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CARBON SINK POTENTIAL OF GREEN BELT AFFORESTATION

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Abstract. In the fight against climate change, forest ecosystems and green belt afforestation that draw down atmospheric carbon dioxide are vital carbon sinks. Beyond carbon storage, these practices deliver multifaceted ecosystem services such as erosion prevention, biodiversity conservation, and the improvement of air quality. This review examines the effects of green belt afforestation on carbon sinks in the light of the national and international literature. Applications worldwide — China's Three-North Shelterbelt, Africa's Great Green Wall, and schemes in Europe — demonstrate that substantial amounts of carbon are stored in biomass and soil. However, large-scale projects in arid and semi-arid regions, as in China, can adversely affect the hydrological balance by increasing water consumption. This makes it essential to strike a delicate balance between carbon capture and the management of water resources. Consequently, the success of green belt projects should not be measured solely by the number of seedlings planted. In future projects, carbon capacity, water balance, and biodiversity should be evaluated together, and ecosystem-based planning should be undertaken in the right place and with the right species.

Keywords: green belt afforestation, carbon sinks, carbon sequestration, climate change, sustainable forestry, ecosystem services.

ЖАСЫЛ БЕЛДЕУЛЕРДІ ОРМАНДЫ ӨСІРУДІҢ КӨМІРТЕГІН СІЦІРУ ӘЛЕУЕТІ

Андапта. Климаттың өзгеруімен күресуде атмосфералық көміртегі диоксидінің деңгейін төмендететін орман экожүйелері мен жасыл белдеулерді орманды өсіру тәжірибелері маңызды көміртегі қоры болып табылады. Бұл зерттеудің мақсаты ұлттық және халықаралық әдебиеттер негізінде жасыл белдеулерді орманды өсірудің көміртегі қорларына әсерін кешенді түрде бағалау болып табылады. Жұмыстың ғылыми және практикалық маңызы көміртегін тұту мен су ресурстарын басқару арасындағы теңгерімді анықтауда жатыр. Зерттеу әдістемесі дүниежүзіндегі ірі жобалардың — Қытайдың Үш Солтүстік қорғаныс белдеуінің, Африканың Ұлы Жасыл қабырғасының және Еуропадағы бағдарламалардың нәтижелерін талдауға негізделген. Негізгі нәтижелер көрсеткендей, бұл жобалар биомасса мен топырақта көміртегінің айтарлықтай мөлшерін жинақтауға мүмкіндік береді. Дегенмен, аридті және жартылай аридті аймақтардағы ауқымды орман өсіру су тұтынуды арттырып, гидрологиялық тепе-теңдікке кері әсерін тигізуі мүмкін. Жүргізілген зерттеудің құндылығы орман өсіру жобаларының сәттілігі тек отырғызылған көшеттердің санымен өлшенбеуі тиіс екендігін дәлелдеуінде. Тәжірибелік маңызы ретінде болашақ жобаларда көміртегі сыйымдылығы, су балансы және биоәртүрлілік бірге бағаланып, экожүйеге негізделген жоспарлау дұрыс орында және сәйкес ағаш түрлерімен жүргізілуі тиіс деген қорытынды жасалды.

Түйін сөздер: жасыл белдеулерді орманды өсіру, көміртегі қорлары, көміртегі секвестрленуі, климаттың өзгеруі, тұрақты орман шаруашылығы, экожүйелік қызметтер.

ПОТЕНЦИАЛ ДЕПОНИРОВАНИЯ УГЛЕРОДА ПРИ СОЗДАНИИ ЗАЩИТНЫХ ЛЕСНЫХ ПОЯСОВ

Аннотация. В борьбе с изменением климата лесные экосистемы и создание защитных лесных поясов (зеленых поясов), снижающие уровень атмосферного углекислого газа, играют роль важнейших стоков углерода. Целью данного исследования является комплексная оценка влияния лесоразведения в зеленых поясах на углеродные пулы в свете национальной и международной литературы. Научная и практическая значимость работы заключается в определении баланса между улавливанием углерода и управлением водными ресурсами. Методология исследования основана на аналитическом обзоре результатов крупнейших мировых проектов — Трех-Северного лесного пояса в Китае, Великой зеленой стены в Африке и экологических программ в Европе. Основные результаты показывают, что масштабные посадки позволяют аккумулировать значительные объемы углерода в биомассе и почве. Однако реализация таких проектов в аридных и полупустынных регионах может нарушить гидрологический баланс из-за повышенного водопотребления насаждений. Ценность проведенного исследования заключается в обосновании того, что успех зеленых поясов нельзя оценивать исключительно по количеству высаженных семян. Практическое значение итогов работы заключается в рекомендации внедрения принципов экосистемного планирования в будущих проектах лесоразведения, где углеродная

емкость, водный баланс и биоразнообразие должны оцениваться совместно, с подбором правильных видов деревьев для конкретных лесорастительных условий.

Ключевые слова: лесоразведение в зеленых поясах, стоки углерода, секвестрация углерода, изменение климата, устойчивое лесное хозяйство, экосистемные услуги.

1. Introduction

From the Industrial Revolution to the present day, the growing use of non-renewable energy, together with rapid population growth, industrialisation, urbanisation, and changes in land use, has led to a substantial rise in atmospheric greenhouse gas concentrations. The accumulation of greenhouse gases – particularly carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) – affects the global climate system, driving increases in temperature, shifts in precipitation regimes, and a greater frequency of drought, flooding, and extreme weather events [14]. The fact that the global mean temperature has risen by approximately 1.1 °C relative to the pre-industrial period demonstrates that climate change is no longer a threat anticipated for the future but a global environmental problem whose effects are already being felt today [14]. As one of the most visible components of nature-based solutions in the fight against climate change, green belt afforestation plays an important role in offsetting anthropogenic emissions by creating carbon-sink areas on the urban fringe [14].

In combating climate change, capturing atmospheric carbon through natural processes is as important as reducing greenhouse gas emissions. In this context, carbon sinks are defined as mechanisms that absorb atmospheric carbon dioxide and store it in biomass, soil, oceans, and other natural systems [15]. Among carbon sinks, forest ecosystems occupy a prominent place owing to their large areal extent, high biomass productivity, and long-term carbon-storage capacity. Through photosynthesis, forests draw carbon from the atmosphere and store it in living biomass components such as the stem, branches, leaves, and roots, while also retaining it for long periods in dead organic matter and soil organic matter [12]. Forest ecosystems worldwide are reported to store approximately 662 billion tonnes of carbon, which constitutes a significant proportion of global carbon stocks [13] (Figure 1).

Distribution of the global forest carbon stock



Figure 1. Distribution of the global forest carbon stock (approximately 662 Gt C) among soil organic matter, living biomass, and dead wood and litter. Source: FAO [13].

The carbon-storage function of forests is not limited to existing carbon stocks; forests also contribute to the removal of significant amounts of carbon from the atmosphere each year. For this reason, afforestation, reforestation, and sustainable forest management are regarded as among the most effective nature-based solutions for mitigating climate change [2,8]. Indeed, a global assessment of natural climate solutions estimated that conservation, restoration, and improved land-management actions — of which forest pathways constitute the largest share — could provide a substantial fraction of the mitigation required to hold warming below 2 °C [25]. In recent years, particularly in regions experiencing rapid urbanisation, green-infrastructure systems and green belt applications have been regarded as important instruments in the fight against climate change.

Green belts are ecological systems composed of wooded areas, stands, recreation areas, walking areas, and other green spaces created around cities or in particular locations. Initially developed to prevent the unplanned sprawl of cities, green belt applications today fulfil numerous ecological, environmental, social, and economic functions [1]. These areas provide multifaceted contributions such as improving air quality, preventing erosion, conserving biodiversity, reducing noise pollution, and enhancing recreational opportunities [9].

One of the most important ecosystem services of green belt afforestation is carbon sequestration. Carbon sequestration refers to the process by which atmospheric carbon dioxide (CO₂) is captured by plants and soil and stored over the long term [16]. As the biomass that develops through afforestation increases, the amount of carbon stored increases proportionally. Fast-growing tree species can fix high amounts of carbon in a short time, whereas long-lived species contribute to the formation of larger carbon stocks over the long term [17].

Carbon storage does not occur only in the roots, stems, and branches of trees. Forest soils are also recognised as an effective carbon pool within the global carbon cycle. Soil organic carbon forms through the decomposition of plant residues and the accumulation of root biomass and can be stored for long periods [18]. The increase in the amount of organic matter entering the soil through afforestation contributes, over time, to an increase in soil carbon stocks. This demonstrates that, over the long term, green belt afforestation can store substantial amounts of carbon not only in biomass but also in the soil [19].

Studies conducted within the scope of urban forestry reveal that the carbon-sequestration capacity of urban trees and green spaces is considerable. While young stands can fix high amounts of carbon during their rapid-growth phase, older stands form larger carbon stocks [20]. In addition, various studies have shown that mixed-species stands have higher biomass productivity and carbon-storage potential than single-species stands [21]. Therefore, in green belt afforestation, not only the size of the area but also species diversity and sustainable forestry should be taken into account.

Studies carried out worldwide show that green belts are of strategic importance for carbon management. In particular, green belt afforestation applied in East Asian and European countries has been found to make important contributions to the protection and enhancement of carbon stocks [6]. Türkiye, owing to its different climatic zones and rich ecological conditions, has considerable potential for afforestation. The erosion-control, rehabilitation, and afforestation efforts undertaken in recent years contribute to increasing the country's carbon-storage capacity. Alongside general afforestation efforts, however, the number of studies that evaluate green belt afforestation specifically in terms of carbon storage and carbon sequestration is limited. Within the scope of combating climate change, revealing the carbon-sink functions of these areas and integrating them into management strategies is of great importance.

2. Green Belt Afforestation

Green belt afforestation refers to afforestation and planting activities established in a planned manner around sensitive ecosystems. It lies at the intersection of the disciplines of modern forestry and urban ecology and is regarded as an important component of sustainable land use. One of the most important functions of green belt afforestation is carbon sequestration — the storage of carbon dioxide by plants. During the growing season, trees store carbon in their roots, stems, branches, and leaves; for this reason, green belt afforestation is recognised as an important carbon-sink area. Its carbon-storage capacity is influenced by many factors, including species selection, climatic conditions, soil structure, the silvicultural interventions applied, and stand age. Whether a stand is mixed or single-species also affects its storage capacity. Mixed-species stands are reported to offer higher ecosystem resilience and carbon accumulation efficiency than monoculture plantations [7]; a recent global analysis of paired plantations likewise found that multispecies stands accumulate, on average, about 25% more aboveground biomass than monocultures [27]. Green belt afforestation is implemented for purposes such as storing carbon, preventing erosion, forming windbreaks, preventing air pollution, reducing noise, and creating recreation areas. One of the most important examples of green belt afforestation in the world is the Three-North Shelterbelt Programme in China.

3. Green Belt Afforestation in the World

Green belt afforestation is one of the important forestry activities applied worldwide to mitigate environmental problems; to combat drought, fire, and desertification; to control urban growth; to conserve biodiversity; and to increase carbon-sink areas. Particularly since the second half of the twentieth century, the pressures placed on natural areas as a result of rapidly increasing population, industrialisation, and urbanisation have led to the spread of green belt applications in many countries [9]. Today, green belts are considered not only an element of urban planning but also part of nature-based solutions in the fight against climate change [14].

In the modern forestry sense, the first applications of the green belt concept emerged in England. Various planning policies were developed, particularly after the Second World War, to prevent the unplanned growth of cities. Within this framework, the London Green Belt is regarded as one of the world's best-known green belt examples. It covers an area of more than approximately five hundred thousand hectares and comprises forests, agricultural land, pastures, and natural habitats [1]. Through this application, the undesirable spread of urbanisation has been limited, the continuity of natural areas has been protected, and recreation areas have been provided for city residents.

Alongside the well-known London Green Belt, the world's largest green belt afforestation effort is being carried out in China. This effort, the Three-North Shelterbelt Programme launched in 1978, is also popularly known as China's Green Great Wall. At its core lie the aims of preventing desertification, reducing sandstorms, protecting agricultural land, controlling erosion, and increasing carbon-storage capacity. According to data from the Chinese government, approximately 50 billion seedlings have been planted and millions of hectares afforested under the programme. Research has shown that substantial amounts of carbon have been stored and that vegetation cover has increased as a result of the programme [3]. At the same time, the project has become open to various criticisms. In particular, it has been argued that intensive afforestation in arid regions lowers groundwater levels and places pressure on the water balance [10,11]. China's Green Great Wall therefore demonstrates that the relationship between carbon storage and the conservation of water resources must be carefully evaluated.

South Korea is one of the countries with intensive urbanisation; nevertheless, it is among the countries that have successfully maintained green belt applications for many years. The green belt established around the capital, Seoul, in particular, was created to control urban sprawl. Research shows that these green belt areas make important contributions not only in terms of carbon-storage capacity but also in conserving biodiversity, improving air quality, and providing recreation services [6].

The most important green belt project on the African continent, the Great Green Wall, encompasses large-scale restoration and afforestation efforts carried out along the Sahel belt to the south of the Sahara Desert. Led by the African Union, the fundamental aims of this initiative are to prevent desertification, increase soil fertility, reduce poverty, increase carbon-storage capacity, and restore ecosystems. According to United Nations data, the project aims, upon completion, to restore millions of hectares of degraded land and to store significant amounts of carbon [22]. In the United States, large-scale protective green belt afforestation was carried out following the Dust Bowl disaster of the 1930s.

Türkiye, with its different climate types, topographic structure, and rich ecological diversity, is among the countries where afforestation has been practised for many years. Increasing urbanisation, industrialisation, the risk of desertification, and pressures on natural resources, particularly after the 1950s, have heightened the importance of green belt afforestation. Green belt afforestation efforts in Türkiye are prominent around large cities, and their fundamental aim is to protect natural resources and to provide healthier living spaces for urban populations. When green belt applications worldwide are considered, it is seen that, despite being established for different purposes, they offer certain common benefits: erosion control, prevention of desertification and air pollution, conservation of biodiversity, development of recreation areas, control of urbanisation, and the increase of carbon sinks.

4. Material and Method

This study was prepared to evaluate the effects of green belt afforestation on carbon sinks. Its material comprises scientific articles, theses, proceedings, technical reports, books, and institutional publications. Within the scope of the literature review, scientific sources were examined using the keywords carbon sequestration, carbon storage, carbon sinks, green belt, green belt afforestation, urban forestry, climate change, combating climate change, afforestation, and sustainable forestry.

On the basis of the data obtained from the literature review, the studies were evaluated under the headings of the green belt concept and its applications, carbon sinks and forestry, green belt afforestation worldwide, carbon sequestration and carbon storage, and the environmental effects of large-scale afforestation projects. In particular, the Three-North Shelterbelt Programme in China, the Great Green Wall project in Africa, and green belt afforestation projects in Europe were examined, and studies addressing the outcomes of these projects in terms of carbon storage, combating climate change, and ecosystem services — as well as the effects of large-scale afforestation on water balance, biodiversity, and ecological sustainability — were evaluated. The data obtained were analysed and the findings of the studies were interpreted comparatively.

5. Discussion

Green belt afforestation has become one of the most prominent nature-based solutions in the fight against climate change in recent years. Large-scale afforestation projects are implemented in many parts of the world to reduce the amount of atmospheric carbon dioxide through plants, to increase carbon-sink areas, to prevent erosion and desertification, and to restore degraded ecosystems to a functional state. In the face of rising carbon emissions at the global scale in particular, afforestation is often regarded as a rapid and effective solution. Green belt afforestation generally provides important benefits such as carbon sequestration, erosion control, combating desertification, conserving and supporting biodiversity, and improving air quality.

The long-term effects of intensive afforestation carried out in arid and semi-arid areas, in particular, have become an important subject of debate among scientists. At the centre of these debates lies the Three-North Shelterbelt Programme in China. Launched in 1978 and planned to continue until 2050, this project is regarded as one of the largest afforestation efforts in the world. According to data released by the Chinese government, tens of billions of seedlings have been planted under the programme, millions of hectares have been afforested, and significant progress has been made in combating desertification in the northern parts of the country [3]. The frequently cited statements that “more than 50 billion seedlings have been planted” are striking in demonstrating the scale of the project. When the positive aspects of the project are considered, important successes are evident, particularly in reducing sandstorms, controlling erosion, and increasing vegetation cover. Studies based on satellite imagery have shown that vegetation density has markedly increased in the northern regions of China [3]. Moreover, it is reported that a significant amount of carbon has been stored and carbon sequestration enhanced through the project, and the Three-North Shelterbelt is therefore presented by many international organisations as a successful afforestation initiative in the fight against climate change.

However, the project has not only been presented as a success but has also drawn criticism. Research over the past two decades, in particular, has drawn attention to the effects of large-scale afforestation on the water balance. At the heart of these criticisms lies the view that intensive afforestation in arid and semi-arid regions can disrupt the natural water cycle [11]. As is well known, trees consume water to sustain their growth, and fast-growing species in particular have high evapotranspiration rates. Because precipitation is scarce and limited in arid regions, an increase in the amount of water consumed by trees can reduce the recharge of groundwater reserves. Some studies conducted in northern China have shown that soil moisture has decreased and groundwater levels have fallen in afforested areas [10].

Studies carried out on the Loess Plateau, in particular, have revealed that although the increase in vegetation cover produced positive outcomes for carbon storage, water consumption at the catchment scale also increased. Feng et al. [10] reported that ecological restoration increased the ecosystem's carbon-storage capacity, while subsequent work by the same research group

demonstrated that the rising evapotranspiration associated with revegetation is bringing the Loess Plateau close to its sustainable water-resource limits, beyond which human water demand would be compromised [26]. This indicates that a balance must be struck between increasing carbon-storage capacity and conserving water resources. Jackson et al. [11], in a particularly striking assessment, stated that in some regions water is effectively traded for carbon.

Nevertheless, it would not be correct to adopt a one-sided approach when evaluating the water-balance criticisms in China, because a significant proportion of the regions in question faced serious problems of erosion, desertification, and land degradation before the project. It is generally known that, through afforestation, soil losses have been reduced, sand movement has been limited, and agricultural productivity has increased in some areas [3]. Therefore, when the project is evaluated in its overall scope, it can be regarded neither as a complete failure nor as a flawless application.

From a scientific standpoint, the real issue is not afforestation itself but where and with which species it is carried out. In their assessments, many researchers note that the characteristics of natural ecosystems were not sufficiently taken into account in China's early applications and that high water-consuming species were preferred in some regions [4]. In addition, it is known that monoculture plantations established over large areas reduce ecological resilience and provide limited benefit for biodiversity compared with mixed plantations. At this point, the new approach that has emerged in recent years is to proceed according to the principle of the right afforestation in the right place.

When this approach is considered, it is seen that, although green belt afforestation efforts worldwide share similar aims in terms of carbon-sink capacity, they produce different outcomes. The Three-North Shelterbelt Programme in China is a large-scale project covering millions of hectares and has achieved important gains in increasing carbon-storage capacity [3,5]. By contrast, although green belt afforestation in South Korea has been carried out over more limited areas, it has produced successful results in protecting existing carbon stocks, limiting land-use change, and sustaining ecosystem services around cities [6]. Green belts applied in European countries, meanwhile, are generally managed with a multi-purpose approach that, alongside carbon storage, includes conserving biodiversity, developing recreation services, and controlling urban sprawl [1].

When the studies in the literature are examined, it is seen that green belt afforestation increases carbon sequestration and enhances the storage of atmospheric carbon in biomass and soil. When evaluated in terms of water balance, green belt afforestation has both positive and negative effects. Afforestation reduces erosion, increases the water-holding capacity of the soil, and can support the infiltration of precipitation. However, intensive afforestation in arid and semi-arid regions in particular can increase evapotranspiration and thereby cause a decline in soil moisture and groundwater levels [10,11,26]. This shows that the success of green belt afforestation is determined not only by the amount of carbon stored but also by water balance, biodiversity, ecosystem sustainability, and the climatic and hydrological characteristics of the region.

Considerable differences exist among various green belt and urban green-space applications in terms of carbon-storage capacity. For China, Fang et al. [5] reported — on the basis of a fifty-year national forest inventory — that the carbon stock in the country's forest biomass was approximately 5.06 Pg C in 1949, declined to about 4.38 Pg C by the early 1980s, and subsequently rose to 4.75 Pg C by 1998, with planted forests sequestering roughly 0.45 Pg C since the mid-1970s and their mean carbon density increasing from 15.3 to 31.1 Mg C ha⁻¹ (Figure 2). It should be noted that these figures describe the trajectory of China's forests at the national scale rather than the Three-North Shelterbelt Programme alone; they nonetheless illustrate how a forest estate can shift from a net carbon source to a net sink as afforestation and regrowth proceed.

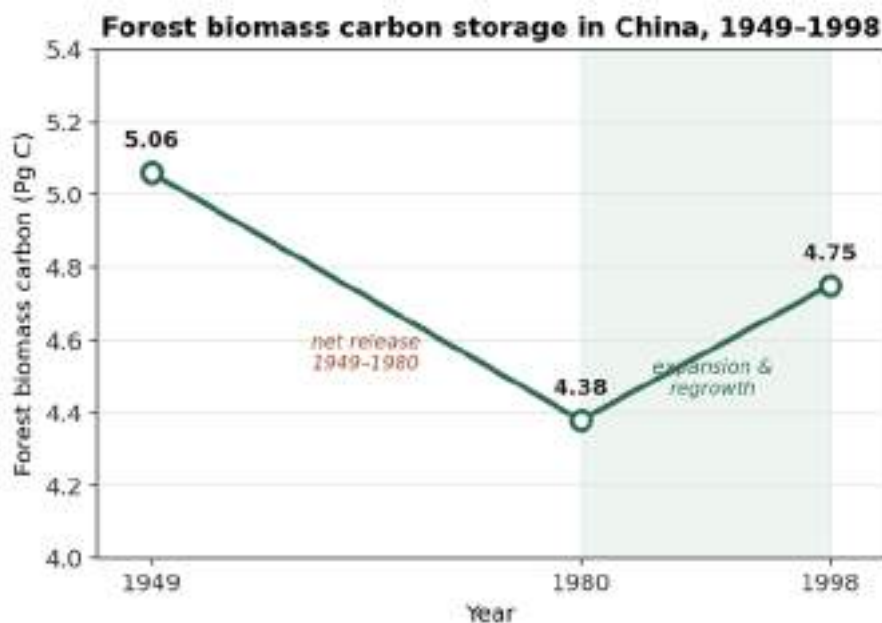


Figure 2. Trajectory of forest biomass carbon storage in China between 1949 and 1998: a net release until about 1980, followed by recovery driven by forest expansion and regrowth. Data: Fang et al. [5].

In South Korea, studies of urban green spaces have quantified carbon storage at both the stand and the city scale. In a study of an urban park in Daejeon, mean carbon storage was determined to be 15.3 t C ha^{-1} , reaching 21.4 t C ha^{-1} in some grid cells [23]. At the city scale, surface-soil carbon stocks (0–30 cm) in the urban green spaces of Seoul, Daegu, and Daejeon were determined to be 105.6 Gg C, 43.6 Gg C, and 26.4 Gg C, respectively [24] (Figure 3). These results show that green belts and urban green spaces are important carbon sinks.

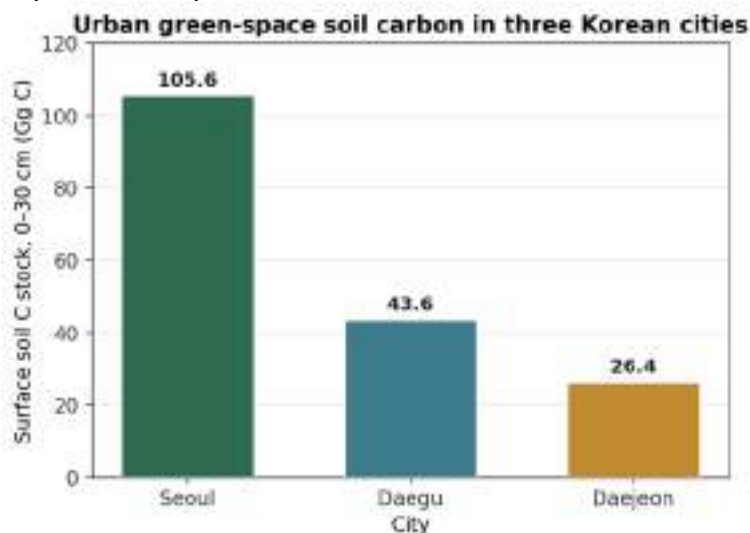


Figure 3. Surface-soil carbon stocks (0–30 cm) in the urban green spaces of three major South Korean cities. Data: Yoon et al. [24].

These differences arise from climatic conditions, soil properties, the species used, stand age, and management practices. Mixed-species stands, in particular, are reported to achieve higher biomass productivity and to store more carbon than monoculture plantations [7,21]. A recent global synthesis of matched single-species and multispecies plantations found that, on average, multispecies stands had about 5% greater tree height, about 7% greater diameter at breast height, and about 25% greater aboveground biomass than monocultures, mainly as a result of interspecific complementarity [27] (Figure 4). For this reason, rather than afforesting large areas solely with fast-

growing species, the establishment of mixed stands suited to ecological conditions is now recommended.

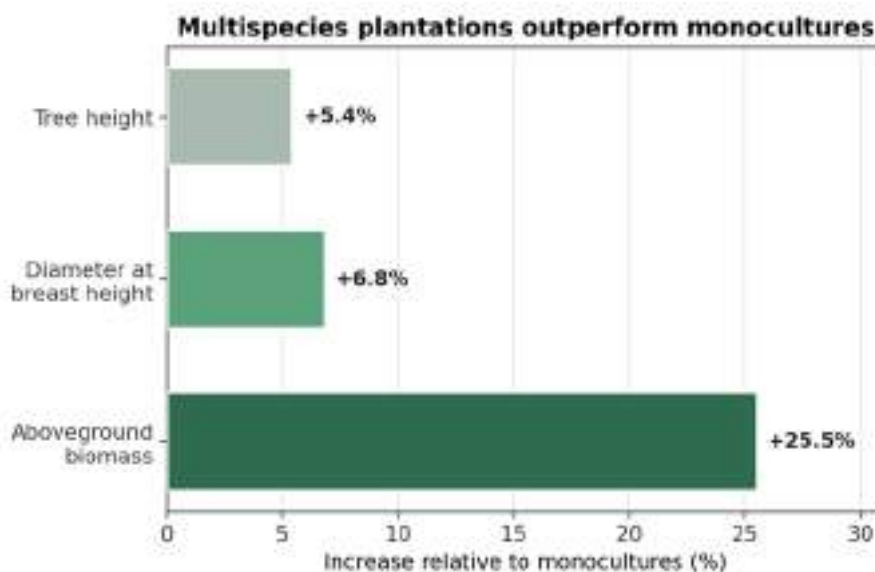


Figure 4. Mean increase in tree height, diameter at breast height, and aboveground biomass in multispecies plantations relative to monocultures, from a global synthesis of paired stands. Data: Feng et al. [27].

When the similarities among the studies are evaluated, all of them reveal that green belt afforestation makes important contributions to erosion control, carbon storage, the improvement of air quality, and the enhancement of ecosystem services. The main subject of debate, however, concerns the long-term environmental effects of large-scale afforestation. While some studies evaluate these projects as successful applications in the fight against climate change [3,5], others stress that the pressure on water resources — particularly in arid and semi-arid regions — must be taken into account [10,11,26]. The scale of the global mitigation that afforestation can realistically deliver is itself contested: although influential analyses have presented tree restoration as among the most effective climate solutions [2], subsequent commentary has cautioned that such estimates can be overstated when pre-existing vegetation and soil carbon, future environmental change, and the displacement of non-forest ecosystems are not fully accounted for [29]. For this reason, the contemporary scientific approach has shifted from planting the maximum number of seedlings toward an understanding of ecosystem-based planning.

When evaluated from Türkiye's perspective, the number of studies addressing the carbon-sink functions of green belt afforestation is seen to be quite limited. One of the principal reasons for this is that afforestation efforts in Türkiye have, over the long term, focused on erosion control, rehabilitation, and the improvement of degraded areas. Where forest carbon has been quantified, the focus has typically been on the dynamics of existing forest estates; for example, an inventory-based assessment of forest carbon pools in western Türkiye reported a measurable increase in stored carbon over recent decades in response to changes in forest structure and management [28]. In addition, the scarcity of long-term carbon-monitoring studies in green belt areas and the lack of regular data on biomass and soil carbon stocks constrain the research that could be undertaken on this subject. With the growing importance of combating climate change and carbon management in recent years, scientific studies aimed at increasing the carbon-storage potential of green belt afforestation should also be prioritised in Türkiye.

In conclusion, when the literature is evaluated as a whole, it is clear that green belt afforestation increases carbon-sink capacity; nevertheless, the success of these projects cannot be explained solely by the amount of carbon stored. A balance must be struck among carbon-storage objectives, water balance, biodiversity, and ecosystem sustainability. For this reason, in green belt afforestation to be applied in the future, it is of great importance to adopt an approach of afforesting in the right place, with the right species, and with an ecosystem-based planning mindset.

6. Conclusion and Recommendations

In this study, the effects of green belt afforestation on carbon sinks were evaluated by considering application examples from around the world and from Türkiye. The literature review revealed that green belt afforestation provides numerous benefits to the ecosystem, such as reducing atmospheric carbon dioxide, increasing carbon-storage capacity, preventing erosion and desertification, improving air quality, and supporting biodiversity. The growing importance of natural carbon sinks in the fight against climate change, in particular, has placed green belt afforestation in a strategic position within sustainable forestry.

In terms of carbon sequestration, green belt afforestation contributes to drawing atmospheric carbon and storing it in biomass and soil. For this reason, it is regarded as an important complementary tool for reducing greenhouse gas emissions and increasing carbon storage. In the light of the literature reviewed, the following recommendations can be made:

- In green belt afforestation, species suited to the region's climate, soil, and water conditions should be selected.
- In afforestation projects to be carried out in arid and semi-arid regions, the necessary analyses of water resources should be conducted and the possible effects on those resources assessed in advance.
- Mixed-species afforestation that protects and enhances biodiversity should be encouraged instead of monoculture plantations.
- Long-term monitoring studies aimed at increasing carbon-storage capacity should be expanded.
- Green belt projects should be planned not with a carbon-only focus but with an ecosystem-services approach, and the criteria of carbon storage, water balance, biodiversity, and ecological sustainability should be evaluated together.
- The green belts established around cities should be more effectively incorporated into climate-change adaptation strategies.

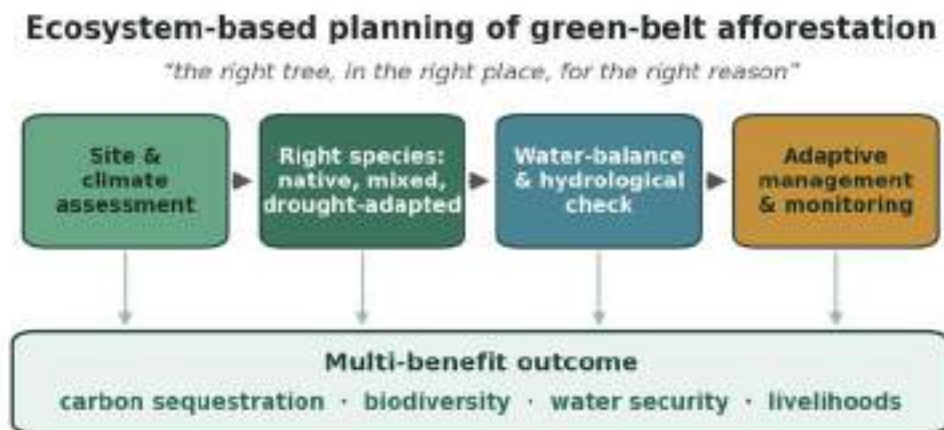


Figure 5. A conceptual framework for the ecosystem-based planning of green belt afforestation, in which site assessment, appropriate species selection, hydrological evaluation, and adaptive monitoring jointly deliver carbon, biodiversity, water, and livelihood benefits.

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