties between a large, influential institution (MoMA PS1) and the local community.

The idea behind the project was that the team could create objects that local businesses would require. Studio asked over 50 local organizations what they needed, designed and built these objects, and held them at MoMA PS1 for the summer (Holding Pattern Newspaper, 2011).

The workflow of this project consists of 3 phases which are source, display, and distribute. In the first phase of the project, Interboro Partners was selected for the installation through the PS1 Competition that is hosted by MoMA, which is a chance for young architects to present innovative projects. Then the studio reached out to the surrounding Community Organizations to determine what they needed to integrate into their installation. In the display phase, Interboro Partners obtains some of the objects from architectural salvage stores and materials to make the remaining objects from local reuse stores. Then in the distribution phase, the studio reaches back out to the Community Organizations to coordinate the delivery of the objects on hold (Figure 3).

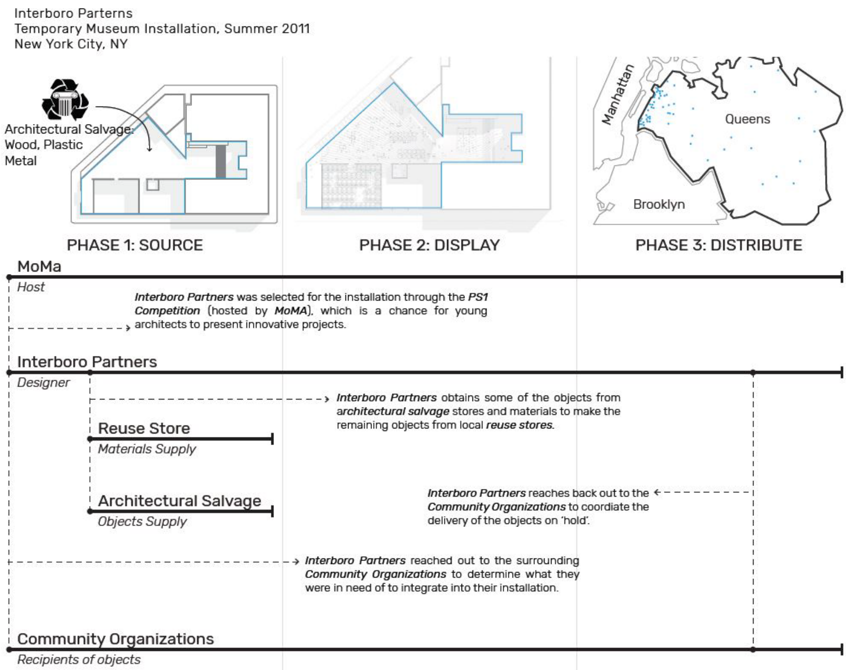

Figure 3. Workflow of Holding Pattern project (Emily Cannon, 2018).

4. Conclusion and Suggestions

This study examined the level of the task in the demolition and reusing processes of the buildings by the architects. It is thought that this work will guide the authorities about the necessity of certain steps which are followed by architects who take on the task of demolition projects. The suggestions about the process for architects who want to be included in the demolition and reusing processes are as follows:

1. The local community, young architects, and architecture students should be involved in the dismantling, and reuse phase of the process to understand the need of the community and train future designers to demonstrate to them the importance of the process.
2. Design meetings should be held with locals to share needs and suggestions about how new life can be given to saved demolition materials for the community.
3. Saved demolition materials should be cleaned, sorted, and stacked carefully to be given for reusing.
4. If the building will be dismantled completely after the dismantling vacant land should be taken care of by designing the landscape to open the site to new possibilities.
5. There should be a contribution with local projects to reuse the materials which are saved after dismantling to retain the memory of the previous function and continue their life in a new form.
6. The building should be carefully investigated to see if there is any valuable part that can be re-evaluated.

7. There should be a collaboration with the historic preservation agencies to help streamline the design and renovation process.
8. Architects should work with the architectural salvage stores to help sustainability.

Thanks and Information Note

The e-book section is the result of a master's level research studio at Northeastern University that took place in fall semester, 2017, and the spring semester, 2018. Project Credits: Ezgi Nizamoğlu, Emily Cannon, Ben Garbow, Yan Qiu He, John Rinaldi, Angela Shi, Danny Sweeney, Kevin Tremblay, Emily Weiser, and Karen Yeung.

The e-book section complies with national and international research and publication ethics.

Author Contribution and Conflict of Interest Disclosure Information

The author contributed fully to the article. There is no conflict of interest.

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Dr. Ezgi NİZAMOĞLU		
E-mail	:	ezgi.nizamoglu@usak.edu.tr
Undergraduate	:	Architecture, Okan University, Turkey
MSc	:	Architecture, Northeastern University, USA
PhD	:	Architectural Technology, Florence University, Italy
Professional experience	:	Dr. Lecturer, Usak University, Turkey

Software Used in Climate-Sensitive Spatial Planning and Design: PET, SVF, ENVI-met Software, UrbClim Model

Prof. Dr. Sevgi YILMAZ [1]

[1]Atatürk University, Faculty of Architecture and Design, Department of Landscape Architecture, Erzurum / Türkiye
ORCID: 0000-0001-7668-5788
E-mail: sevgiy@atauni.edu.tr, syilmaz_68@hotmail.com

Citation: Yılmaz, S. (2023). Software Used in Climate-Sensitive Spatial Planning and Design: PET, SVF, ENVI-met Software, UrbClim Model. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches**. 2023, Chapter: 9, 234-271. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

With the global climate crisis affecting the entire world, the interaction between planning and urban climate has become increasingly important. The concept of climate, which is defined by the Turkish Language Association as "the long-term state of the effects that occur depending on weather conditions at any location on Earth," is now associated with words such as crisis, change, and problem. In order for cities to minimize the negative effects of climate change and become sustainable, they must adapt to these changes and use spatial planning as a tool in this process (Carter et al., 2015).

According to United Nations data, urbanization rates are rapidly increasing worldwide. The global urban population increased from 751 million in 1950 to 4.2 billion in 2018, a 4.6-fold increase. It is estimated that this number will continue to rise and reach 6.4 billion by 2050 (UN, 2019). As a result of this population growth in urban areas, the demand for housing is also rapidly increasing. The city, which is a comprehensive phenomenon, is responding to this demand by increasing its construction and its hard and impermeable surfaces every day (Chandan et al., 2019; Bharath et al., 2019). Non-nature-based urban planning inevitably leads to increased energy consumption, air pollution, economic damages, increased impermeable surfaces, decreased green areas, and consequently, the increase of low-standard urban spaces (Topcu & Girgin, 2016; Liu et al., 2017; Huang et al., 2021).

The concept of space is given different meanings in planning disciplines such as modernist architects, post-modernist architects, designers, philosophers, landscape architects, etc. However, regardless of the scale or the discipline in which the concept of space is addressed, it should not be overlooked that the determining element that defines space is humans. In this process, the characteristics of the urban climate must be taken into account during planning and design stages. Studies aimed at increasing the spatial belonging of individuals in human-centered space designs are directly related to space quality. Although climate is only one of the parameters that affect space quality, it should be given priority in all planning decisions and physical constructions (Yılmaz, 2020).

William Shakespeare's quote "Nature's bequest gives nothing but doth lend" should never be ignored. To produce sustainable, ecology-based, livable spaces by taking the existing resources in the environment that hosts many living and non-living beings out of the focus of consumption and to offer enjoyable spaces for every living being, thereby contributing to the environment that hosts; it is necessary to take a step towards a sustainable future with climate-based design approaches (Yılmaz, 2020) by supporting spatial designs with micro-climate-focused solutions. However, due to many reasons such as neglecting natural values, rapid physical construction, and insufficient interprofessional organization, climate data is not given enough importance in urban planning and design. In urban ecosystems, not only humans but also all living beings' climate parameters should be taken into consideration for their living spaces.

The concept of climate should be included in the planning and design stages, and various data such as urban climate maps, urban thermal comfort maps, and urban climate modeling and simulation maps should be used to integrate climate considerations into the planning process (Balık and Duman Yüksel, 2014; Dursun et al., 2020; Dogan et al., 2023; Cetin et al., 2023). Urban design approaches that respond to the topography, climate, and the needs of living creatures while taking into account users' spatial affiliations and listening to the sounds of the space should be at the forefront. Cities are frequently faced with the risks and threats brought about by climate change, which are influenced by various factors such as geographical, climatic, economic, sociological, and more. It is expected that cities will continue to face the negative consequences of climate change in the future. Climate and urbanization are intertwined, and as much as climate affects cities, cities also affect the climate. For example, urbanization leads to various changes within the current system. Studies are being conducted under the concept of urban climate to express the impact of climate change, climate atlas, thermal comfort maps, urban design scenarios, and changes in the water cycle. It is necessary to emphasize the importance of using data that supports studies with different methods and incorporating them into spatial planning. Researchers working in this field state that the built-up areas of cities and the surrounding areas of the city undergo changes in terms of climate. The rapid decrease in land surfaces (open-green areas, agricultural areas) due to urbanization affects the temperature difference between night and day. The changing temperature difference brings about problems such as fog formation, reduced air movement, and disruption of plant texture (Bakan & Konuk, 1987). The temperature difference between urban and rural areas varies depending on the characteristics of the area under study, but it is generally between 4-6°C. There are many studies indicating that rural areas are always cooler than cities (Oke, 1987; Toy & Yılmaz, 2010; Connor et al., 2013; Yilmaz et al., 2021a).

Urban areas, which cover approximately 2% of the earth's surface, constitute an important source of environmental problems (Gago et al., 2013). Since the mid-20th century, academic studies on investigating and taking measures against these problems have rapidly increased. Rapid and unprepared urbanization, haphazard construction, non-purposeful land use, decreasing green areas, and increasing impermeable surfaces in urban areas have exacerbated the Urban Heat Island (UHI) effect. It has been determined that the UHI effect has progressed to dimensions that negatively affect not only energy issues but also the lives of living beings (Santamouris, 2016; Oke et al., 2017; Yucekaya and Uslu, 2020; Enteria et al., 2021; Bozdogan Sert et al., 2021; Menteş et al., 2023). To reduce urban heat islands, it is necessary to consider the urban climate in every space designed or intervened in cities. Spaces designed based on climate data also increase spatial quality. Successfully and accurately interpreting and communicating climate data also enables users to use outdoor spaces. Nowadays, in areas affected by rapid construction, migration, and unplanned and uncontrolled growth, climate data is not given enough importance. However, every space designed based on topographical structure and climate data contributes to sustainable land use. Planning based on topographical data in urban spatial analysis directly affects user comfort. Concepts such as topography, wind, sunlight, and humidity directly affect spatial comfort and therefore, space users. Constructions designed based on climate data are examples of achieving comfort conditions without using technology (Rapoport 1969, 2006). The climatic information of regions is determined through meteorological studies. Within the scope of these studies, various data such as the average rainfall amount for each month, the average number of sunny hours, the average number of days of drought, the percentage of humidity throughout the year, wind direction and speed are obtained (Beer, 1990). Every designed and inhabited space is closely related to this data and should be considered as a priority in design criteria. The concept of climate, which is not adequately emphasized today or cannot be fully implemented, has been successfully dealt with in primitive societies in the past. Examples of building materials with high heat capacity such as adobe, mud, and structures that are positioned according to the wind and protect each other, surface openings that vary according to the temperature during the day, and the relationship between water and structure can be seen. Spaces shaped according to the climate region have also played a role in the formation of urban identities.

Architectural development shaped by the climate of the area where it is located has led to increased spatial comfort and the emergence of motifs specific to the region. In the Southeast Anatolia region, courtyard architecture strengthens the relationship between the interior and exterior, while in cold climate regions, a more compact architectural design is preferred to minimize heat loss. However, nowadays, repeated and identity-free architectural examples are frequently encountered, disregarding the characteristics of the space and its natural, socioeconomic, and cultural features. In points where climate data is not included in the design process, a range of economic problems emerge in addition to unqualified architectural development. It is observed that solutions produced to increase user comfort when the development of designed spaces is not climate-focused come with high costs. Many designed spaces fall short in meeting user requirements because they are not thought of in a multidimensional way, regardless of their qualities and target audience. The conditions where living beings feel most comfortable and do not require heating or cooling are defined as thermal comfort (Mayer & Höppe, 1987; Mayer, 1993). Psychological, thermo-physiological, and body heat balance approaches are involved in determining thermal comfort conditions (Shakir, 2006). In the "Psychological approach," as defined by Höppe (2002), thermal comfort is entirely related to the human brain's perception of temperature. In this context, human thermal comfort is defined as "the human brain being satisfied with the temperature of the surrounding environment." According to ASHRAE (1992- American Society of Heating, Refrigerating, and Air-Conditioning Engineers), in an older definition compared to others, bioclimatically comfortable environments are defined as "environments where 80% of individuals sitting or performing light work are not complaining about the temperature." According to Toy (2010), the first thermal comfort study is Haldane's (1905) study in England, which aimed to determine the temperature stress of miners. Previous thermal indicators have focused on the adverse effects of climates on humans, such as hot and cold stress. Initially, the studies conducted for these miners in indoor environments were later continued with Olgyay's (1963; 1973) outdoor thermal comfort research. Fanger (1970) stated that thermal comfort is an influential factor on human performance and that mental, physical, and perceptual performance will be at their highest point. Taking into account these factors known to affect human thermal comfort, more than 40 thermal comfort calculation indices have been developed in the past century (Epstein and Moran, 2006). These indices are divided into two groups: simple and complex indices. Simple indices only evaluate temperature and humidity, while complex indices include the characteristics of the working area, such as its topography and morphology, as well as the individual's psychological, thermo-physiological, and body heat balance characteristics in calculations (Mayer, 1993; Matzarakis et al., 1999). In the past century, over 165 thermal indices have been developed worldwide to assess thermal conditions for humans, define thermal comfort, and determine thermal stress (de Freitas & Grigorieva, 2017). Some of these are listed in Table 1.

2. Material and Method

In this study, models used for temperature prediction related to future climate, urban heat island density, reduction of urban heat island effects, outdoor thermal comfort in urban design scenarios, and energy-efficient settlement areas are examined at meso, local, and micro scales. The lack of sufficient meso-scale climate prediction in cities in Turkey hinders the implementation of local climate adaptation strategies effectively.

Table 1. Some simple and complex indexes used from past to present (Developed from Epstein & Moran 2006; Potchter et al., 2018).

Indeks	Indeks name	Source
T_w	Wet-bulb temperature	Haldane, (1905)
ET	Effective temperature	Houghton and Yaglou 1923
WBGT	Wet bulb globe temperature	Yaglou and Minard (1957)
DI	Discomfort index	Thom (1959)
THI	ThermohygrometricIndex	Thom (1959); Kyle 1994
HI	Heat Index	Steadman 1979
AT	Apparent Temperature; Heat Index	Steadman 1984
ITS	Index of Thermal Stress	Givoni, 1963
TSI	Thermal Strain Index	Sharma and Ali, 1986
WCI **WCET**	Wind Chill Index Wind Chill Equivalent Temperature	ISO/TR 11079, 1993
PET	Physiologically Equivalent Temperature	Höppe, 1999; Matzarakis et al., 1999
PMV	Predicted Mean Vote	Fanger 1970; Höppe 1993 and 1999; Gulyas *et al.* 2003
PT	Perceived Temperature	Staiger et al.,1997
SET	Standard Effective Temperature	Gonzalez and Gagge 1973; Gagge *et al.* (1986)
UTCI	The Universal Thermal Climate Index	(http://www.utci.org/); Jendritzky et al., 2009
mPET	Physiologically Equivalent Temperature	Chen and Matzarakis, 2018
ENVI-met	ENVI-met Microclimate Simulation Software	Bruse and Fleer, 1998; Bruse, 2020
UrbClim	UrbClim Model	De Ridder et al., 2015; Hooyberghs et al., 2015

It is emphasized that it is necessary to increase studies on minimizing the impact of climate change on cities in the future and generating site-specific scenarios. The concept of the study is based on the introduction of models used in the production of climate change and outdoor thermal comfort urban design scenarios, as well as climate models. In this context, the PET, SVF, ENVI-met, and UrbClim software models currently used have been introduced. In general, low-resolution global climate models do not create definitive judgments for cities. It is seen that the use of high-resolution local micro-climate data at the city scale enables the production of more realistic strategies for adapting to climate change in cities. The predicted urban heat island effect for the future density, along with urban design scenarios proposed today, will contribute to the awareness of people living in the city and their living in a healthier environment, in addition to adapting to the climate.

3. Findings and Discussion

Some software programs that are widely used today for simulating proposal landscape designs prepared within the scope of spatial planning and design in urban areas are also used by our project team. Descriptions related to these are given below.

3.1. Up-to-Date Climate Software Models

Various software can be used to predict the problems that arise in today's cities. According to the World Meteorological Organization (WMO), there are two important factors that affect thermal comfort: individual characteristics (height, weight, age, gender, clothing, etc.) and environmental factors. The environmental factors include the atmosphere (precipitation, temperature, humidity, wind, etc.), radiation, and air pollution. The thermal comfort software used today is evaluated in a group of complex indices. The current software used in simulations aimed at determining or improving thermal comfort zones in different landscape designs is listed below.

3.2. The RayMan Pro Model

Although there are numerous software models used in thermal comfort studies, the RayMan pro 2.1 model is the most commonly used in urban design studies (Potchter et al., 2018). These developed models are classified as simple and complex indices according to the characteristics of climate-environmental parameters. While only the temperature and humidity of the environment are used in simple indices, more detailed features such as the individual's physical characteristics, the topography of the area, building heights, street widths, street tree planting, tree species, etc. can be used in complex indices (Mutlu et al., 2018; Irmak et al., 2018; Yilmaz et al., 2018a, 2021b; Yilmaz et al., 2021c). The standards determined based on the characteristics of an individual who is 35 years old, 1.75 meters tall, and weighs 75 kilograms with a jacket are entered as fixed coefficients according to European standards. The hourly temperature (°C), humidity (%), wind (m/s), cloudiness (octas), or solar radiation parameters are used to determine the thermal comfort of the working environment (Matzarakis et al., 1999; Fröhlich et al., 2019; Javanroodi & Nik, 2020). Hourly data is used to evaluate the comfort of the working area by months, years, or day and night. The value obtained as a result of these calculations is the Physiologically Equivalent Temperature (PET), which is expressed as the Physiologically Equivalent Temperature (PET) value. The user interface of the model used in this software and the range of thermal comfort values used are given in Table 2 and Figure 1, Figure 2.

The data in Table 1 prepared for Europe is used in the evaluation of PET analyses. According to the measurements made in Europe, the most suitable values for thermal comfort are seen as 18.1-23.0 0C. However, these values vary for different climatic regions. For this purpose, work on the thermal comfort value range table is ongoing within the scope of a

TUBITAK project for cold climate regions such as Erzurum. To obtain this table, at least 250 surveys were conducted every month for one year, and measurements and surveys were conducted simultaneously with the device and global thermometer shown in Figure 3. In these surveys, the individual's age, gender, activity, clothing, etc. characteristics are also processed in detail. These surveys were regularly conducted by star trainees in Erzurum for the year 2022.

Table 2. Thermal stress categories of the PET index (Matzarakis & Mayer, 1996)

PET (°C)	Thermal perception	Grade of physiological stress
< 4.0	Very cold	Extreme cold stress
4.1 – 8.0	Cold	Strong cold stress
8.1 – 13.0	Cool	Moderate cold stress
13.1 – 18.0	Slightly cool	Slight cold stress
18.1 – 23.0	Comfortable	No thermal stress
23.1 – 29.0	Slightly warm	Slight heat stress
29.1 – 35.0	Warm	Moderate heat stress
35.1 – 41.0	Hot	Strong heat stress
> 41.0	Very hot	Extreme heat stress

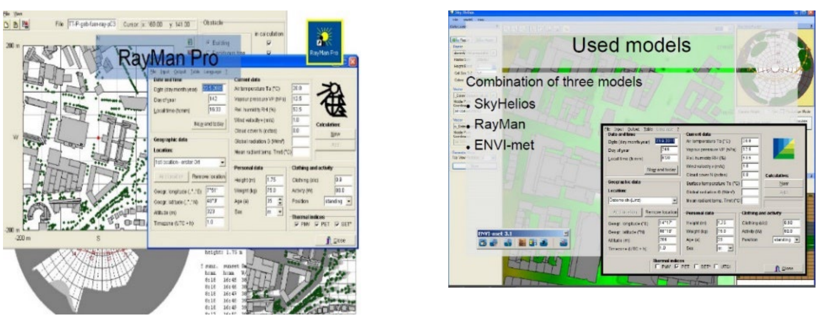

Figure 1. RayMan pro 2.1 software model interface images (Matzarakis et al., 2007).

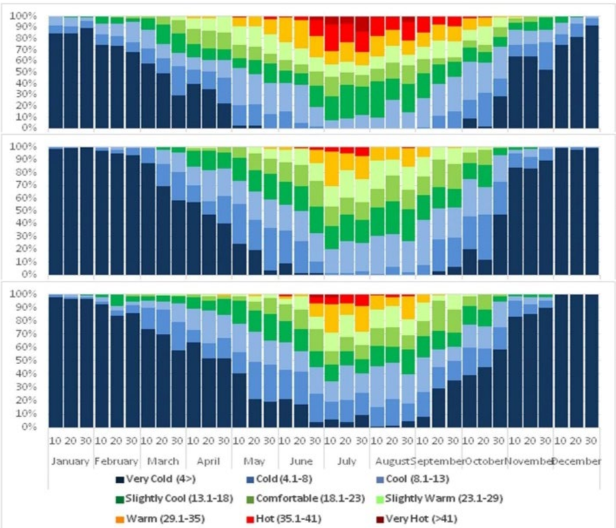

Figure 2. Image of PET analysis (Yilmaz et al., 2021a).

Figure 3. Survey application of Star scholars with a global thermometer.

Micro-climatic measurements conducted in residential structures with different usage characteristics located in urban areas are used to calculate thermal comfort. In a study conducted in Erzurum City (Bulgan et al., 2014), it was stated that thermal comfort is better in areas with a high percentage of greenery, while in areas with open and impermeable surfaces, especially during summer months, there is a high level of heat stress (Figure 4).

3.3. Sky View Factor (SVF)

This is an analysis conducted using the RayMan Pro model. The algorithm, which is used with a fisheye lens attached to a camera, takes different screen shots at each location (Figure 5). GGO-SVF is a parameter that represents how much solar radiation affects a location, depending on the settlement geometry.

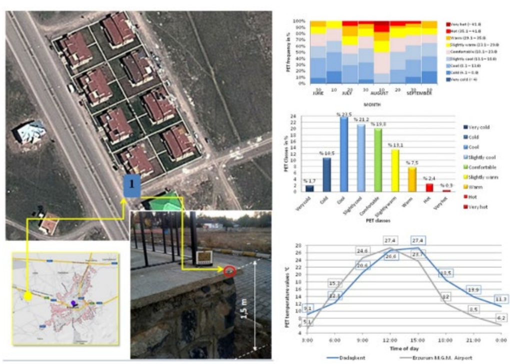

Figure 4. Thermal comfort PET analyzes in urban space (Bulgan et al., 2014).

SVF is defined as the fraction of visible sky in a hemisphere and is expressed as a value between 0 and 1. As this value approaches 1, it indicates that the sky is more visible, while as it approaches 0, the visibility of the sky decreases (Algeciras et al., 2016; Li et al., 2020). Surface points with higher SVF have less obstruction to absorb solar energy (Oke, 1987). Increasing the height of buildings in urban canyons reduces SVF on the canyon surface (López et al., 2016). Additionally, there is a strong correlation between building density and SVF (Chatzipoulka et al., 2016). SVF can indicate the geometric complexity of a city, allowing the impact of street geometry on temperature and pedestrian thermal comfort to be studied using this factor (Krüger et al., 2011; Sari et al., 2020). A study conducted in the humid climate of Beijing showed that highly shaded areas (SVF <0.3) were exposed to less heat in summer and severe cold in winter, while moderately shaded areas (0.3 <SVF <0.5) had longer periods of outdoor thermal comfort throughout the year (He et al., 2015). However, Karakounos et al. (2018) stated that the results of such studies cannot be generalized and that the relationship between SVF and micro-climatic parameters and thermal comfort needs to be investigated separately for each case. Urban geometry or canyon is one of the important factors that affect the microclimate of urban streets. In urban climate research, SVF, which is the approach of 3D urban geometry, is widely used to evaluate the UHI and long-wave radiation heat loss in night cities (Brandsma and Wolters, 2012; Oke, 1987; Unger, 2004; Lee et al., 2020; Yilmaz et al., 2021c). The SVF is an effective synthetic parameter on outdoor thermal comfort that summarizes the direct and reflected short and long wave radiation flows that the humans' bodies are exposed to (Johansson et al., 2014; Yilmaz et al., 2021c).

Figure 5. Image was analyzed with a fisheye lens and the RayMan pro.

3.4. The ENVI-met Software

The ENVI-met computer model is used to generate possible scenarios for better planning of urban spaces in terms of climate-focused thermal comfort. This model, developed by Bruse and Fleer (1998), allows climate data to be used in planning, from regional planning to urban planning, and even for alternative designs in a home garden, to produce simulations in terms of thermal comfort. In urban planning, simulations can be conducted on various scenarios by changing the positioning of buildings, plant species, street orientations, building heights, roof gardens, or ground cover materials. By using multi-year or at least 24-hour climate data, the micro-climatic situation of the space can be analyzed. Thermal comfort maps are commonly used in conjunction with climate data such as SVF and PET to analyze suitable thermal comfort zones (Bruse, 2020). The ENVI-met model has also been used to focus on improving pedestrian thermal comfort in urban spaces through various scenarios (Middel et al., 2017).

In a study conducted in Kolkata, India, it was determined that the three-fold increase in urbanization areas in the last twenty years had increased surface temperature by 10.6 ^{0}C, while green areas and permeable surfaces had significantly decreased (Nimish et al., 2020).

During the demo usage of the program, only limited data can be entered into the system, whereas when the program is purchased, data can be entered at the neighborhood scale and various design scenarios can be generated. Within this context, the ENVI-met Bio+ Science software was purchased through TUBITAK 1001 project. Different design scenarios for urban spaces can be analyzed using microclimate data. Thus, design models for different tree species, street canyon characteristics, impervious surface ratios applied in urban parks, etc. are modeled and analyzed using this software, and thermal comfort calculations can be made (Yilmaz et al., 2018b; Dursun et al., 2020; Yilmaz et al., 2021c; Yücekaya et al.,2022). The visuals of some studies conducted for this purpose are given in Figure 6.

3.5. The UrbClim Model

The most up-to-date urban microclimate model used to create forward-looking urban climate projections has been confirmed to comply with international scientific standards. The UrbClim model, designed by VITO in 2013, has been applied in many cities in Europe to model the urban heat island effect with a spatial resolution of a few hundred meters, predict the future, and estimate the combined effects of continuous urbanization. The model was first tested for a short period of time in the cities of Tolouse and Ghent (De Ridder, 2015; Hooyberghs et al., 2016). As part of the

Ramses project, this method was seen as the most suitable model for making urban-scale climate predictions for the current (1986-2005) and future (2081-2100) periods using urban meteorological data and land parameters with a resolution of 250 meters. According to some research results obtained using this method, the temperature differences in cities in the future are determined to be as follows: 2.47 °C in Germany, 2.30 °C in Antwerp, 2.70 °C in Berlin, 2.12 °C in Bilbao, 2.98°C in London, 3.57°C in New York, and 2.95°C in Rio and Skopje (Lauwet et al., 2015). By adding vegetation to the model, research has been conducted on the impact of urban heat islands and the effects of climate change on air quality in the future. According to the results, it was concluded that having large parks in urban centers, rather than small parks, has a more positive effect on urban cooling and air quality (Hooyberghs et al., 2015; Lobaccaro et al., 2015). In a study aimed at evaluating the effects of nature development projects on urban heat island, the potential of vegetation in the future was tested for Antwerp city using UrbClim simulations. The research found that additional greenery would have a positive ecological impact (Zulian et al., 2017). Considering that climate change can be reduced by urban adaptation, temperature and urban heat island density estimates were made for Skopje city using the UrbClim model, and the results showed that mortality rates could increase depending on the density of the heat island (Martinez et al., 2018). In a study on the evaluation of the current and future urban heat island of Brussels using the UrbClim model, it was found that the temperature would increase by 3.2°C and the number of heat wave days in urban areas would be 2-3 times higher than in rural areas.

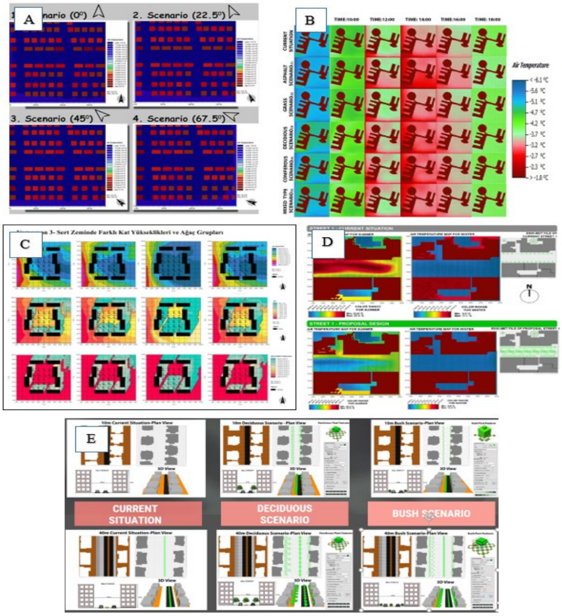

Figure 6. ENVI-met spatial analysis scenarios a) Mutlu et al.,2018; b) Yilmaz et al., 2021a, c) Yavaş & Yılmaz 2020; d) Yilmaz et al., 2021b; e) Yilmaz et al., 2022)

The findings emphasize the need to focus on the key points of urban climate to design climate strategies in urban areas (Lauwaet et al., 2015). For the temperature analysis, the model was validated with observational data and run in three cities in Belgium to assess the robustness of the analysis. The results showed that temperature-time profiles were significant for all built-up areas in the urban environment regardless of the center (Verdonck et al., 2018).

Scenario analysis for climate change for the years 2050-2070 is being conducted for the city of Erzurum within the scope of the current TUBITAK 1001 project. The UrbClim software model is being used to determine future climate change. This software was purchased from VITO company under the TUBITAK 1001 project with the number "119O479". To run the model, the input region and meteorological NetCDF files must be prepared to start the UrbClim simulation. Only a compiled model in an executable file and a configuration text file with the model's operating characteristics, input and output file names, and output variables set need to be provided. The raw output data of UrbClim can be processed using an offline post-processing tool written in the Matlab language, which has a graphical user interface. The interface is available for both Windows and Linux. The output NetCDF files are transformed into some predefined parameters related to hourly temperatures and the entire simulation period (mean temperature, tropical days and nights, heatwave days, cold days, etc.). The results are provided in PNG, GeoTIFF, or KMZ format (Lauwaet et al., 2017). This model works with a workstation and a Linux operator.

The UrbClim Model is a model designed to simulate and analyze urban climate change at a spatial resolution of a few hundred meters. To run the model, climate data must be obtained and processed into software programs. UrbClim is an urban boundary layer climate model designed to cover agglomeration scale areas with a high spatial resolution of up to 100 meters (De Ridder et al., 2015; Lauwaet et al., 2015). The model consists of a three-dimensional atmospheric boundary layer module and a simplified land surface scheme that includes urban physics. Information on setting up and running the model is shown in Figure 7, which illustrates the workflow for conducting model simulations. The model operates with two types of input data: first, land data (2D maps), and second, meteorological data (1D vertical profiles). It can be run on a Unix-based computer system. The UrbClim model can then generate hourly maps of atmospheric and spatial surface variables. The model graph for processing land data is created in Matlab or IDL, and coordinate transformations are processed with the open-source Geospatial Data Abstraction Library (GDAL) (300x300). Grid division was determined by the organization producing the model as the ideal scale. In the second step, satellite imagery for different variables is projected onto the defined UrbClim grid. For input of meteorological data, a NetCDF file is generated independently with a MATLAB program or IDL code in VITO. This code essentially interpolates data from a large-scale meteorological master model, often the ECMWF ERA tool, but it could be any meteorological or climate model that can provide this data temporarily or permanently (Lauwaet et al., 2017).

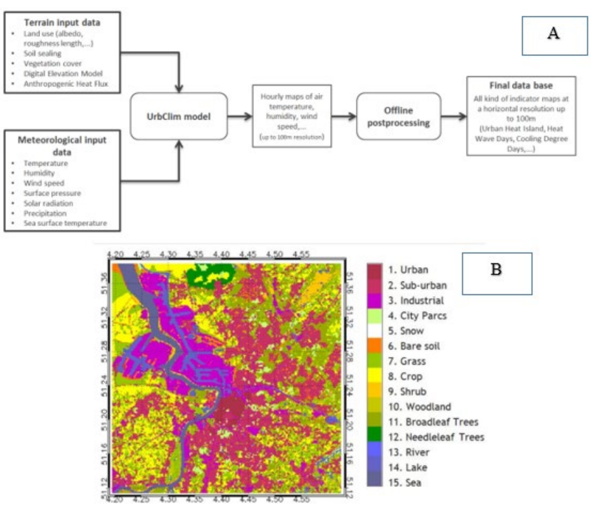

Figure 7. A) Workflow Chart of UrbClim Model (Lauwaet et al., 2017) and B) Sample analysis with UrbClim for the city of Antwerp (De Ridder et al., 2015- dirk.lauwaet@vito.be; koen.deridder@vito.be)

Urban planning and design can prevent problems that may arise by considering natural elements in urban spaces through scenario analyses. As part of the TUBITAK project, the software "The UrbClim Model" was purchased from Belgium and implemented. Climate change scenarios are being determined for the years 2050-2070 for the city of Erzurum. The following image is taken from the ongoing analysis (Figure 8).

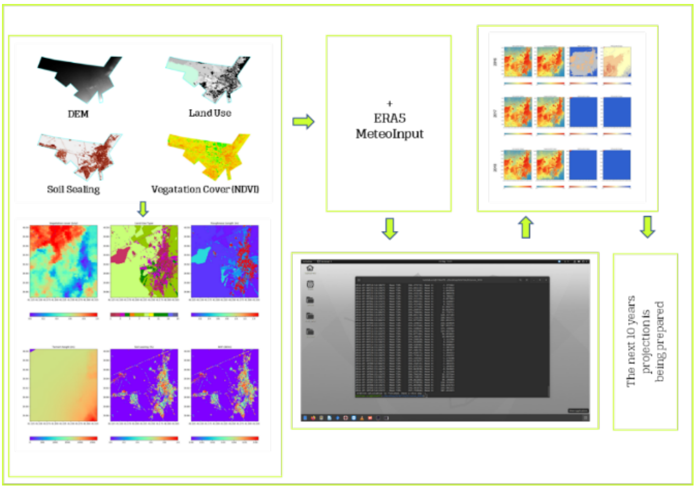

Figure 8. 2050-2070 UrbClim model for Erzurum city (Yilmaz et al., 2023).

In 2011 and 2014, workshops were organized with Prof. Dr. Andreas Matzarakis (Freiburg University, Germany) on the use of current climate models (Figure 9). In another workshop organized as part of the project, Professor Zerrin Yılmaz from Istanbul Technical University's Faculty of Architecture and Professor Fatih Terzi from the Department of Urban and Regional Planning, also from the same faculty, contributed their knowledge and experience (Figure 9).

Figure 9. The workshops held within the scope of the projects.

A workshop was organized in April 2021 for software developers and users currently used in academic research. The visual of the workshop and program is given in Figure 10. Due to the Covid 19 pandemic, the workshop was held online via Zoom. The screen visual of this workshop is given in Figure 11. In urban areas, computer software programs developed using resources such as climate, microclimate, topography, and meteorological data have contributed to spatial planning and design projects alongside project teams. Prof. Dr. Andreas Matzarakis, the developer of RayMan Pro software, Prof. Dr. Michael Bruse, developer of ENVI-met software, and Dr. Filip Lefebre, developer of UrbClim software, introduced these models. Prof. Dr. Rohinton Emmanuel, Prof. Dr. Adeb Qaid Ahmed, Prof. Dr. Andre Santos Nouri, and Prof. Dr. Francesca Olivieri, who use these models in their academic studies, gave presentations about their research.

Figure 10. Workshop presentations.

Figure 11. International workshop with up-to-date software.

4. Conclusion and Suggestions

The concepts that shape the formation and meaning of a city, such as building forms, surface coating materials, landscaping efforts, selected plant species, and circulation patterns of urban life, have an impact on the urban climate. Although there is a regional and objective approach to the climate values of cities, each city has its unique qualities. Considering these qualities during the spatial planning/design stages is crucial for generating healthy urbanization models. While making these designs, the natural features and microclimate data of the region should be utilized. Neighborhood and housing settlement plans should be made based on the data used as a substrate in every physical planning and design area. In this context, designs that utilize sunlight, emphasize topography, and provide the best wind circulation should be seen as a necessity for sustainable urban designs. By doing so, it is possible to achieve an improve in livable and sustainable environmental standards. Indeed, the analysis conducted reveals that the thermal conditions of the environment can be improved when the natural features of the space are considered in urban planning and landscape design studies. There is a direct relationship between the quality of a space and the comfort of its users. Space users do not prefer to stay in an uncomfortable open or closed space for a long time. According to Zenon, the founder of Stoicism, happiness is "to act moderately and live in accordance with nature." In our daily lives, it is necessary to contribute positively to the city with nature-oriented design criteria. It is not seen as a correct approach to impose the stress of the city on people dealing with various other problems in the ongoing struggle of life. As a result, in the urban renewal works almost in every city in Turkey, natural and cultural resource values should be well analyzed, and carefully considered in each threshold plan and implementation. It is seen possible to obtain more livable urban spaces with ecological urban development models that incorporate climate and microclimate data into planning from natural resource values. It should now be seen that mankind has no other chance than to live in harmony with nature.

Thanks and Information Note

This study has been supported by the Scientific and Technological Research Council of Turkey, TÜBİTAK under Project No: 215O627 and TÜBİTAK under Project No 119O479. The author presents their special thanks to the Turkish State Meteorological Service (DMI) for sharing their data free of charge.

This e-book chapter complies with national and international research and publication ethics.

Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

The author contributed fully to the article. There is no conflict of interest.

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Prof. Dr. Sevgi YILMAZ

E-mail	:	sevgiy@atauni.edu.tr
Undergraduate	:	Çukurova University, Faculty of Agriculture, Department of Landscape Architecture
MSc	:	Çukurova University, Institute of Natural and Applied Sciences, Department of Landscape Architecture
PhD	:	Atatürk University, Faculty of Agriculture, Department of Landscape Architecture
Post-Doc	:	Cornell University, Agriculture and Life Sciences, Department of Landscape Architecture, USA
Professional experience	:	Atatürk University, Faculty of Architecture and Design, Department of Landscape Architecture

Ecological Approaches to Weed Control in Sustainable Agriculture: Organic Mulches

Assist. Prof. Dr. Derya ÖĞÜT YAVUZ [1]

[1]Uşak University, Faculty of Agriculture, Department of Plant Protection, 1 Eylül Campus, Uşak/Türkiye.
ORCID: 0000-0001-9248-410X
E-mail: derya.ogutyavuz@usak.edu.tr

Citation: Öğüt Yavuz, D. (2023). Ecological Approaches to Weed Control in Sustainable Agriculture: Organic Mulches. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches**. 2023, Chapter: 10, 272-300. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

Agriculture, defined as the science and technique of creating plant and animal organic resources via the use of air and water variables, is a sector whose economic importance is growing and must continue to grow. In general, agriculture is defined as the production and evaluation of goods of plant and animal origin; in ecological terms, it is also defined as the science and technology of creating plant and animal organic materials with organisms that best evaluate soil, water, and air elements.

Agricultural activities carried out in harmony with nature under natural conditions for thousands of years did not harm the environment and did not cause environmental problems. However, to meet the food needs of the world's rapidly increasing population and to acquire more products from the same amount of land, artificial elements introduced into agriculture have become a sector that disrupts the natural environment and causes environmental problems.

Although it is believed that the hunger problem will cause severe deaths of humans in many regions of the world and that diseases will spread as a result of malnutrition, owing to current agricultural practices, this problem has not materialized as expected. On the other hand, due to the increase in the amount of product obtained from the unit area, the natural habitats necessary to meet the food needs of the increasing world population were prevented from being opened as new agricultural areas. As a result, millions of hectares of land and forest areas, as well as natural ecosystems and biodiversity have been preserved.

After man transitioned to agricultural culture, he did not see the environment as a part of nature but saw nature as a collection of resources that would meet his own needs, thus inviting the destruction of the environment. The majority of environmental issues are caused by the natural equilibrium being lost as a result of human interference with and exploitation of nature. Productivity has increased as a result of the use of new technology and methods in animal and plant production. However, it is not possible to achieve an infinite product increase with the applied methods and techniques. In this way, although a quantitative increase in the product is achieved, some problems also arise. From the beginning of time to the present, man has struggled to master nature. The human being, who has grown stronger as a result of scientific advancements, freely uses and even exploits nature.

Agriculture is an occupation that has existed from the beginning of time and will continue to grow in importance. These activities take place in a certain environment. The environment influences the efficiency and quality of production in proportion to its suitability for the formulation of these activities. The growing environment in agriculture is the environment that provides suitable conditions for the life and development of living things as much as possible.

When soils are not effectively maintained in agricultural areas, agroecosystems suffer greatly in many parts of the world. Soil quality is directly affected by agricultural applications, while optimum practices improve soil production capacity and make it sustainable. All economic activities have an impact on soil conditions and performance, either directly or indirectly. Agriculture is the most common economic activity that requires land, and an enormous amount of people make a living from it.

Agriculture, which has been the primary source of life since the beginning of civilization, is currently facing significant challenges. A few of the issues that can be immediately recognized are the rapidly expanding world population, the increasing demand for nutrients, the limited capacity of arable land expansion, the rise of factors that lead to crop yield losses, and the emergence of pesticide residue and resistance issues. In this situation, increasing productivity - that is, obtaining more products per unit area - is the only option to improve agricultural production.

The model of large-scale, intensive, mechanized few essential crops supported by inputs of pesticides and fertilizers currently dominates agricultural systems, especially in developed nations. These techniques involve the long-term use of herbicides or tillage to manage weeds, which can be harmful to both the environment and long-term agricultural yield. However, the studies and methods applied in this direction also bring some disadvantages. Overuse of herbicides can cause environmental contamination, non-target crop damage, loss of natural flora and soil biodiversity, and harm to farmworkers' and the public's health. Due to frequent processing, the fertility of the soil decreases, and chemical products used for fertilization and plant protection can adversely affect the yield and nature.

Unfortunately, agricultural activities in today's conditions have made the soil the primary location for the accumulation of chemicals and waste products that risk the health of all living things, whether intentionally or unintentionally. When these chemicals and wastes get into the soil, they become part of the cycle that impacts all life forms, and they eventually get to people through the food and water cycles, becoming the wastes even more harmful.

When the soil's buffer capacity for one or more pollutants is surpassed, the soil frequently loses its ability to protect water, the atmosphere, and organisms irreversibly. The soil's biogeochemical balance changes, resulting in adverse effects on soil parameters such as pH, organic matter concentration, soil atmosphere, and structure.

Both the soil and the environment are polluted by improper agricultural practices and typically dose, timing, and kind of pesticide applications. As a result of intensive and unconscious pesticide use, the pesticide or the decomposition products used in food, soil, water, and air have negative effects on other non-target organisms and humans. By leaving behind residues, pesticides have a harmful impact on the environment and human health when they are not used as recommended.

Pesticides are needed tools to maximize the output from the current agricultural lands and feed a growing global population. Among agricultural control techniques, pesticides are largely favored because they produce results rapidly, are easy to use, and are economical. Chemical control plays a significant role today, having a success rate of over 95% in eliminating microorganisms that affect crops. Although pesticides are known to have negative effects on people, other living things, and the environment, they are preferred for agricultural areas.

Today, with the increase in environmental awareness, the protection of human health, the environment, and biological diversity has come to the fore in all studies. For this reason, it is now essential to establish pest management techniques that take into account sustainable agricultural production, agroecological analysis, and a reduction in pesticide use. This will be possible with the application of sustainable methods and permanent solutions in agriculture.

Sustainable agriculture involves systems and practices that will improve the production of sufficient and high-quality foods at reasonable prices, the economic vitality of global agriculture, environmental and natural agricultural resource protection, and global population welfare. Sustainable agriculture; is the production of plant and animal products with techniques that protect the environment, public health, society, and animal welfare by ensuring food security. It includes the development of ecological agricultural practices that can preserve soil fertility, limit the use of nonrenewable natural resources, and integrate with local biodiversity and landscape.

To be encouraged the use of agricultural methods that increase food production without damage from soil erosion, excess water, nutrients, or pesticide use. Reducing the environmental impact of agricultural activities is essential for the sustainability of agriculture and food security. To meet the demand for sustainable agriculture, a variety of agricultural management systems and innovative agronomic techniques have been suggested and applied.

Food safety is endangered by disease, pests, and weeds that cause major yield losses in agriculture. In addition to the economic losses produced by these factors, one of the most significant consequences is the damage to the ecosystem caused by invasive species, which causes a decrease in biodiversity.

Due to the growing demand for environmental preservation and sustainability, the global decline in biodiversity, and the rise in human population, plant health is now more crucial than ever. İt is required of obtaining high-quality products without pesticide residues by using alternative methods and techniques in the management against factors that cause yield loss in crop plants. Using pesticides only when necessary, or choosing ecologically friendly pesticides, and applying them at the time and dose, reducing the inputs used for agricultural control is possible. It will therefore contribute to reducing the negative impacts of pesticides, such as the disruption of the natural balance, negative effects on people and warm-blooded, environmental pollution, the risk of product residue, and resistance.

2. Limiting Factor: Weeds

The need for agricultural products is growing as the world's population rises, and this circumstance shows that plant output needs to be raised to fulfill the nutritional demand.

It is known that the crops are limited by biotic and abiotic factors and there is a decrease in yield, and one of these factors is weeds. Weeds are recognized as a significant limiting factor in achieving high yields in crop plants. Weeds are the most significant restriction factor to yield in most crops, accounting for an estimated 43% of the world's losses. Weeds are plants that can adapt to their environments and have been related to crop yield from the beginning of agriculture. It is stated that when weeds are not adequately controlled or controlled, product losses range from 20 to 95%. Weeds significantly reduce not only crop yield but also product quality. The rate of damage can differ caused by weeds on crops; some present trouble only in a single crop plant, while others cause a loss in yield in many crops. Furthermore, crop losses due to weeds vary geographically. Crop production decrease to diseases, pests, and weeds that influence crops (wheat, corn, rice, cotton, and soy) is around 67.15% worldwide, with weeds accounting for 31.62% of this. Weeds reduce crop yields by competing with the crop for nutrients, water, light, and place. These losses depend on variety, environmental conditions, weed species and densities, and crop and weed growth stages. Weeds, generally, are more adaptable to the agroecosystem than crops. Weeds acquire an edge by utilizing more resources due to the crop's slow growth at first. Herbicides are preferred in agriculture to control weeds due to the rise in labor and cost, to be effective, easy application, and low cost. Herbicides are used to control weeds in both agricultural and non-agricultural, including roads, irrigation canals, airports, and historical buildings. When used improperly and frequently, herbicides have major adverse impacts on the environment and ecology. However, they have negative consequences on biodiversity, bee populations, soil and water pollution, human health, and agriculture. Herbicide-resistant weeds have become a significant weed problem in modern agriculture, which is raising production costs.

Effective weed control is critical to agricultural productivity. Using herbicides against weeds is far from sustainable management because of the tendency of consumers to turn to organic products and the growing sensitivity of people to the environment, even though they are still preferred because they are economical and biologically effective. Only by using sustainable growing techniques that reduce resource depletion, protect the environment, and maintain high crop yield and profitability in the cropping systems can adequate food production be maintained. Therefore, the basic principle regarding how weed species respond to control techniques and environmental factors needs to be defined. The sustainability and success of agriculture as a whole are substantially impacted by the effectiveness and sustainability of weed management measures.

3. Sustainable weed management objectives and approaches

The essential objectives of sustainable weed management, preserve and enhance the environment and natural resources, to utilize weed control resources as effectively as possible, to provide sufficient high-quality, safe food, to create cultivation methods that reduce weeds and enhance soil quality, as well as evaluate the effectiveness of weed management systems. Sustainable weed control management involves a variety of approaches.

Preventive weed control

Weed prevention includes whatever is performed to prevent the introduction and spread of undesirable plants. Any attempts to prevent weeds from getting in, settling, and/or spreading are considered preventative measures. It is a long-term strategy to control or manage weeds. Must be avoided using crops that have weed seeds in them while sowing, and avoid giving farm animals feed that contains weed seeds. Weed management programs should aim at eliminating seed production.

Some preventive measures include keeping irrigation canals, field boundaries, and uncultivated areas clean to ensure, there are no weeds and to prevent weed proliferation. Sand and gravel cleaning and weed seeds being returned to the soil less frequently, using fresh or partially decomposed compost are not available. Cleaning farm equipment properly before planting and keeping weeds out of the irrigation/drainage channel and farm bund, preventing the spread of weed seeds with irrigation water, product and herbicide rotation, and measures quarantine, etc.

Cultural methods

By limiting weed establishment cultural practices provide crops a competitive advantage against weeds. Cultural methods include tolerance cultivars, stale seedbeds, crop rotation, sowing/planting time and methods, cover crops, and intercropping, tillage techniques, rate of sowing and fertilizer, mulching etc.

Mechanical methods

Mechanical weed management techniques, such as hoeing, hand weeding, sickling and mowing, tillage, digging, and brush weeding are applied in early weed growth stages.

Thermal weed control

The use of fire, flaming hot water, steam, and freezing using liquid nitrogen or carbon dioxide snow, ultraviolet light, CO_2 laser cutting, hot foam and dry heat, and soil solarization are all examples of thermal weed management.

Mulching

In sustainable agriculture, to minimize all the negativities of chemical control, it is effective, as well as least damaging to the agroecosystem, methods should be determined and alternative applications should be evaluated. Herbicide-free weed management has become chosen in environmental production and ecological farming. Mulching is one of these approaches. Mulches are covers applied to the soil's surface. It is a procedure in which organic or synthetic materials are applied to the soil surface. Mulching inhibits weeds' growth by limiting light. So it has a smothering impact on weed control. Even if the weed seeds grow and reach the soil surface due to the material covering the soil surface, they won't survive since they are not able to photosynthesize. It is an agroecological method that can reduce weed problems by inhibiting the germination of weed seeds or the growth of seedlings. It is effective against annual and some perennial weeds. In addition, it reduces soil erosion, evaporation, increases infiltration, and enhances the population of beneficial microorganisms. It contributes to maintaining soil moisture, nutrient uptake, disease prevention, and soil temperature regulation.

Dry or green plant material, plastic sheet, or polyethylene film can be used for mulching. Considerations of mulch should be thick enough to restrict light transfer and so prevent photosynthesis. Several studies show that it preserves soil temperature and prevents freezing, inhibits water and wind erosion, improves the amount of beneficial nutrients and organic matter in the soil, and improves the activity and number of microorganisms. Furthermore, it promotes and accelerates root system development in plants. It improves soil quality as well as yield. With all of these benefits, mulching is regarded as an effective weed control approach as well as an important plant production component. Moreover, the mulches could help reduce pesticide consumption and decrease the production cost. So mulches have been commonly used in many countries. Mulching is mainly utilized to preserve soil moisture and control weeds. Mulches have a variety of forms, though. It is divided into three categories; organic, inorganic, and living mulch. These mulching techniques can be used alone or in combination with other methods. It is essential to consider the systems approach when selecting a mulch type.

Mulch type

Mulching, which is considered to be one of the alternative weed management methods, covers the soil surface with living or non-living materials, prevents soil moisture loss, and inhibits the germination of many weed seeds, particularly by blocking light from penetrating the soil. Also, different discs in pots can be used to suppress weeds. These discs could be geotextile discs, coconut fiber discs, and plastic discs. In addition to protecting the soil structure, these treatments must be applied at a thickness that cuts out light. Also, different mulching techniques have been preferred for weed control in different forest and conifer nurseries in recent years. Mulch treatments, according to studies, increase the yield of agricultural plants, both annual and perennial. Reduced root zone competition, more accessible nitrogen in the soil, and improved usable water all contribute to the increase in production. Mulching material has several properties. Climate, cost, and type of plant are important factors in the selection of suitable mulching materials. Mulching materials of different types are used in agricultural fields in a variety of techniques and combinations. Several recent studies have provided data on the impact of different mulching systems on preserving water through rainwater gathering for maize, wheat, and mixed agricultural techniques. Various benefits are offered by agricultural mulching systems.

Advantages include saving water, preventing the physical, chemical, and biological degradation of the soil, and reducing the need for irrigation.

Organic mulches

Organic mulches are those that are found in nature and can be decomposed by soil organisms. Agricultural waste, wood industrial waste, processing residue, and animal waste can all be used as organic mulching materials. Organic mulch improves soil fertility by providing nutrients to the soil. Mulch may be effectively made from a wide variety of organic components. Materials such as straw, bark chips, sawdust, plant leaves, nutshell, oyster shell, perlite, bark, clipped grass, pumice stone, compost, and rice husk are used.

Types of some organic mulches

Barks

Hardwood and softwood bark mulch are the two varieties. They are quite useful when used and wood mulches are widely available. They last more time. Mulch can come in a variety of forms, such as shredded bark, coarse, ground chips, color-enhanced mulch, recycled wood, or recycled wood chips. The rate at which a given kind of mulch decomposes might vary. While mulches degrade and supply organic matter to the soil. These mulches with a high moisture content make excellent mulch since they have more moisture and can retain it for a longer period. They so aid in supplying moisture to the crop as it grows. They are extensively utilized in landscaping. Its usage in the cultivation of vegetables should be avoided due to its acidic character. Before the application, it should be aged wood- or bark-based mulches to reduce their allelopathic impact. Mulches made of wood chips and bark shouldn't be stacked up against the roots of trees or shrubs since doing so could encourage fungi diseases.

Bark (Hardwood)

It is a waste product from the wood and paper industries that may be converted into mulch. One of the typical mulches used in rural areas is hardwood bark. Hard bark contains more nutrients than soft bark, but getting to them might be challenging.

Bark (Softwood)

Hardwood barks are more easily decomposed than softwood barks.

Straw

One of the earliest mulches ever utilized is straw. It has a good impact on soil structure, temperature, and moisture. But there is a risk of spreading weeds, including cover crop residues, to a new crop plant. It is easily applied in the field and utilized in vegetable fields for winter protection as well as summer mulch. These mulches are useful for insulation, water penetration, and weed control. Straw should be covered on the soil surface to be about 6-8 inches thick when mulching. It shows a lower level of weed control effectiveness than that attained by living mulches. It has also the advantage that it can be plowed when it is no longer needed.

Sawdust

The debris that remains after lumber has been processed in the carpentry industry is known as sawdust. This is now considered thin and thick. The type of tree from which the sawdust is obtained, and the duration of use are important in plant cultivation. In regions where it is easily available, sawdust is a common type of mulch. Decomposition occurs relatively slowly because of the high C: N ratio. Its disintegration will result in a nitrogen deficiency in the soil, thus fertilizer has to be applied often. It should not be utilized in soils with an acidic pH because of its acidic nature. It has, however, hold moisture for a longer time. Its disadvantages include keeping the soil wet and airless, having allelopathic effects on some crops, and providing a favorable germination medium for disease and weed seeds.

Furthermore, it may not exhibit its impact if washed away by rain, especially in sloping areas.

Compost

Compost can be easily created at home by composting a variety of waste products, such as leaves, straws, grass clippings, and plant leftovers. Compost is a useful substance for enhancing soil health. Due to the excess nitrogen and potential weed seeds, it shouldn't be used in vegetable fields.

Newspaper

Newspaper mulching is a simple and easily available method for weed management. Within a short period, the newspaper layer decomposes into the soil.

Inorganic mulch

Polyethylene plastic sheets are petroleum-based products, and synthetic polymers are glimpses of inorganic mulching materials.

In various agricultural production systems, materials such as black polyethylene are used to control weeds. It has been proved that mulches are effective at controlling weeds. Aluminum-coated plastic and foil mulching materials are mainly confined to vegetable crops. Mulches made of aluminum-coated plastic also help vegetable crops reduce viruses, aphids, and other insects.

Special type

Also available as environmentally friendly materials are biodegradable and photodegradable plastic films.

The role of organic mulches in weed management

The dispersal of weed seeds into the soil and their ability to emerge are limited by organic mulches. Organic mulches can reduce weed populations by reducing the amount of oxygen that affects the germination of weed seeds. Additionally, the mulch layer's thickness needs to be sufficient to block light. O_2 availability reduces as mulch layer thickness increases. Because organic mulches, which are applied on the soil's surface, prevent sunlight from accessing the soil, which is essential for photosynthesis, and restricted weed seeds from germinating. A thin layer of organic mulching keeps the soil moist and provides it with essential nutrients, but allows the weeds to grow and emerge. The thickness of organic mulching should be determined by the predominant weed species. Mulching is used to reduce competition for light, temperature, nutrients, and space among weeds and crops. Effective weed control depends on applying the proper mulch at the right time and in sufficient quantities. By releasing substances that are harmful to many weeds, allelopathic residues from some organic mulches can reduce weed growth. But weed seeds carried by organic mulches like straw, hay, compost, leaves, etc. can be difficult to control once they emerge. In many products, the fact that organic mulching invites disease and pest problems limits its use in some products. Over-mulching reduces the oxygen availability in the soil, which eventually inhibits crop germination and root development negatively. It can be difficult to uniformly apply the thickness of the organic mulches at the soil surface on all sides, completely blocking the penetration of sunlight into the soil. Even if applied initially, some weeds can germinate and develop if there are occasional gaps due to effects such as irrigation, rain, or wind.

4. Conclusion and Suggestions

Since they grow at the same level as the crop and are using some of the resources required for plant growth, weeds are important components in agricultural production systems. Weeds uncontrolled inevitably result in significant agricultural output decreases and an increase in production costs. Weed control is necessary to prevent yield losses. Weeds significantly reduce crop quality and yield. However, weeds cause different agricultural losses depending on the region and type of cultivated plant. Early growth stage weed control is essential to prevent crops from reducing yield. Chemical weed control methods become common in agricultural areas because of their fast effects, easy application, and low cost due to the rise in labor and prices. Due to their unconscious and extensive use many herbicides used to control weeds can seriously damage the environment and ecological systems. One of the alternative methods to chemical control in sustainable agriculture is mulching. Mulching is one of the non-chemical strategies to get rid of the negative effects of weed management. It has been shown that weed emergence is prevented in many crops. Mulching, which is considered to be an alternate strategy, involves covering the soil's surface with living or non-living materials to reduce moisture loss and the emergence of weed seeds, particularly by restricting the intake of light into the soil. Mulching, which is one of the most effective methods of weed control, is both environmentally friendly and effective in terms of product quality. Various organic and inorganic mulches (such as polyethylene cover, straw, sawdust, hazelnut shell, oyster shell, perlite, pumice, and crushed rubber) can be used for this purpose to effectively suppress weed growth.

The most adaptable and often utilized organic mulches include hay, straw, and freshly cut forage or cover crops. They are relatively simple to use, limit evaporative losses of soil moisture while permitting rainfall to reach the soil, and can control weed germination and emergence when applied at appropriate rates. Weeds are prevented by organic mulch in a variety of manners. These mulches by preventing the light from reaching the soil, reducing the soil temperature, and significantly reducing the temperature changes between day and night, not only suppress weeds but also act as a physical barrier, preventing the emergence of germinating weeds. Mulches provide physical barriers that prevent weed growth. The confined seedlings die if the mulch is too thick to allow light to reach them. Some mulch materials can also suppress weeds by producing organic compounds that inhibit the growth of weed seedlings for weeks after application. Organic mulching should be evaluated for numerous crops, especially in dryland areas, taking into account its role in environmental safety, as well as some, added benefits beyond weed management. Although certain issues with organic mulching prevent weed control in crops from being fully performed, it is still a very promising approach for weed control in an agricultural field in terms of both sustainable and environmental consequences.

Thanks and Information Note

This e-book chapter complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

Author Contribution and Conflict of Interest Disclosure Information

The author contributed fully to the article. There is no conflict of interest.

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Assist. Prof. Dr. Derya ÖĞÜT YAVUZ		
E-mail	:	derya.ogutyavuz@usak.edu.tr
Undergraduate	:	Adnan Menderes University
MSc	:	Adnan Menderes University
PhD	:	Adnan Menderes University
Professional experience	:	Uşak University

Fertiliser Applications and Techniques in Ecological Agriculture

Hakan LEVENTOĞLU [1]

Isparta University of Applied Science, Institute of Postgraduate Education,
Department of Forest Engineering, Isparta- Türkiye.
ORCID: 0000-0001-8028-0759
E-mail: d1740120001@isparta.edu.tr

Citation: Leventoğlu, H. (2023). Fertiliser Applications and Techniques in Ecological Agriculture. In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches**. 2023, Chapter: 11, 301-322. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

The ever-increasing world population and the related nutritional and food requirements have brought new dimensions to agricultural inputs and methods. In the developing and multiplying global world, technology has been used intensively to obtain more products from unit areas. In the agricultural struggle applied for this purpose, more pesticides and, more chemical fertilizers are used to minimize product loss and to increase product quality and quantity, more water is used to increase the uptake of chemical fertilizers by plants, and excessive use of inputs has started to leave many negative effects on the environment. The use of soil parent material, which has an important place in agricultural activities, is an indispensable necessity to ensure its function and continuity. The way to realize this is to be able to use this material as much as possible for its purpose and without damaging it. Turkey's soils and natural nursery soils are generally poor in organic matter. This is a situation that has a direct effect on productivity. To increase the productivity of poor soils in organic matter, soils must be enriched through organic matter.

All inputs available in all kinds of activities carried out in agricultural production are whole and should be evaluated based on certain criteria. It is useful to evaluate the basic inputs as a whole, whether it is the production of saplings for a stand to be established in an industrial sense or in all kinds of activities carried out in a closed greenhouse environment to meet the need for vegetables. Because the main materials are firstly the soil (growing medium) and secondly the requirements of the grown plant material. The processes to be passed through in the process from the seed stage to the sapling are the same. The only difference here is that the variety we grow has different ecological requirements according to its morphological structure (Leventoğlu, 2022).

Fertilization is used to regulate soil reaction. Nutrient uptake in seedling production and microorganism activities in the soil are closely related to soil reaction. In Turkey, agricultural soils, and especially many growing environments are highly calcareous and high in pH. Therefore, there is a necessity to comply with some rules in the fertilization activities to be carried out, for example, in the alkaline soils of Turkey, even if iron and phosphate are present in the soil or these nutrients are given to the soil, calcium binds them as insoluble compounds and the plant cannot take these nutrients, (Ürgenç, 1998; Çiçek et al., 2022).

Scientific studies and information seen in the literature have shown that fertilization activities are important for the product grown. The main goal should be to analyze the concept of fertilization well and to ensure that it is carried out with the proper methods. Compliance with the minimum basic rules in the fertilization process will lead to the success of the process.

As seen from Table 1, besides the factors affecting fertilization, one of the important issues is to decide how, in what dose, and when to apply fertilizers, taking into account the chemical properties of the fertilizers to be applied. In addition to the fertility status of the soil, the plant production system and irrigation method are also important in determining the fertilization method.

Table 1. Factors affecting fertilization (Karaöz, 1992).

Soil Factors	Climate Factors	Plant Factors	Human Factors
*Soil fertility	*Amount of precipitation	*Plant type	* Soil cultivation
*Soil moisture	*Precipitation distribution	*Plant age	*Disease and weed control
*Soil depth	*Temperature	*Plant size	*Planting spacing and distance
*Soil reaction	* Amount of light		*Planting or planting method
*Soil texture			Human Factors
*Soil structure			
*Soil organic structure			

1.1. Organic Fertilizers

Plant and animal residues or wastes are transformed into organic fertilizers that can be used in plant production after being subjected to certain processes. In addition to these organic fertilizers, green fertilizers are also made by mixing plants grown for fertilization into the soil. Microbial fertilization, in which plant nutrients are added to the soil as a result of the activities of microbial organisms present in the soil, is included in the classification of organic fertilizers.

The soils of Turkey and natural nursery soils are generally poor in organic matter. This has a direct effect on productivity. To increase the productivity of poor soils in organic matter, soils must be enriched through organic matter. This situation causes new inputs in the sapling production process and increases the cost (OGM, 1986; Çiçek, 2021).

Organic Matter (%): Organic matter content of soils. It was determined by the modified Walkley-Black method as reported by Jackson (1958). The classification of soils according to their organic matter values given in Table 2 provides important data for the evaluation of the analyzed soil values.

Table 2. Classes of soils according to organic matter values (Ülgen & Yurtsever. 1995).

Organic matter (%)	Evaluation
<1,0	Very little
1,0-2,0	Less
2,0-3,0	Middle
3,0-4,0	Good.
>4,0	High

1.1.1. Animal fertilizers

Animal-based organic fertilizers (barnyard manures) manure of cattle and sheep and goats are generally called barnyard manure and consist of three separate parts: solid part (solid excrement), liquid part (urine), and bedding. Poultry and poultry droppings are also widely used as organic fertilizer and are subject to this classification. Animal manure is the fertilizer that provides the best nutrients for soil structure and soil texture. If it is properly applied to the soil, it is preferred because it has better nutrient content than commercial fertilizers and is economical.

When animal manure is applied to the soil; it enriches the soil in terms of nitrogen, phosphorus, potassium, and sulfur and increases the water-holding capacity of the soil (Kacar & Katkat, 2009).

As understood from Table 3, the amount of macro elements in grams per 100 g of dry matter is given. These values, which are especially present in the wastes of cattle, sheep, horse, and poultry groups in the classification of animal manure, are important in terms of increasing the organic matter of the soil. At the same time, they enrich the growing environments in terms of macro and microelements with these nutrients.

Table 3. Chemical structures of some animal fertilizers (Sezen, 1984).

Type	H_2O(%)	Dry Matter(%)	N(%)	P_2O_5(%)	K_20(%)	CaO
Cattle	83,2	16,2	0,29	0,17	0,1	0,34
Horse	75,7	24,3	0,44	0,35	0,35	0,15
Sheep	65,5	34,8	0,55	0,31	0,15	0,46
Goose, Duck	75	25	0,8	1	0,8	1,3
Pigeon, Chicken	62	38	1,7	1,6	0,9	2

Table 4. Chemical structure of urine of some animals in terms of fertilizer value (Sezen, 1984).

Type	H_2O (%)	Dry matter (%)	N (%)	P_2O_5 (%)	K_2O (%)	Ca (%)
Cattle	93,8	6,2	0,58	0	0,49	0,01
Horse	90,1	9,9	1,55	0	1,5	0,45
Sheep	87,2	12,8	1,95	0,01	2,26	0,16

Table 5. Essential nutrient contents of different animal manures (Taban, 2011).

	Nutrients, % in dry matter		
Fertilizer	N	P	K
Cattle manure	2	1	2
Horse manure	1,7	0,3	1,5
Sheep manure	4	0,6	2,9
Chicken manure	3,9	2,1	1,8

Table 6. Some properties of various animal feces (Taban, 2011).

Type	Ash(%)	Organic Matter (%)	Organic C (%)	pH (1:5)	ECmS cm-1(1:5)
Cattle	31,42	68,58	39,78	8,36	10,8
Sheep	38,22	61,78	35,83	8,34	5,69
Chicken	41,59	58,41	33,88	8,01	8,641
Sheep+Cattle+Chicken	30,3	69,7	40,43	8,46	9,116

Table 7. Properties of liquid bat guano (URL 3).

Organic Matter	15%
Total Nitrogen (N)	1,50%
Total Phosphoruspentaoxide (P2O5)	2%
Water Soluble Potassium Oxide (K2O)	1%
Total Humic+Fulvic Acid	2%
Ec (dS/m)	6,8
pH 4.5-6.5	4,5-6,5

Table 7. Analysis results of vermicompost (URL 4).

Organic Matter	42,0%
Total Nitrogen (N)	%1.2
Organic Nitrogen	%1.1
Max. Humidity	35,0%
C/N	14,8
pH	6--8
Max EC	4 dS/m

1.1.2. Compost

In composting, plant stems, leaves, pruning residues, agricultural industrial residues (canning oil, tobacco), forestry industrial residues (sawdust, bark, cones, etc.), and all organic materials of animal origin can be used (URL 1; Çiçek & Yücedağ 2021).

In the study conducted by Akgül (1985), it was emphasized that compost, green manure, and other organic fertilizers should be preferred instead of artificial fertilizers unless it is compulsory, and it was stated that especially the use of compost formed from various organic residues increases productivity in nurseries. Although green waste compost varies depending on its source, these changes are less than those of farmyard manure compost. There is a tendency for lower yields when green waste compost is used as an alternative to barnyard manure compost. This is because they contain nitrogen in a more stable form. Compared to barnyard manure, it offers similar characteristics in terms of utilization, especially since the macro elements they contain are chemically more stable. Green waste compost is an important input to improve the organic structure, but it is preferred only after farmyard manure in terms of the plant nutrients it contains. As a result of the digestion of different organic wastes and residues by some earthworms, very valuable organic fertilizer is obtained in terms of content used in agricultural production. This compost product, called vermicompost, is also preferred as a soil conditioner (Edwards & Bohlen, 1996).

Vermicompost contains a high percentage of symbiotic bacteria, nitrogen-fixing bacteria, and mycorrhizal fungi from asymbiotic microorganisms. Since the secretion substances of the worms contain high and excessive nutrients, these secretion substances are mixed with the feces of the worms, allowing the plant to grow better and to be resistant to adverse environmental conditions.

In recent years, "organomineral fertilizers", which contain organic and mineral substances together, have also been used in the preference of growing multiple crops, which is called intensive agriculture. Organomineral fertilizers produced from animal and vegetable waste-derived compost are designed for the full use of organic substances and macro and microelements in their structure by plants (URL 2).

1.1.3. Green fertilizer

To increase the amount of organic matter in poor soils the group of cultivated plants that are specially produced and given to the soil parent material is called green fertilizer. The process of mixing these plants into the soil at a certain stage of their development while they are still green is called green fertilization. As green fertilizer plants, leguminous plants that can bind nitrogen through nodules in their roots and thus provide nitrogen to the soil and increase the activities of microbial organisms in the soil are generally preferred. Among the legume species in green fertilization, clover, meadow clover, stone clover, soybeans, fodder peas, fodder cowpeas, red clover, Japanese clover, and wild hairy vetch can be counted. Non-legume crops include rye, oats, barley, millet, buckwheat, wheat, grass, Sudan grass, mustard, rape, etc. To meet the organic matter deficit in nursery soils, sowing for green manuring or organic matter supplementation is required (Warkentin, 1984).

Green fertilization is important in terms of regulating the physical structure of the soil by increasing the amount of organic matter, enriching the soil with plant nutrients, and contributing biochemically. Green fertilizers increase microorganism activities and the amount of organic matter in the soil, while increasing the water-holding capacity of the soil, protecting it from natural phenomena such as erosion and weed invasion. Green manure plants retain the chemical fertilizers given to the soil and keep these nutrients as soluble organic compounds in their bodies. The released plant nutrients are absorbed as they are in a usable form for the seedlings and plants produced. In this way, irrigation water and rain prevent the washing away of nutrients. Although organic matter constitutes a very small proportion of the soil, it plays an important role in the physical, chemical, and biological structure of the soil and plays an important role in the conversion of many plant nutrients in the soil, especially nitrogen (Buck, 1996).

1.1.4. Biological fertilizer

They are microorganisms that are introduced into the soil or mixed into the soil with seeds to increase the amount of useful plant nutrients. These organisms make them available to plants by retaining (fixing) the free nitrogen in the air or by converting the phosphorus in the soil into a soluble form. The development and use of alternative products to the use of chemical products is of great importance for sustainable agriculture and environmental protection. Related studies and awareness activities are carried out by the Ministry of Agriculture and Forestry under the name of "good agriculture" and the damages are tried to be minimized (Gökhan et al., 2016).

Fertilization methods have a special importance in ecological agriculture. Because in sustainable agriculture, protecting the soil's parent material and transferring its functionality from generation to generation can be realized with organic fertilization and methods. This can be achieved with organic origin materials that will support and even substitute the inorganic structure as much as possible to protect the natural balance (Leventoğlu, 2022).

1.2. Fertilization in Ecological Agriculture

If there are not enough nutrients in the soil to meet the needs of the grown plants, it is essential to supplement the soil with plant nutrients through fertilization. If the soil is not sufficiently nourished, yield losses are observed after a while due to the lack of nutrients. To grow sufficient and high-quality seedlings, soil nutrition is essential. As known, fertilizer is a naturally or artificially obtained complex chemical structure that contains one or more nutrients necessary for the nutrition of plants. Fertilization is the process of applying fertilizers to the soil (solid or through irrigation) or directly to the plant (Karaöz, 1992).

Feeding has become a very important element as a result of the analysis of the growing environment (soil parent material) by adhering to scientific methods and methods. To determine the amount of fertilizer to be used during production; first of all, it is necessary to analyze the soil well (Güçdemir, 2006).

Fertilizer and fertilization techniques applied in normal cultivation may not be suitable for ecological agriculture. Applications and methods made with generic products (Chemical fertilizers) in agricultural production do not comply with the logic of ecological agriculture. Therefore, plant nutrition products and methods suitable for ecological agriculture should be preferred in the first place. Although many fertilizers and raw materials preferred in today's production stages are touted as organic origin products, the fact that these products have organic certificates that can be used in ecological agriculture and have formulations and structures that can be used in organic agriculture is one of the factors that should be paid special attention. As a result of the incorporation of plant and animal residues into the soil and their decomposition, The soil is enriched in terms of organic matter. Chemical fertilizers are often not suitable for fertilization and it is more beneficial to use them together with plant residues and animal residues to improve soil fertility quality (Anonymous, 1998).

Animal manure is the fertilizer that provides the best nutrients for soil structure and soil texture. If it is properly applied to the soil, it is preferred because it has better nutrient content than commercial fertilizers and is economical. When animal manure is applied to the soil; it enriches the soil in terms of nitrogen, phosphorus, potassium, and sulfur and increases the water-holding capacity of the soil (Kaçar & Katkat, 2009).

Preferring the methods of not fertilizing more than necessary before and after the time (appropriate dosage, appropriate time, and correct fertilization). It has been demonstrated that seedlings fed with fertilization at the right time and with the right dosage gain appropriate morphological and physiological characteristics and are therefore successful in field conditions (Özdemir, 1971; Tacenur & Efeoğlu, 1979).

Karaçal (2004) observed that if organic compounds and products are preferred, they have positive effects on soils. The main ones are especially forming organic structures with plant nutrients (Kileyt), increasing soil microbiological activity, accelerating nutrient uptake, especially facilitating the uptake of nitrogen, phosphorus, and sulfur, and providing rapid release of plant nutrients by dissolving minerals in a shorter time, intensifying the activities in this region by stimulating root cells and thus increasing the uptake of plant nutrients, improving the soil structure, increasing the water holding capacity of the soil parent material. Among the Humin substances whose use has increased in recent years, especially "Humic Acid" is used as fertilizer in plant nutrition and has assumed the functionality of organic substances.

To the 1994 regulations published in the Official Gazette No. 22145, the principles of fertilization methods for ecological agriculture should be followed.

2. Material and Method

To examine the effects of organic origin products on the fertility of soils with different characteristics and on the yield and nutrient content of cultivated plants grown on these soils, a total of 62 soil samples were taken from 8 locations with different characteristics from different provinces in Turkey (Antalya, Kütahya, Konya, Samsun, Eskişehir, Urfa, Erzurum, Denizli), 31 soil samples were taken from lands that grow crops with minimum compliance with ecological conditions and 31 soil samples were taken from lands that grow crops under uncontrolled conditions and experiments were carried out by growing cultivated plants determined as target crops in these soils.

These samples, which were taken from the 40 leading farmers who participated in the present study by adhering to the soil sampling criteria, were cleaned from contaminated materials (such as plant, rock, stone particles, etc.) and subjected to air dry process and then ground and sieved. The soil samples were labeled according to land location information, production location, and product type and analyzed in an accredited authorized laboratory. The product materials grown in the fields where soil analysis was carried out were compared based on samples taken from uncontrolled fields (farmers' growing environments) in the vicinity, and the morphological results of the obtained crops were recorded and compared

The fertilization process is important according to the time, amount, method of fertilization, biological characteristics of the species, soil qualities of the planting area, and climatic conditions of the city (Gezer & Gül, 2009; Gezer & Yücedağ, 2006; Gezer & Yücedağ, 2013).

3. Findings and Discussion

The concept of fertilization, which is one of the most sensitive issues of ecological agriculture, should be implemented by taking the necessary measures in production plans to minimize the impending danger to the soils in Turkey. Organic fertilizers play an important role in increasing soil fertility and sustainability. Studies conducted in different parts of the world have shown that organic fertilizers improve soil properties and increase the yield of crops.

The fact that the soils used in the current are generally in the Alkaline group shows that the amount of nitrogen fertilizer to be applied per decare in the organic matter content (%) 0-1 range is 14 kg-18 kg, while the amount of nitrogen fertilizer to be applied per decare in a soil containing 2-3% OM is 8 kg-10 kg. In a doctoral study, the amount of nitrogen fertilizer to be applied per decare in soils in the Alkaline group taken from nurseries during the sapling production phase in the organic matter content (%) range of 0-1 is 14 kg, while the amount of nitrogen fertilizer to be applied in a soil containing OM in the range of 2-3% is 10-11 kg per decare (Leventoğlu, 2022).

Therefore, it is essential to increase the organic structure of the soil with organic products. In particular, well-burned farm fertilizers, which have been subjected to at least 1 year of waiting, and which have been purified from toxic components such as urea and uric acid such as NH_3 should be preferred. Although some producers use chicken and pigeon manure, albeit in limited amounts, chicken and pigeon manure seems to be rich in microelements in terms of content but considering that it may have negative effects on the soil in terms of EC values and salinity, it should be preferred by taking into account the EC degree according to the analysis reports when determining the amount of use.

According to the results of the samples taken from the lands with high pH (7,8-8,8), OM content below 1%, and clay content far above the critical values, it was determined that most of them did not prefer to use organic groups close to fossil such as Leonardite, Humic Acid, Humate, Humate, Humin, Fulvic Acid, which have positive effects on soil texture structure. In particular, it was understood that the species grown in nurseries with low pH soil structure showed more development compared to other species in terms of both the amount of bcm they removed from the soil and morphological characteristics (Leventoğlu, 2022).

Existing fields and producers especially in the coastal areas are excluded from this group. The need for organic matter increases in hot-arid or cold-humid regions. A good development process of the produced material is closely related to the physical and chemical properties of the soil environment in which it grows. The most commonly used method to improve and maintain the physical properties of the soil is to add materials of organic origin to the soil. Since humic acids are obtained by decomposing leonardite, which is in the natural mineral group, into smaller molecules after extraction processes, the Carbon, Hydrogen, and Oxygen bonds they contain react with the insoluble compounds and elements present in alkaline soils, allowing them to dissolve and be more easily absorbed by the nursery roots. Approximately 72% of the producers who participated in our survey did not prefer these products at all, and it was determined that the producers who used them used them in amounts that had a very weak effect on the soil. In addition to organic structures such as farm manure, litter, compost, green manure, biological fertilizer, and plant nutrition products obtained with these and similar inputs, it is necessary to increase the awareness of the producers, especially in our inner and eastern regions, to increase the promotion and launch of application methods and techniques and to increase the incentives for use.

4. Conclusion and Suggestions

Approaches in ecological agriculture practices have become more prominent with activities that are suitable for their purpose in recent years. Especially in Western countries, commodities and inputs used in agricultural activities serve this purpose. In Turkey, the situation is different. Unfortunately, the current state of the soil structure as a result of unconscious practices is in a position to turn agricultural activities to minimum levels after the next few decades.

Carrying out activities by the criteria of organic agriculture is no longer a whim, but a necessity considering the soil structure in Turkey. Human and animal health is under serious threat. The used inorganic (chemical) components used and the pesticides, chemical fertilizers, and other inputs created with them have become a threat to living life as well as the soil parent material.

The final situation caused by the unconscious and excessive use of such products in agricultural activities applied in Turkey harms the national economy. the value of product quality, quantity, and economic value is decreasing over time. The disease agents, residues, etc. that occur in the grown crops with inorganic products, trying to eliminate them with products of the same quality is a loss in every sense.

Promoting agricultural policies in Turkey that prioritize human and animal health, particularly regarding breeding, should be a key objective. In addition, sanctions should be applied to prevent the use of certain inputs that may cause environmental and climate issues. Water resources in Turkey, which are indispensable for agricultural activities and the life cycle and which are decreasing day by day, are being polluted and disappearing. The protection of a vital asset such as water will be ensured through ecological activities.

Thanks and Information Note

I am grateful to my professors at the Faculty of Agriculture and the Faculty of Forestry who guided me in gaining all my academic knowledge and skills as well as my years of experience in the realization of this study.

Throughout my 25 years of professional life, I owe a lot to my beloved family and especially to my wife and children, who have supported me at every stage of my life. I would like to thank my professors, whose names I have mentioned in the bibliography section, whose works I have referred to in the preparation of this publication, and whose valuable studies they have done in the past, which I had the opportunity to support my thesis.

I would like to thank Prof. Dr. Atila GÜL and his colleagues for bringing together distinguished academicians on such a useful subject, pioneering the creation of an excellent book, and working day and night as an editor.

Author Contribution and Conflict of Interest Disclosure Information

The author contributed fully to the article. There is no conflict of interest.

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Dr. Hakan LEVENTOĞLU

E-mail	:	d1740120001@isparta.edu.tr
Educational Status	:	Agriculture Engineer
MSc-	:	Eagen University-Faculty of Agriculture
PhD	:	Isparta University of Applied Sciences, The Institute of Graduate Education, Department of Forest Engineering
Professional experience	:	Soil science and plant nutrition

The Role of Plants in Reducing Air Pollution in Urban Planning

Assist. Prof. Dr. Aysel ULUS [1]

[1]İstanbul University-Cerrahpaşa, Faculty of Forestry, Department of Landscape Arhitecture, Valide Sultan Cad. No:2 Sarıyer, İstanbul/Türkiye.
ORCID: 0000-0002-9038-994X
E-mail: ulusay@iuc.edu.tr

Dr. Fatmagül BOLAT[2]

[2]İstanbul University-Cerrahpaşa, Vocational School of Forestry Valide Sultan Cad. No:2 Sarıyer, İstanbul/Türkiye
ORCID: 0000-0003-1714-3334
E-mail: fatmagul.bolat@iuc.edu.tr

Citation: Ulus, A., Bolat, F. (2023). The Role of Plants in Reducing Air Pollution in Urban Planning In Türker, H. B. & Bolat, F. (Eds.). **Architectural Sciences and Ecological Approaches**. 2023, Chapter: 12, 323-350. ISBN: 978-625-367-073-3. Iksad Publications.

1. Introduction

People have started to build cities from the moment they developed certain levels of production and related social organizations (Tuna, 2011). However, rapid urbanization followed in the footsteps of industrialization in the later part of the 18th century. It has continued with growing speed to this day. By the beginning of the 21st century, urban population had surpassed rural population for the first time in world history (UN, 2022). According to UN predictions, the world's urban population will reach 60% of the total in 2030 (UN, 2022). For this reason, some researchers refer to the current period as the "urban age" (Steiner, 2011).

Accelerated urbanization after 1945 has gone parallel to unrecorded levels of degradation of the environment and overconsumption of natural resources on a global scale, leading to drastic changes on the whole ecosystem (McNeill, 2000). Therefore, urbanization has often been considered as the source of these problems (Elmqvist et al., 2013). The intense and accelerating urbanization process brings with it some ecological problems. Urbanization affects all components of the environment and adversely affects the quality of life of urban dwellers and living creatures by creating environmental problems.

Urbanization is a process that is leading to degradation in green areas in the city or around it. Many urban planners tried to bring green or the "nature" back into the cities throughout the history of urban planning. Whether for ecological, aesthetic or economic reasons, the way to create more livable cities is always through increasing vegetation in other words green spaces.

Urban green spaces have several functions. They contribute to mitigate several environmental phenomena such as urban heat island (UHI) effect (Gunawardena et al., 2017), carbon sequestration (Strohbach et al., 2012) and the climate change (Mabon et al., 2019). They improve air quality by filtering pollutants (Heidt & Neef, 2008), they provide habitats for wildlife, and promote biodiversity. Green spaces also contribute to human well-being and provide other ecosystem services for the resilience and sustainability of cities (Bolund & Hunhammar 1999). They provide opportunities for recreational activities and social interactions. Green spaces have aesthetic values and can be a part of a cultural element of a city hence the identity of the city. They also have economical benefits by increasing the land value and support economical activities such as tourism or new job opportunities (Fam et al., 2008).

Urban green spaces should be designed and planned with certain principles in mind to maximize their potential functions. While these principles may vary based on city-specific variables such as urban planning policies, cultural, ecological, economic, and political structures, there are common goals that should be achieved in every planning (Türker & Gül, 2022). These goals include accessibility for all segments of society, producing ecological benefits while being interconnected, planning in line with sustainable principles, developing community awareness and increasing participation, suitability for various activities, contribution to biodiversity, and maintenance and sustainability at affordable costs. The right plant selection plays a significant role in achieving these goals. Easily pruned plants can be used for visual space control, while plants with various sensory qualities such as smell, texture, and form can be used for sensory guidance. By selecting natural species, green spaces can be designed sustainably, at low costs, while effectively providing ecosystem services. Edible landscapes and pollination gardens can also contribute to community awareness and the ecosystem. An important factor in selecting the right plant species is their ability to reduce air pollution.

The process of removing or neutralizing pollutants in an environment using various plants is defined as phytoremediation (Aybar et al., 2015). Strategic selection of tree, shrub, and ground cover species known for their efficacy in air purification within urban green areas can yield significant improvements in urban air quality. These species fulfill their filtering functions through their leaves and root systems and filter pollutants in the air such as carbon dioxide, nitrogen dioxide, particulate matter and volatile organic compounds. Furthermore, these plant species serve as barriers, effectively curbing the dispersion of pollutants. According to Eisenman et al. (2009), urban trees also reduce asthma by improving air quality. Considering that some of the plant species can trigger allergies, it is important to select propriate species to reduce asthma and allergic reactions. Thus, meticulous consideration in choosing right plant species contributes to a cleaner and healthier urban air environment.

2. Urban Green Spaces and Their Role in Reducing Air Pollution

Urban green spaces provide numerous advantages that help both humans and the environment. Urban green spaces contribute to ecological, economic and social structures of the city (Türker & Bakır, 2022).

Urban green spaces provide numerous advantages that help both humans and the environment. Urban green spaces contribute to ecological, economic and social structures of the city. However, the effectiveness of green spaces depends on choosing the right plant species and design strategies. The foremost function of urban green spaces is to support urban ecosystems in various ways. Plants are improving air quality through photosynthesis but also certain plant species possess exceptional air purification capabilities, effectively removing pollutants from the atmosphere by capturing or holding hold dust, pollen, chemical compounds, and other contaminants in the air (Yang, 2008). When choosing plants, their specific abilities in filtering various pollutants should be considered as well. For instance, deciduous trees are known for their effectiveness in absorbing gaseous pollutants, while conifers are more adept at capturing particulate matter.

In addition to their ecological benefits, green spaces provide economic advantages to cities. Designing and tending to thoughtfully conceived green spaces is known to have multiple positive outcomes such as increased property value, business and/or tourism attractivity. They contribute to economic development by creating job opportunities, supporting local businesses, and improving the quality of urban life.

Socially, green spaces offer opportunities for recreation, relaxation, and community engagement. Accessible and well-designed green spaces provide settings for physical activities, such as walking, jogging, and sports, which contribute to improved public health and well-being. These spaces also serve as gathering places for community events, cultural activities, and social interactions, strengthening the bonds between local denizens.

To ensure the effectiveness of green spaces, selecting the right plant species is crucial. Different plant species have varying capacities for air purification, and their suitability for specific pollutants should be considered. Proper implementation and design methods are equally important.

Tree groups such as urban forests, woods or green belts, for instance, are 2 to 16 times more successful in reducing air pollution than shorter vegetation (Tallis et al. 2011) while shrubs and hedges can be strategically placed to complement the air-filtering capabilities of trees. Permeability and porosity of green spaces should be considered, as they influence air flow and the contact between pollutants and leaves (Wesseling, 2004).

Designing green spaces with appropriate width, height, and spacing helps create protected areas and optimize air flow, reducing the negative effects of concentrated pollution. Implementing diverse plant species within green spaces enhances their ability to filter out various air pollutants.

Urban green spaces are critical for supporting ecological, economic, and social well-being. Choosing the correct plant species, together with smart implementation and design methodologies, improves air purification effectiveness and contributes to a healthier and more sustainable urban environment. Cities may leverage the multiple benefits afforded by green areas and create more livable and vibrant urban landscapes by emphasizing the selection of appropriate plants and implementing effective design tactics.

3. Air Pollution

Air is defined as a combination of gases that constitute up the atmosphere and is one of the most important environmental elements that enable humans and other living things to survive. In its pure form, air is a mixture primarily composed of nitrogen (78%) and oxygen (21%), accompanied by other gases such as carbon dioxide, argon, water vapor, neon, helium, methane, krypton, hydrogen, nitrogen monoxide, xenon, ozone, ammonia, and nitrogen dioxide. Carbon dioxide and noble gases are present at a rate of 1% (Müezzinoğlu, 1987). Air pollution is referred to as a change in the ratio of the gases that make up the air, negatively affecting the vitality and the environment.

Airborne pollutants are chemical substances that change the natural composition of the air and can be found in solid, liquid and gaseous forms. In general terms, emission pollutants can be classified as Combustion Gases (SO_2, NO_x, CO), Particulate Matter (PM), heavy metals, Volatile Organic Vapors and Compounds (VOC), Fluorine, Chlorine, Polycyclic Hydrocarbons (PAH), Dioxin-Furans, Radioactive Substances etc.

These pollutants affect the human respiratory tract, disrupting its normal mechanisms and causing inflammation and narrowing of the bronchi. As a result of these changes, chronic bronchitis, pharyngitis, laryngitis, breathing difficulties, asthma and emphysema are the most common types of diseases. Research shows that air pollution is an important cause of the occurrence and increase in lung cancer. It has also been determined that the lifespan of people living in regions with air pollution is 2-3 years shorter than those living in regions without air pollution. In addition, polluted air can also have negative psychological effects on people, reduce the body's resistance to epidemics and delay the recovery of diseases. These events are more effective especially on infants and children of developmental age, pregnant women, the elderly, those with chronic respiratory and circulatory system diseases, those working in industrial enterprises, smokers and those in low socioeconomic groups.

Carbon and Carbon emissions

The two most important components of carbon emissions are CO (carbon monoxide) and CO_2 (carbon dioxide). Carbon monoxide gas is colorless, tasteless, odorless and chemically inert (a chemical substance that does not react) and is a major air pollutant that is created when carbon-containing fuels are burned inefficiently. The effects of urban airborne carbon monoxide on human health are significant. The most significant of these effects is that carbon monoxide decreases hemoglobin's ability to transport oxygen in the blood. As the body receives less oxygen, this could result in death. Carbon monoxide concentrations are particularly high in cities with heavy traffic and congested roads.

Sulfur Oxides

Among gaseous pollutants, sulfur oxides, a non-flammable and colorless gas, are one of the best-known primary air pollutants. Fossil fuel combustion is the main source of sulfur oxides. According to estimates, industrial sources account for more than 80% of anthropogenic sulfur oxide emissions (Huang & Han, 2021). The most common sulfur oxides are sulfur dioxide (SO_2), sulfur trioxide (SO_3) and sulfur heptoxide (S_2O_7). There is between 0.5% and 6% sulfur in fossil fuels like coal and oil

(Reddy & Venkataraman 2002). The combustion of these fuels therefore releases sulfur into the atmosphere, mostly in the form of SO_2. SO_2 can affect lung function and the respiratory system and can cause eye irritation.

Nitrogen oxides

Nitrogen oxides (NO_X) are highly reactive gases formed at high temperatures (1200 °C). Most forms of nitrogen oxides are colorless and do not dissolve in water. The most important types in terms of air pollution are NO and NO_2 gases. Nitrogen monoxide (NO) and a small amount of nitrogen dioxide (NO_2) are usually formed as a result of combustion at high temperatures. NO released into the atmosphere turns into NO_2 as a result of oxidation. NO_2, which is widely present in the atmosphere, is a strong oxidant and can be seen as a reddish-brown layer in urban areas when present with particles.

Two major sources are motorized land and sea vehicles and thermal power plants. Other sources of NO_x include other industrial plants, fuel consumption for commercial and domestic heating. NO_x concentrations increase with the increase in the number of vehicles, especially in urban areas. Maximum NO concentrations occur mostly in the late fall and winter months. These months are characterized by the maximum need for heating energy, low wind speeds and the lowest solar radiation. NO_2 does not show seasonal variations like NO.

Exposure of healthy people to very high concentrations of NO_2, even for a short time, can cause severe lung damage. For people with chronic lung disease, exposure to these concentrations can lead to short-term lung dysfunction. Long-term exposure to NO_2 concentrations can lead to a significant increase in respiratory diseases.

Ozone (O_3)

Ozone is a highly reactive gas in the natural composition of the atmosphere, reaching the highest concentrations in the stratosphere. There is up to 8 mm^3 of ozone in $1m^3$ of air. Ozone is formed as a result of photochemical reactions on the earth's surface, especially in urban areas where nitrogen oxides and volatile organic compounds (VOCs) are concentrated and in summer months. One of the most important parameters affecting this reaction is sunlight and high temperature.

Since ozone is a secondary pollutant, it is directly related to other factors affecting air pollution and meteorological factors. Ozone is considered an air pollutant if it is in the breathing air (troposphere layer). Ground-level ozone (tropospheric ozone), on the other hand, is not a pollutant emitted into the atmosphere from pollutant sources but is formed in the atmosphere by the side effects of various pollutants, such as VOCs and NOx, and with the help of factors such as sunlight. The most important causes of increased ozone in urban areas are domestic heating and increased traffic load (Topçu & İncecik, 2002).

Particulate Matter (PM)

Particulate Matter (PM) are suspensions of solid and liquid substances in a gas, also called aerosols. Coarse particles with an aerodynamic diameter of less than 10 µm are defined as PM_{10}, while fine particles of less than 2.5 µm are called $PM_{2.5}$. This range corresponds to the majority of particles suspended in the atmosphere (Beckett et al., 1998).

Particles are divided into two groups: natural and anthropogenic. Examples of natural ones include pollen, spores, bacteria, viruses, protozoa, fungi and volcanic dust. Anthropogenic (artificial) ones include smoke, fly ash, metal oxides and other inorganic dusts.

Particulate pollution is a broad spectrum of pollution, including smoke and aerosols leaking into the atmosphere. The negative effects of such particles on human health have been thoroughly demonstrated by studies conducted in recent years. Especially PM_{10} concentrations and their effects on human health are an important research topic. The most important effect of particulate matter is irritation on the respiratory system. It is known to cause health problems such as heart diseases, impaired lung function, lung cancer and stomach cancer. Particulate matter with adverse effects consists of heavy metals, carbon, polycyclic aromatic hydrocarbons and other suspended matter and is predominantly of anthropogenic origin (Sæbø et al., 2012). Although particulate matter is emitted into the urban atmosphere from both natural and anthropogenic sources, the most notable source of PM is vehicular traffic (Watkins, 1991).

Sources of PM_{10} come from industrial plants in the form of smoke and dust; agricultural emissions and roads. Pollen can also be added naturally. $PM_{2.5}$ is associated with volatile organic compounds (VOCs), heavy metals, traffic and forest fires. PM_{10} can accumulate in the respiratory system and worsen the health of people with asthma, chronic lung and heart disease. Other pollutants in dust can travel deep into the lungs. Many of the fine particles can reach the alveoli in the lungs, where toxic substances can enter the bloodstream.

$PM_{2.5}$ is more dangerous than PM_{10} in terms of health effects. The smaller the particles, the easier it is to reach the lungs. Small particles can enter and be effective in closed environments. These particles can cause problems in the heart and respiratory tract and increase mortality rates. It is estimated that more than 500 000 people die annually due to $PM_{2.5}$ pollution in the world (İncecik & İm, 2013).

Volatile Organic Compounds (VOCs)

Organic compounds constitute a large fraction of the air pollutants commonly found in urban atmospheres. In general, they are compounds containing at least one carbon atom and one or more hydrogen, halogen (chloride, fluoride, bromide, etc.), oxygen, sulfur, phosphorus, silicon or nitrogen. Organic compounds are divided into three main groups: volatile, semi-volatile and non-volatile organic compounds. Volatile organic compounds (VOCs), which are among organic compounds, are chemically gaseous organic compounds in the ambient air and are important air pollutants found at ground level in the atmosphere in all urban and industrial areas. VOCs can be present in the air in gaseous form or bound to particles. VOC concentrations in the atmosphere are determined by emissions, evaporation, deposition and photochemical reaction processes in the presence of sunlight. The main sources are motor vehicles, incomplete combustion of fuels, evaporation of gasoline etc., decomposition and decomposition of plants and animals, chemical industries and power plants.

Biogenic Volatile Organic Compounds (VOCs)

As a result of their biological activities using sunlight, plants release significant amounts of volatile organic compounds into the atmosphere along with their main photosynthetic products. These volatile organic compounds (VOCs), which are of biogenic origin, are compounds produced by plants and play an important role in plant growth, development, reproduction and resistance to environmental influences.

BVOCs are mainly divided into four main groups: isoprene, monoterpenes, sesquiterpenes and others (oxygenated species, aliphatic and aromatic hydrocarbons, etc.), of which isoprene and monoterpenes are the most common species. VOCs cause ozone formation in the troposphere by entering into photochemical reactions with nitrogen oxides (NO_x) and therefore they are of great importance in atmospheric chemistry (Yaman et al., 2012). Especially isoprene is more reactive than many anthropogenic VOCs and is involved in the formation of oxidants in the atmosphere. Studies have shown that broadleaf species tend to emit isoprene, while coniferous species tend to emit monoterpenes (Yaman, 2013). On a global scale, BVOC emissions are predominantly produced by terrestrial vegetation (Pugh et al., 2013).

Heavy metals

The most important heavy metal pollutants from traffic are lead (Pb), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni) and zinc (Zn).

Lead: One of the biggest sources of air pollution is lead (Pb) from the exhaust of motor vehicles. Health problems caused by lead include decreased sensory and nerve communication speed, irreversible brain damage, anemia, moodiness, irritability, moodiness, headaches, muscle tremors, muscle coordination disorders and memory loss.

Cadmium: Cadmium is a silvery white metal. This metal quickly turns into cadmium oxide in the air. It is found in small amounts in nature. Cadmium is used in the metal industry and plastics. It is found in motor oils and tires of vehicles. It can enter the air as a result of combustion and tire wear. Excess cadmium causes hypertension because it damages the circulatory system. Cadmium deposits on living organisms are mostly seen in the kidney and liver.

Chromium: Chromium is a metallic element. The behavior of chromium in living organisms, especially in the human body, depends on the oxidation step and its chemical properties in the oxidation step and its physical structure in the environment. Chromium is used in metal alloying and as a pigment for paints, cement, paper, rubber and other materials. Exposure to low levels of chromium causes skin irritation and ulcers. Long-term exposure can cause damage to the kidneys and liver and can destroy the circulatory system and nervous tissues.

Copper: The effect of copper on plants and living organisms depends on its chemical form and the size of the organism. While it is a poison for small and simple creatures, it is a basic structural component for large creatures.

Nickel: Nickel is used in industry for plating, electronics, coins, batteries and in the food industry (as a catalyst) and in the production of stainless steel. Although nickel is a metal with low toxicity, it is formed during the interaction of active nickel with carbon monoxide. Nickel is emitted into the air as a result of the burning of fossil fuels. Nickel is absorbed into the body through the respiratory tract. It increases the risk of lung and nose cancer.

Zinc: Zinc is used in metal plating, alloys, paints, tires and cosmetics. It is released into the atmosphere in excessive amounts as a result of the wear and tear of automobile tires. They reach the soil environment through wet and dry precipitation. Very high doses of zinc in living organisms cause poisoning.

4. Plants and their effects on Air Pollutants

All plants have the ability to filter dust and gaseous pollutants from the air much more effectively than other surfaces (Fowler et al., 1989). Plants affect air quality directly and indirectly. In the direct effect, air pollutants are captured and bound by the leaves and root systems of plants. In the direct effect, depending on the planting method used, trees or tree communities affect the concentration and distribution of air pollutants by changing wind speed and turbulence. As a result, which plant is used is as important as the methods used.

In order to reveal which species are more effective against air pollutants, pollutants can be grouped under three main headings: gaseous pollutants, particulate matter and organic compounds.

4.1. Capture and binding of gaseous pollutants by plants

Plants both absorb gaseous pollutants through the stomata and deposit them on the cuticle. The cuticle is the outermost layer of the leaf. It is composed of oil-containing substances and protects the plant from drying out. Stomata allow the leaf to continuously exchange gas with its environment, i.e. air in and out.

Nitrogen oxides and ozone are mainly taken up by the leaf through the stomata. Each leaf has a network of cavities, i.e. a large system of many cavities in its interior. These cavities, through the stomata, provide the leaf's connection and contact with the air in the external environment. The carbon dioxide of the air in the cavities inside the leaf is taken up by the cells of the leaf, oxygen and water are given to the outside air. The gaps in the leaf greatly increase the leaf surface and therefore the gas exchange capacity.

Large quantities of air have to flow through the leaves in order for the plant to take up enough carbon dioxide. The permeable structure of the tree, formed by its branches, shoots and leaves or needles, allows the wind and other elements in the air to come into contact with the spaces inside the leaf (Gromke, 2011). It is known that nitrogen oxides and ozone dissolve well and that the absorbed parts are reprocessed and exchanged in the leaf. Stomata are open during the day and closed at night. Therefore, the filtration of gaseous pollutants from the air by plants is greater during the day than at night (Nowak, 1994).

4.2. Retention of Particulate Matter

Particulate matter either spontaneously falls on the leaf or is attached to the leaf by the wind (impaction). If the particulate matter comes into direct contact with the leaf, the particulate matter is electrostatically attracted. Indentations and protrusions on the leaf, i.e. roughness or hairs on the leaf surface, increase this electrostatic effect. The wetness of the leaf, the stickiness of the leaf, and the dense branching and dense leafiness of the tree crown are also effective (Figure 1).

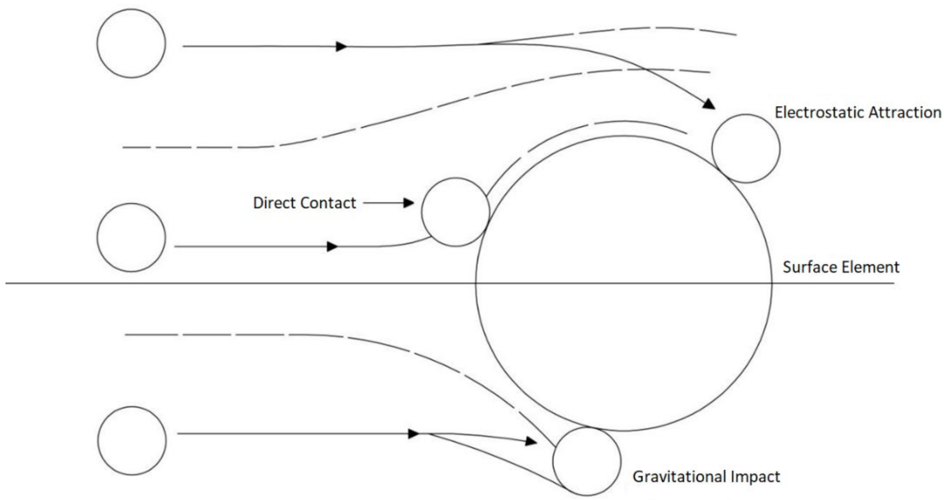

Figure 1. The mechanism by which airborne particles move away from the air stream as a result of contact with a surface (Boubel et al., 1994).

Coniferous trees in particular retain particulate matter very well. Particulate matter is retained not only by needles or broad leaves, but also by the trunk, branches and shoots of the plants. A very dense and thickly branched, irregularly branched canopy has a positive effect. Since particulate matter cannot reach the inner parts of the leaf, it is not treated like gaseous pollutants. They remain on the tree for a long time in the form of dust particles. The filtering of this dust by trees and plants is the result of their resistance to wind. Throughout the year, the amount of dust particles trapped by the leaves gradually increases (Bealey et al., 2007).

Some of the dust particles trapped by the leaf remain attached to the leaf in such a way that they cannot be separated from the leaf. Another part is washed away by strong winds and rain. Dust that has fallen to the ground is either carried with the water to the sewers or is retained and stored for a very long time. Some compounds attached to dust particles or particulate matter are decomposed and rendered harmless by microorganisms in the soil (Beckett et al., 1998).

4.3. Retention of volatile compounds

The uptake of many volatile organic compounds by plants occurs as follows: The cuticle seems to be the most important transportation route for the uptake of many volatile compounds such as PCBs, dioxin, furans, etc. The aforementioned substances and compounds are generally insoluble in water but are well soluble in the fatty tissue of the cuticle (Fowler et al., 1989). Thus, it is through the cuticle that leaves take up and bind volatile organic compounds. This also has the following advantage. The uptake of volatile organic compounds through the cuticle continues even at night when the stomata are closed. The same is true for the winter months. Volatile organic compounds are taken up by the leaves even during periods of reduced activity of evergreen plants. These volatile compounds taken up by the cuticle are slowly (gradually) transferred to the inner parts of the leaf. Leaves with a thick cuticle layer are best suited for the removal of volatile organic pollutant compounds or substances from the ambient air. Accordingly, many coniferous tree species are suitable for this purpose.

5. Principles for the choosing the right species for improving air quality

As a result, the principles to be considered in plant species selection are as follows:

- Coniferous plants are more effective than deciduous plants in filtering particulate matter.
- Within the deciduous trees category, rough and hairy leaf surfaces are more effective than smooth and flat leaves in retaining particulate matter (Beckett et al., 2000).
- Within deciduous trees, smooth and smooth surfaces are more efficient in absorbing nitrogen oxides than rough and hairy surfaces.
- Evergreen plants retain more particulate matter than deciduous plants (Nowak et al., 1998).
- Trees with large leaf surfaces retain more particulate matter than those with small leaf surfaces (Nowak et al., 1998).
- Deciduous trees are more efficient than conifers in absorbing nitrogen oxides.
- Plants with a large leaf surface retain more nitrous oxide than species with a small leaf surface. Therefore, trees are more effective than shrubs.
- Trees and shrubs absorb nitrous oxides, the more nitrous oxides they store, the less ozone is formed (Benjamin & Winer , 1998).
- Trees and shrubs can also absorb ozone itself (Baldocchi et al., 1987).

- In the selection of tree species, species that emit allergens and volatile organic compounds should not be preferred.

The final design of a Green Space Planning is therefore always should be custom, which specialized knowledge is required about trees, their growth characteristics and their ecological demands. Research projects on this subject have been conducted in many countries in recent years. The focus is on knowledge of the urban climatology and the effect of trees and green structures on air currents. Planting and maintenance of appropriate tree species should be considered carefully. Computer-aided simulations are being used to analyze the effects of different planting techniques and compositions on the microclimate and the transport of contaminants.

The basic principle to be considered in the green space planning in terms of filtration of air pollutants is: All trees (and other vegetation) remove contaminants from the air and are effective for the local and regional air quality improvement. Regional protection depends primarily on large-scale contamination to improve the overall air quality of the air filter. This called as the "mass filter". On municipal level the following general recommendations can help to keep the effective surface in green status and to enlarge (Table 1).

Table 1. Recommendations for the effective use of green in the city.

1	Boost natural filtering capacity through proactive tree plantation policy.
2	Optimize growing space and access to water, nutrients and protection against mechanical and natural harmful impacts to ensure the wellbeing hence the capacity to filter of the trees.
3	To ensure that trees can grow successfully.

4	Trees that are adapted to the urban environment and require little care must be selected.
5	Diversity of plant species is necessary to filter out as many pollutants efficiently.
6	Coniferous plants (preferably evergreen) are effective on absorption of particulate matter throughout the year.
7	Deciduous trees with rough and hairy leaves are effective on intercepting particulate matter.
8	Deciduous trees with flat, broad leaves are effective on absorption of nitrogen oxide and ozone.
9	It should be avoided from the use of sensitive plant species to air pollution.

In the vicinity of an emission source, e.g. a busy street, green spaces and structures can help to reduce the concentration of pollutants on the spot (local protection) (Table 2). One should anticipate diminished concentration only locally and mostly against the dominant direction of the winds. The protective effect can be strengthened if at some distance, a second row of trees will be planted.

Table. 2. Recommendations for planting near an emission source

1	The treetop must transmit polluted air (with >50 percent porosity), whether through the proper species selection or through targeted maintenance.
2	Trees should not prevent the airflow in the vicinity of the source (so-called 'green tunnel effect').
3	Trees should be combined with a lower planting of herbaceous plants and shrubs to have at various heights effective leaf mass.
4	Highly branched trees affect air circulation and thus also the pollutant concentration, even if there is no more leaves on the tree.
5	The arrangement of the trees should follow a perpendicular alignment with respect to the direction of the air flow and be consistently replicated throughout the area.
6	There should be an unobstructed lateral flow around the plants.
7	

	Plantings should be located not only in the vicinity of the emission source, but also for sensitive areas such as schools, hospitals and retirement homes.

Trees affect the local climate. Especially the shading effect of trees is very important, but also the increase in humidity due to evaporation through the leaves is useful (Table 3).

Table. 3. Planting for shading effect

1	Trees prevent overheat of urban atmosphere by embowering the firm ground and cars.
2	Alternative green structures such as green facade, pergolas and roof green can be used when there is no room for trees, or if the airflow is too limited.
3	It is important to provide adequate root zone for trees (keeping the seed disc) in order to have a fully growth and a high evaporation rate.

6. Conclusion and Suggestions

Plants play a pivotal role in mitigating pollution within urban planning by actively addressing environmental challenges such as the urban heat island effect, carbon sequestration, and climate change. They effectively enhance air quality by acting as natural filters, removing pollutants from the atmosphere, while also providing valuable habitats for wildlife and promoting biodiversity. Moreover, green spaces offer recreational opportunities, enhance human well-being, and generate economic benefits. However, to optimize the effectiveness of green spaces, meticulous attention must be given to the selection of plant species and the implementation of design strategies. Different plant species possess varying abilities to purify the air, necessitating careful consideration of their suitability for specific pollutants. Thoughtful choices of trees, shrubs, and ground cover species, known for their air purification efficacy and their capacity to capture and retain dust, pollen, chemicals, and other airborne contaminants, are essential. Additionally, the design of green spaces should incorporate factors like tree groupings, permeability, and porosity to optimize airflow and facilitate effective pollutant interception. By adhering to these principles and selecting appropriate plant species, urban green spaces can significantly contribute to the reduction of air pollution, fostering a cleaner and healthier urban environment.

In cities, where various environmental problems arise from urbanization such as high population density, traffic, impermeable surfaces, and intense construction-related pollutants, plants and greenery are important problem-solving materials. However, these plants can exhibit their expected performance through proper species selection. The careful selection of plants holds paramount importance in establishing verdant spaces that not only combat air pollution but also substantially contribute to the ecological services within urban environments. It is crucial to recognize that inappropriate plant choices can lead to adverse consequences, including the exacerbation of air pollution levels, health complications, escalated maintenance expenditures, and inefficient water usage. Consequently, the development of sustainable and resilient cities hinges upon the meticulous planning of green areas, underpinned by judicious plant selection that incorporates scientific and ecological consideration.

Thanks and Information Note

The article complies with national and international research and publication ethics.

This article is based on the report on "Eurasia Tunnel European Side Ventilation Shaft Surrounding Planting Project" prepared by the late Prof. Dr. Yahya AYAŞLIGİL together with Aysel ULUS and Fatmagül BOLAT between 2015-2016. We would like to dedicate it to the memory of our departed colleague and professor.

Author Contribution and Conflict of Interest Disclosure Information

There is no conflict of interest. All authors contributed equally to the article.

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Assist. Prof. Dr. Aysel ULUS		
E-mail	:	ulusay@iuc.edu.tr
Undergraduate	:	Istanbul University, Faculty of Forestry, Department of Landscape Architecture, 1990
MSc	:	Istanbul University, Institute of Graduate Studies in Sciences, Department of Landscape Architecture, 1993
PhD	:	Istanbul University, Institute of Graduate Studies in Sciences, Department of Landscape Architecture, 2001
Professional experience	:	Assistant Professor, Istanbul University, Faculty of Forestry Department of Landscape Architecture (1993-2016) Assistant Professor, Istanbul University-Cerrahpaşa, Faculty of Forestry Department of Landscape Architecture (2016-…)

Dr. Fatmagül BOLAT		
E-mail	:	fatmagul.bolat@iuc.edu.tr
Undergraduate	:	Cukurova University, Faculty of Agriculture, Department of Landscape Architecture. 2003.
MSc:	:	Cukurova University, Institute of Natural and Applied Sciences, Department of Landscape Architecture, 2006
PhD	:	Istanbul University-Cerrahpasa, Institute of Graduate Studies, Department of Landscape Architecture, 2021
Professional experience	:	Lecturer Artvin Coruh University Faculty of Forest, Department of Landscape Architecture. (2008-2011) Research assistant: Isik University Faculty of Design and Architecture Department of Landscape Architecture. (2011-2012) Lecturer Cerrahpasa University Vocational School of Forestry (2018-……)