

Review

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The Evolution and Sustainable Management of Turfgrass: Historical Insights and Future Challenges

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Posted Date: 22 April 2025

doi: 10.20944/preprints202504.1878.v1

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Review

Turfgrass Across Time: Historical Uses, Cultural Values, and Sustainability Transitions

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Abstract: Turfgrass has evolved from a fundamental element of natural landscapes to a key component of ornamental, recreational, and ecological systems. This review examines its historical trajectory, from ancient civilizations and medieval monastic gardens to modern urban green spaces, highlighting cultural, technological, and environmental influences. The study integrates historical analysis with agronomic and ecological research to assess turfgrass's role in soil conservation, carbon sequestration, water management, and biodiversity enhancement. The methodological approach combines a historical-literary review with an analysis of scientific advancements in turfgrass management, focusing on low-input species, precision irrigation, and climate-adaptive strategies. Findings indicate that while turfgrass contributes to urban resilience and ecosystem services, conventional high-maintenance practices pose sustainability challenges. The review underscores the need for multifunctional turfgrass systems that balance aesthetics with ecological benefits. A shift toward eco-friendly management practices will be essential for the long-term sustainability of turfgrass in modern landscapes.

Keywords: turfgrass history; sustainable management; climate adaptation; ecosystem services; urban resilience

1. Introduction

The history of turfgrass is deeply interwoven with the evolution of human landscapes, reflecting shifts in cultural values, land use, and environmental management practices. From the ornamental gardens of ancient civilizations to the modern multifunctional green spaces, turfgrass has undergone profound transformations, shaped by technological advancements, aesthetic ideals, and ecological considerations [1,2]. Initially, natural grasslands provided essential ecosystem services such as soil stabilization and livestock forage, but over time, turfgrass became a deliberately cultivated feature in gardens, parks, and sports fields, serving both functional and symbolic roles [3].

The earliest known references to turfgrass cultivation date back to ancient Egypt (circa 1500 BCE), where enclosed gardens incorporated lawns to contrast with the arid desert landscape [4]. Similarly, in Persian and Babylonian gardens, turfgrass symbolized fertility and paradise, reflecting a cultural appreciation for lush, green landscapes [5]. The Greeks and Romans refined this concept by integrating turfgrass into sacred groves, courtyards, and public gathering spaces, emphasizing its role in both aesthetics and leisure [6]. However, during the Middle Ages, the use of ornamental lawns declined in Europe, persisting primarily in monastic gardens, where they were associated with meditation and self-sufficiency [7].

A significant revival occurred during the Renaissance, when turfgrass became a formalized element of European garden design. Influenced by classical principles of symmetry and proportion, Italian Renaissance gardens, such as those described by Leon Battista Alberti in *De re aedificatoria* [8], used turfgrass as a structured component of geometric parterres. This tradition evolved further in 17th-century France, where André Le Nôtre's designs for Versailles incorporated vast expanses of meticulously maintained turf, emphasizing grandeur and human dominance over nature [9,10]. In contrast, the English landscape movement of the 18th century, led by Capability Brown, championed

a more naturalistic approach, integrating turfgrass with rolling meadows and water features, laying the groundwork for public parks and open green spaces [11].

With the Industrial Revolution and urban expansion, turfgrass became a key component of modern landscapes, extending beyond aristocratic estates into public parks, sports facilities, and suburban lawns. Its proliferation was driven by advances in turfgrass science, including breeding for resilience, irrigation innovations, and soil management techniques [12,13]. Today, turfgrass plays a critical role in urban sustainability, contributing to biodiversity, air purification, temperature regulation, and water conservation [14]. However, concerns regarding water consumption, pesticide use, and maintenance costs have led to an increasing emphasis on low input turfgrass species, regenerative landscape practices, and precision turf management [15].

This review aims to explore the historical evolution, cultural significance, and modern sustainability challenges of turfgrass, bridging historical perspectives with contemporary agronomic research. By examining its transformation from a natural pasture to a scientifically managed component of urban ecosystems, we highlight its ongoing role in landscape resilience, environmental sustainability, and multifunctional land use in the 21st century.

2. Materials and Methods

This study adopts an interdisciplinary approach that combines historical analysis and agronomic research to explore the evolution and sustainable management of turfgrass. The literature review was carried out through a structured and iterative process, integrating historical, horticultural, and environmental research. Major academic databases—including Scopus, Web of Science, JSTOR, ScienceDirect, and Google Scholar—were consulted to identify both classical and contemporary references. Keyword combinations included: *"turfgrass history," "historic garden management," "Roman lawns," "low input turfgrass," "landscape ecology,"* and *"sustainable turf systems"*. Boolean operators were used to refine search results, and filters were applied to prioritize peer-reviewed material and relevant historical sources in English, Italian, French, and Spanish.

Sources (from 2000 to 2025) were selected based on relevance to the study's objectives, with priority given to materials that offered either direct historical accounts or scientific perspectives on turfgrass use, species, or ecological function. Non-scholarly or redundant materials were excluded.

The methodology integrates a comprehensive literature review, case study analysis, and comparative evaluation of different management strategies across historical and environmental contexts.

To trace the historical trajectory of turfgrass, classical texts, manuscripts, and architectural treatises were examined, including the writings of Pliny the Younger [16,17] (Leon Battista Alberti [8] and other key historiographical sources. These references provided insights into the cultural and functional significance of turfgrass in various historical periods, from ancient civilizations to contemporary landscapes.

The study also incorporates peer-reviewed agronomic research, reports from environmental agencies, and scientific literature addressing the ecological benefits of turfgrass, such as soil conservation, water management, biodiversity support, and climate resilience and to clarify the research base, Table 1 presents an overview of the categories of sources used, including classical writings, archaeological reports, peer-reviewed articles, and technical case studies. Additionally, case studies of urban parks, sports fields, and sustainable landscaping projects were analyzed to assess the practical applications of modern turfgrass management techniques.

The collected literature was analyzed using a thematic and diachronic approach, tracing key transformations in turfgrass function and management across six major periods: ancient, classical, Islamic, medieval, early modern, and contemporary. Within each period, attention was given to the role of turfgrass in cultural symbolism, landscape architecture, environmental interaction, and practical care (e.g., irrigation, mowing, fertilization). Thematic categories such as aesthetic value, recreational function, resource use, and ecological performance were used to compare past and present systems and to frame the evolution of turfgrass as both a cultural and ecological asset.

A comparative analysis was conducted to evaluate historical and contemporary turfgrass systems, focusing on key factors such as environmental impact, maintenance requirements, and ecological functionality. Management strategies were assessed based on their water efficiency, reduction of chemical inputs, carbon sequestration potential, and biodiversity enhancement.

Table 1. Types of Primary and Secondary Sources Consulted.

Type of Source	Description	Examples
Primary Historical Sources	Original texts and treatises relevant to garden design and landscape theory.	<i>Alberti, Vitruvius, Pliny the Younger, Bacon</i>
Archaeological Reports	Site-specific excavation and restoration data.	Pompeii and Herculaneum site reports
Peer-Reviewed Articles	Recent scientific literature on turfgrass, sustainability, and urban ecology.	Articles from <i>Agronomy, Urban Forestry, Grasses, Land</i>
Case Studies	In-depth studies of specific gardens or parks.	Villa Lante, Reggia di Caserta, Royal Botanic Gardens
Technical Guidelines	Manuals and institutional reports on turf and irrigation management.	FAO, USGA, EPA publications
Visual and Iconographic Sources	Paintings, engravings, and historical garden plans.	16th–19th century garden illustrations

3. The Evolution and Legacy of Turfgrass: From Agricultural Resource to Cultural and Ecological Asset

The history of turfgrass cultivation reveals a long trajectory, from early utilitarian and symbolic uses in ancient societies to its integration into modern ecological and recreational landscapes. This section traces the development of turfgrass across key historical periods, highlighting its shifting cultural meanings, aesthetic functions, and environmental roles.

3.1 Early Uses of Turfgrass in Ancient Civilizations

The history of turfgrass cultivation dates to the earliest human civilizations, where its role evolved from a fundamental agricultural resource to an essential element of landscape design. The earliest documented use of managed grasslands can be traced to ancient Egypt (circa 1500 BCE), where enclosed gardens within temple complexes and elite residences featured carefully maintained grassy areas [18,19]. As observed in Figure 1, these gardens were designed to create a striking contrast with the surrounding arid landscape, emphasizing both aesthetic and symbolic functions. These green spaces symbolized fertility and contrast against the arid desert while reflecting an early understanding of landscape irrigation and soil management [20]. Archaeological evidence from Deir el-Bahari and Tell el-Amarna suggests that primitive channeling systems were used to sustain these cultivated lawns, demonstrating the Egyptians’ advanced hydraulic engineering in garden maintenance [21–23].



Figure 1. Tomb fresco of a high-ranking official in the service of Pharaoh Amenhotep II (circa 1400 BCE). The image illustrates the early use of managed green spaces and turfgrass-like elements in ancient Egyptian gardens, which stood in stark contrast to the surrounding arid environment. These gardens, characterized by geometric layout, pools, and shaded vegetation, represent some of the earliest documented examples of cultivated lawns for aesthetic and symbolic purposes.

The integration of turfgrass into garden landscapes has deep cultural and literary roots, extending back to ancient Mesopotamian, Persian, and Arabic traditions. However, it was in Greek and Roman civilizations that turfgrass became a defining element of the garden, as reflected in literary descriptions, artistic representations, and philosophical ideals [24]. One of the earliest known references to grass as an intrinsic component of the garden appears in Homer's *Odyssey*, Book V, in the description of Calypso's dwelling on the island of Ogygia.

Homer's passage portrays a paradisiacal landscape, where the natural environment seamlessly blends with cultivated beauty:

"Around the cave, a flourishing wood grew—alder, poplar, and fragrant cypress. Here birds roosted, spreading their wings: owls, hawks, and the chattering sea-crows. A vine trailed, heavy with grapes, and four springs in a row sent sparkling water flowing in all directions. Soft meadows of violets and parsley flourished around them, filling the air with fragrance. Even an immortal would gaze in wonder at such a sight and feel joy in his heart." [25,26]

This passage introduces the concept of the *locus amoenus*—an idyllic, fertile landscape characterized by lawns, shaded groves, flowing water, and floral abundance, which would become a fundamental motif in Western Garden traditions [27,28]. The meadow surrounding Calypso's cave is particularly significant, as it represents one of the earliest literary allusions to turfgrass as a key element of an idealized garden [29].

As observed in Figure 2, the 17th-century painting "Fantastic Grotto with Ulysses and Calypso" by Jan Brueghel the Elder visually interprets Homer's description, presenting a lush, verdant environment where nature, art, and mythology intertwine [30]. The depiction of soft grass carpets interwoven with flowers, flowing water, and tree canopies reinforces the harmonious relationship between humans and nature, a principle that influenced classical garden design [31,32].



Figure 2. *Fantastic Grotto with Ulysses and Calypso*, by Jan Brueghel the Elder (1568–1625), oil on canvas. The painting portrays an idyllic fusion of natural and architectural elements, where soft grass carpets, flowering meadows, abundant vegetation, and flowing water evoke the classical ideal of harmony between humans and the landscape. This romanticized vision draws on Homeric themes and reflects early modern interpretations of ancient garden imagery.

3.2. Turfgrass in Classical Antiquity: Greek and Roman Traditions

The Homeric vision of nature had a profound impact on Greek garden philosophy, particularly in Athenian culture, where green spaces were conceived as extensions of the surrounding landscape rather than isolated, enclosed entities. The concept of *kepos* (κήπος), originally meaning “garden”, evolved to denote a broader vision of the landscape as a cultivated paradise [33].

Unlike the rigid, enclosed gardens of the Near East, Greek gardens embraced continuity between cultivated land and the natural environment, with turfgrass playing a crucial role as the connective element between garden and landscape [34]. This can be observed in sacred groves, gymnasia, and philosophical schools, where grassy areas were used for intellectual discourse, athletic training, and spiritual reflection [35].

A key example of this philosophy was the Academy of Plato, an outdoor space surrounded by olive groves and lush meadows, where students engaged in philosophical dialogues while immersed in a natural setting [36]. These early green spaces functioned as both physical and metaphorical realms, representing fertility, intellectual growth, and the harmonious coexistence of humans and the environment [37].

The duality of *kepos* is particularly significant:

- It refers to a cultivated garden, a carefully maintained space symbolizing human control over nature.
- It also evokes the maternal womb, a place of protection, generation, and renewal, reinforcing the symbolic and existential significance of gardens in Greek thought [38,39].

The evolution of Roman gardens reflects a gradual transition from sacred, untouched landscapes to structured, decorative, and multifunctional spaces integrated within domestic and suburban architecture. The earliest documented Roman gardens date back to the Republican period (509 BCE – 27 BCE), when two distinct forms of garden design coexisted. On the one hand, the *lucus* (sacred grove) was a natural, untouched space inhabited by the *genius loci*, where human intervention was strictly prohibited [40]. These groves, closely associated with temples and sanctuaries, embodied the deep religious reverence for nature that characterized early Roman culture. On the other hand, the *hortus conclusus* (enclosed garden) was a small, fenced space at the rear of the house, dedicated to the cultivation of fruits, vegetables, and medicinal plants [41]. Functioning as a utilitarian extension of

the *domus*, it provided self-sufficiency to Roman households and emphasized the practical relationship between humans and nature [42]. By the 2nd century BCE, Greek influence had profoundly shaped Roman garden design, leading to the introduction of the peristyle garden, a model that transformed enclosed courtyards into ornamental and leisure spaces [43]. Pliny the Younger's *Epistulae* provide extensive descriptions of villa gardens, where turfgrass was used to create cool, comfortable surfaces for leisure activities:

"In front of the colonnade lies a lawn, edged with boxwood hedges, beyond which stretches a variety of trees and flowerbeds, arranged in elegant symmetry. This area is particularly inviting in the afternoon, where the grass remains cool, offering respite from the heat of the day". [16,17]

This passage highlights three key functions of turfgrass in Roman gardens:

- Thermal regulation: Providing cool surfaces for leisure and relaxation.
- Aesthetic enhancement: Structuring green spaces in geometric harmony with built architecture.
- Social interaction: Creating welcoming environments for conversation, dining, and entertainment [44].

This shift marked the beginning of a new conceptualization of the garden, no longer limited to agricultural production but designed for aesthetic enjoyment and social gatherings. Unlike the earlier *hortus*, the peristyle was conceived as an architectural feature, carefully arranged with ornamental plants, fountains, statues, and symmetrically planned pathways. As seen in Figure 3, a well-preserved example from Pompeii, peristyle gardens became an integral component of elite Roman residences, illustrating the deliberate fusion of natural and built environments [45]. Turfgrass, while not dominant, as in later European traditions, contributed to the aesthetic harmony and comfort of these spaces, providing a cooling effect, softening the rigid geometry of colonnades, and enhancing the visual harmony between greenery and architectural elements [46]. Between the 2nd and 1st centuries BCE, the increasing wealth and cosmopolitanism of Roman society led to the rise of the villa suburbana, expansive country estates that blended architecture with carefully curated landscapes. Inspired by Hellenistic models, these villas reflected the elite's desire for a refined retreat in which nature was not merely cultivated but carefully orchestrated to create idealized, picturesque environments [47]. These estates featured vast stretches of open grassy spaces, shaded walkways, artificial water features, and terraces that overlooked rolling landscapes. The design sought to integrate the villa seamlessly with its surroundings, reinforcing the illusion of a boundless, cultivated paradise [42,48].

One of the most striking aspects of Roman garden design was the use of *trompe-l'œil*, a technique employed in fresco painting to create the illusion of extended gardens beyond interior walls [49]. In places such as Pompeii and Herculaneum -Italy-, where space was often restricted, painted garden scenes adorned the walls of houses, offering inhabitants an artificial sense of immersion in nature [46,50]. The Villa of Livia at Prima Porta in Rome, Italy, provides one of the most famous examples of this practice, with frescoes depicting lush greenery, exotic birds, and rolling meadows reinforcing the Roman vision of a perfected landscape extending seamlessly from interior to exterior. [51].

The role of turfgrass in Roman gardens, though limited in extent, was essential to their functional and symbolic composition.. Lawns provided a visual contrast to the structured symmetry of gardens, helped regulate temperature in enclosed peristyles, and served as spaces for walking, relaxation, and private leisure [52]. The concept of integrating soft, green surfaces within garden layouts would persist throughout history, influencing later developments in Renaissance villa gardens and 18th-century English landscapes [53]. Roman garden design established fundamental principles that would shape landscape aesthetics for centuries. The peristyle model would later be adapted in medieval monastic cloisters, while the illusionistic techniques of *trompe-l'œil* found renewed expression in Baroque Garden compositions. Moreover, the Roman vision of the garden as a place for intellectual and social engagement, rather than mere agricultural utility, laid the foundation for

the modern concept of public parks and urban green spaces [54]. By exploring the role of turfgrass in these ancient settings, it becomes evident that its function transcended simple decoration, serving as a vital element in the evolving relationship between humans and their environment.



Figure 3. Peristyle garden of a Roman domus in Pompeii. This well-preserved example illustrates the typical layout of an enclosed Roman courtyard garden (*hortus peristylus*), characterized by geometric symmetry, ornamental vegetation, fountains, and turfgrass areas. The integration of grassy surfaces within the architectural framework reflects the Roman ideal of combining aesthetic harmony with functional leisure space.

3.3. Turfgrass in the Medieval and Islamic World

While the decline of ornamental turfgrass in post-Roman Western Europe has been well documented, medieval Islamic societies—particularly in Persia and al-Andalus—maintained and further developed sophisticated horticultural practices that prominently featured grassy surfaces [55]. The Persian garden tradition, epitomized by the *chahar bagh* quadripartite layout, integrated rectangular lawns with flowing water channels, fruit trees, and flowering plants. These gardens were not merely aesthetic, but cosmological and spiritual compositions meant to evoke paradise (*janna*), as described in the Qur'an. Grass, in this context, symbolized divine abundance and natural order [56,57].

This design philosophy traveled westward with the expansion of the Islamic Caliphates, leaving a profound mark on the landscapes of Islamic Spain. The gardens of the Alhambra in Granada—especially the Generalife—exemplify this synthesis of symbolic geometry, water management, and soft green surfaces, where turfgrass functioned as a soothing visual and tactile element within shaded courtyards [58]. These lawns, sustained by advanced irrigation systems (*qanats*, channels, cisterns), reflected an integrated approach to water ecology and landscape aesthetics [59,60].

Unlike the more enclosed and contemplative lawns of European monastic gardens, Islamic turfgrass areas were part of a broader vision of environmental harmony, technological innovation, and cultural continuity rooted in Greco-Roman agronomy and adapted to arid environments [61]. Their continued use through the medieval period reveals a parallel development of lawn culture that complicates Eurocentric narratives of turfgrass evolution.

During the Middle Ages, while pleasure gardens continued to flourish in the Islamic world, the decline of Roman urban life and the fortification of medieval cities led to a gradual disappearance of ornamental gardens in Western Europe [55,62]. The instability following the fall of the Roman Empire meant that cultivated green spaces became increasingly restricted to enclosed settings, either within monasteries, castles, or small cloistered courtyards [29,63].

Medieval society viewed nature with dual symbolism—as an untamed wilderness outside city walls and, conversely, as a harmonious microcosm within sacred enclosures [31,41]. Unlike the

expansive villas and peristyle gardens of antiquity, the medieval garden was defined by its enclosed nature, reflecting both practical needs and religious ideals. It was within monastic cloisters that horticultural traditions were preserved, giving rise to a structured model of self-sufficient green spaces, which gradually evolved to include aesthetic and spiritual dimensions [41]. Monastic gardens, particularly those of the Benedictine and Cistercian orders, were designed to reflect both agricultural necessity and theological order [64]. The Plan of St. Gall (9th century CE), one of the earliest surviving monastic blueprints, details a layout in which the garden was divided into distinct functional areas, including:

- The *hortus conclusus* (enclosed garden), dedicated to medicinal herbs and food production.
- The cloister garden, an inner sanctuary for meditation and prayer, often featuring a central lawn or fountain, symbolizing paradise and divine harmony [41].
- The physic garden, used for growing medicinal plants, reinforcing the monastery's role as a center for healing and scientific knowledge [46].

As depicted in Figure 4, the cloister garden of the Benedictine Abbey of Polirone (late 15th century) exemplifies this structured approach, where manicured hedges and geometric pathways emphasize order and contemplation. Though turfgrass was not widely cultivated as an ornamental feature in early medieval gardens, grassy courtyards and cloisters gained symbolic and functional relevance, offering tranquil settings for prayer and reflection. [65].

By the 14th and 15th centuries, medieval gardens began to incorporate more elaborate aesthetic elements, as reflected in literature, art, and architecture. The concept of the *hortus conclusus*—a walled garden symbolizing both earthly paradise and monastic retreat—became a dominant motif in European landscape design. These enclosed gardens, often associated with religious symbolism, were inspired by biblical descriptions of the Garden of Eden and were particularly prominent in depictions of the Virgin Mary within sacred settings. At the same time, they responded to the security concerns of medieval society, serving as protected sanctuaries of tranquility and reflection, distinct from the wild, untamed landscapes beyond the city walls [66].



Figure 4. Cloister garden of the Benedictine Abbey of Polirone (late 15th century). This example showcases the medieval monastic garden model, characterized by a structured layout of enclosed gravel pathways, neatly trimmed boxwood hedges, and central grassy areas. Designed for contemplation, order, and symbolic reflection, such cloisters combined functional, spiritual, and aesthetic dimensions within enclosed religious spaces.

The idea of the enclosed medieval garden as a place of escape and renewal is also vividly captured in literary works of the period. A striking example is found in Giovanni Boccaccio's *Decameron* (14th century), in which a group of Florentine nobles, fleeing the devastation of the plague, retreat into a villa surrounded by a walled garden. In the prologue to the third day, Boccaccio

describes an idyllic green space, enclosed by high walls and centered around a vast, carefully maintained lawn.

"Upon entering, they found themselves in a garden entirely enclosed by walls. At first glance, it seemed astonishingly beautiful, but as they examined its details, they saw a lush lawn of the finest green grass, interwoven with thousands of flowers. Surrounding this verdant space stood a grove of orange and cedar trees, bearing fruits, flowers, and a delightful fragrance. At the garden's center, a marble fountain sent clear water flowing into delicate channels that nourished the greenery. It was a place so enchanting that they declared if paradise could be made on earth, it would surely take this form." [67].

The garden, adorned with a variety of flowers, fruit trees, and water features, is portrayed as an earthly paradise, offering both aesthetic pleasure and emotional solace. His description emphasizes the harmonious composition of nature, where the lush turf, flowering plants, and flowing water create an environment so perfect that it is likened to paradise itself [29].

This literary representation reflects the growing importance of turfgrass as a key feature of enclosed gardens, where it was no longer merely a functional element but an integral part of the garden's aesthetic and symbolic identity. The vibrant green lawn at the heart of Boccaccio's Garden was not just a backdrop but a defining characteristic of the space, reinforcing its image as a sanctuary of peace, renewal, and contemplation [68].

As these ideals spread, the *hortus conclusus* evolved into a highly structured environment, defined by neatly trimmed hedges, symmetrical layouts, and carefully arranged floral compositions, creating the foundation for the Renaissance Garden tradition.

While medieval gardens were initially defined by their functional and religious purposes, the role of turfgrass expanded into recreational and symbolic domains [65].

By the 12th century, grassy surfaces began to be cultivated within the courtyards of castles, serving both ornamental and practical functions. The development of turfgrass for recreational use was particularly evident in the emerging traditions of lawn sports, including early forms of cricket and lawn bowls, which required carefully maintained grass surfaces.

At the same time, the maintenance of turfgrass remained largely dependent on agricultural techniques, as specialized gardening tools were still rudimentary. In large estates and enclosed green spaces, grazing animals such as sheep and goats were commonly used to keep the grass trimmed, while manual labor with scythes and sickles was employed to shape and control the lawn's appearance. Given the labor-intensive nature of lawn maintenance, the cultivation of turfgrass for non-productive purposes was a luxury reserved for the aristocracy, a symbol of status and refinement [69].

By the late medieval period, three distinct uses of turfgrass had emerged, reflecting broader social and economic transformations. Turfgrass continued to serve productive functions, particularly within monastic gardens where it was part of the self-sustaining agricultural system. At the same time, it gained importance in recreational and sporting contexts, becoming essential to early lawn games and courtly pastimes [70].

Most significantly, it evolved as an ornamental feature, enhancing the visual appeal of enclosed gardens, where neatly manicured lawns became associated with harmony, serenity, and prestige. This transformation laid the foundation for the formalization of turfgrass in Renaissance and Baroque gardens.

3.4. Historical Turfgrass Species and Management Practices

While most historical sources focus on the symbolic and aesthetic functions of turfgrass, archaeological and horticultural evidence allows us to reconstruct early techniques of turf management and species usage [71]. In ancient civilizations such as Egypt and Mesopotamia, green surfaces were integrated into garden courtyards and temple complexes, often maintained through

primitive but effective irrigation methods. Native species like *Cynodon dactylon* (Bermudagrass) were likely used for their drought tolerance, ability to spread via stolons, and resilience to foot traffic [72,73]. These early lawns were not ornamental in the modern sense but served as cooling surfaces, spiritual symbols of fertility, and signs of elite cultivation.

In the Greco-Roman world, turfgrass appeared in peristyles, gymnasias, and sacred groves [74]. Although there is no record of intentional monoculture planting, low-growing grasses such as *Agrostis capillaris*, *Festuca ovina*, and even *Lolium perenne* may have dominated [75]. The choice of species was shaped more by regional availability and durability than by aesthetic consistency. Maintenance relied on seasonal irrigation, simple hand tools, and in some cases, the natural moderation of growth due to shade and arid soil conditions [76]. Turf functioned both as a soft flooring material and as a physical and symbolic boundary between built and natural spaces [77].

During the Islamic Golden Age, particularly in Persia and al-Andalus, turfgrass areas were more intentionally cultivated. The chahar bagh design incorporated quadrants of grass bordered by rills, trees, and flowers, with sophisticated irrigation techniques like qanats, pools, and manually regulated channels [78]. Grass in this context symbolized divine order and earthly paradise. While records rarely name species, it is plausible that local varieties of *Poa* and *Festuca* were favored for their fine texture and ability to survive intermittent moisture [79,80].

In medieval Europe, turfgrass appeared primarily in enclosed, functional spaces—monastic cloisters, castle courtyards, and later, noble estates [81]. Grasses were trimmed using scythes and sickles, or managed through controlled animal grazing. Lawns were fertilized with compost, ash, or manure, and trimmed manually by laborers. These practices persisted until the late Middle Ages, when lawns began to be associated more with leisure and status.

Across all these contexts, turfgrass was a managed surface shaped by ecological adaptation and cultural meaning. The species used were local, robust, and variable. Unlike modern systems reliant on visual uniformity and synthetic inputs, historical turf practices embodied principles of resilience, resourcefulness, and integration with the broader landscape [82]. Recognizing these approaches helps position sustainable turfgrass management not as a rupture from tradition, but as a return to place-based, ecologically aware landscape practices [84].

3.5. Humanism and the Renaissance: The Garden as a Manifestation of Rationality and Art

With the advent of Humanism, a new philosophical paradigm emerged, placing man at the center of the universe and emphasizing his ability to understand, control, and shape nature. This intellectual shift, rooted in the rediscovery of classical texts and a renewed appreciation for ancient ideals, fueled a profound transformation in the arts, architecture, and landscape design. The medieval vision of the garden as a functional, enclosed, and contemplative space gave way to a more structured and aesthetically driven concept, where rationality, geometry, and artistic composition played fundamental roles [65].

The transition from the medieval cloister garden to the Renaissance Garden was neither abrupt nor uniform. Rather, it developed gradually throughout the 15th century, initially manifesting as theoretical principles rather than fully realized projects. A pivotal moment in this evolution was the publication of Leon Battista Alberti's *De re aedificatoria* (1452) [8], which laid the foundation for Renaissance Garden design. Alberti envisioned the garden as an extension of the villa, positioned in a panoramic and harmonious setting, adorned with sculptures, fountains, and carefully arranged vegetation. His treatise advocated for the use of precisely pruned boxwood hedges, geometrically arranged plants, and architectural elements that reinforced the symmetry and order of the landscape [48].

As the Renaissance Garden evolved, it moved away from the utilitarian and enclosed medieval model, becoming a stage for artistic expression and human control over nature. The turfgrass, once an incidental or practical feature, was now incorporated as a fundamental component of spatial composition, adhering to the rules of architectural design. The transformation of natural elements into ordered, rationalized, and highly aestheticized forms reached one of its most refined expressions

in Francesco Colonna's *Hypnerotomachia Poliphili* (1499) [84]. This allegorical novel describes an ideal garden, where plants and trees are no longer left to grow freely but are meticulously shaped to serve the artistic vision of the designer. In this approach, nature was not merely cultivated but consciously sculpted into an artistic masterpiece, solidifying the Renaissance ideal of the garden as an extension of human intellect and creativity [85]. The Renaissance Italian Garden, often referred to as the "giardino all'italiana", embodied the principles of order, symmetry, and controlled perspective. Unlike the enclosed medieval gardens, these landscapes were open, expansive, and designed to integrate with their surrounding environment. The topography of the land played a crucial role in shaping these gardens, often requiring the construction of terraces, staircases, and ramps to facilitate movement between different levels. The planting schemes were highly structured, with flower beds arranged in parterres, framed by precisely clipped evergreen hedges, and adorned with fountains, sculptures, and architectural elements [86].

As part of this aesthetic vision, turfgrass assumed a predominantly ornamental role, reinforcing the geometric composition of the garden. The lawns were not intended for physical interaction but rather functioned as visual elements, enhancing the contrast between green surfaces, gravel pathways, and elaborate floral designs. The choice of plant species reflected the Renaissance pursuit of permanence and perfection, favoring evergreens such as cypress, boxwood, yew, holm oak, pine, myrtle, and laurel, which provided a stable, year-round display of greenery [50]. This emphasis on permanence and structure was deeply connected to the broader Humanist ideal of dominion over nature, reinforcing the belief that the garden—like architecture—should reflect human ingenuity and mastery [87]. In this context, turfgrass selection was less about ecological function and more about visual harmony. However, in contemporary urban design, turfgrass selection plays a critical role in mediating aesthetic expectations with ecological performance, especially under conditions of climate stress and soil constraints. This shift marks a broader transition from symbolic control over nature to adaptive, performance-based landscape strategies [88].

A quintessential example of this approach is Villa Lante in Bagnaia (Figure 5), designed in the second half of the 16th century. This masterpiece of Italian Renaissance Garden design illustrates the interplay between structured parterres, water features, and carefully maintained turfgrass areas. The garden's symmetry, elaborate fountains, and precisely sculpted hedges exemplify the idealized vision of nature as a harmonious, ordered entity, reflecting the intellectual and artistic ambitions of the era [89].



Figure 5. Villa Lante in Bagnaia (late 16th century). This iconic example of the Italian Renaissance garden exemplifies the structured use of turfgrass within geometrically arranged parterres, symmetrical terraces, and sophisticated hydraulic features. The garden's formal layout reflects principles of order, control over nature, and visual harmony, with grassy surfaces accentuating the design's compositional balance.

Alongside the grand, geometrically structured gardens, a more intimate variation emerged—the "giardino segreto" or "secret garden." Designed as a private retreat within the larger garden complex, these hidden spaces provided an area for solitude, contemplation, and intimate social gatherings. Shielded by vegetation or enclosed within walls, these gardens featured rare plants, intricate hedges, and ornamental fountains, creating an atmosphere of exclusivity and mystery [90].

Within these enclosed gardens, turfgrass found a unique application, serving as a soft, inviting surface for relaxation. Unlike the large-scale parterres of the grand gardens, the turf in 'giardini segreti' was often directly experienced, either by walking barefoot or reclining on its lush surface. This marked one of the first instances in which lawns were valued not only for their aesthetic contribution but also for their tactile and sensory appeal. The presence of turfgrass in these intimate spaces emphasized its ability to evoke serenity and connection with nature, a theme that would later reappear in the pastoral gardens of the 18th century [91].

By the late 16th century, knowledge of lawn maintenance became more widespread. The publication of "L'Agriculture et Maison Rustique" (1564) by Charles Estienne and Jean Liebault provided one of the earliest detailed descriptions of soil preparation and turfgrass cultivation. The text outlined methods for sowing, cutting, and maintaining lawns, reflecting the growing interest in grass as a deliberate and refined component of the garden [92]. As the Renaissance progressed into the late 16th century, a shift in artistic sensibilities began to emerge. The once unwavering confidence in human dominion over nature started to waver, giving way to more complex, enigmatic, and theatrical expressions in garden design. This transition, associated with Mannerism, introduced elements that challenged the rigid, geometric order of earlier Renaissance gardens, incorporating unexpected perspectives, intricate mazes, and dramatic visual effects [93].

Gardens from this period often played with illusion and ambiguity, creating spaces that evoked both wonder and unease. Water features became more elaborate, with hidden fountains, trick jets, and grottoes that surprised visitors. The structured linear perspectives that had dominated the early Renaissance were gradually distorted and manipulated, as seen in the increased presence of dense woodlands and shadowed groves within garden compositions.

Turfgrass, while still a central visual element, was now integrated into these more dynamic and unpredictable settings, reinforcing the idea that nature was not simply a passive subject to be controlled but rather a living entity capable of mystery and transformation. This shift in perspective foreshadowed the dramatic changes that would unfold in the Baroque Garden tradition, where grandeur, movement, and theatricality would take precedence over pure geometric order [94].

3.6. *Turfgrass in the Baroque Garden: Geometry, Perspective, and Theatricality*

The scientific advancements of the 17th century, including Copernican and Galilean theories, introduced a new perception of space, infinity, and movement, which deeply influenced Baroque art and landscape design. The static, enclosed gardens of the Renaissance gave way to expansive, theatrical compositions, where nature was not merely structured but orchestrated to create dynamic and illusionistic effects [89]. The Baroque Garden was conceived as a grand spectacle, emphasizing dramatic perspectives, elaborate water features, and the seamless integration of architecture with the surrounding landscape.

Unlike the ordered rationality of Renaissance gardens, which sought to impose human control over nature, Baroque gardens celebrated movement, depth, and the infinite. The formal geometric framework remained, but it was now extended to vast scales, creating illusionistic compositions that guided the viewer's gaze towards distant vanishing points. These gardens no longer terminated within their own boundaries but visually extended into the broader countryside, reinforcing the idea that nature and design were interconnected [29,95].

In this context, turfgrass played a crucial aesthetic role, providing a soft, uniform surface that enhanced the clarity of the elaborate geometric compositions. As Francis Bacon observed in 1625, "nothing is more pleasing to the eye than a finely mowed lawn," highlighting the increasing appreciation for manicured grass as a visual and sensory element in garden design [96]. The smooth,

verdant lawns contrasted with the intricate parterres, gravel pathways, and ornamental fountains, reinforcing the symmetry and depth that were fundamental to Baroque spatial illusions [97,98].

While Italian Baroque gardens retained elements of Renaissance order, it was in France that the most rigorous and theatrical expression of Baroque landscape design emerged. The French formal garden (*jardin à la française*), perfected by André Le Nôtre, embodied the principles of grandeur, control, and optical precision [99].

One of Le Nôtre's most celebrated projects, Vaux-le-Vicomte (Figure 6), exemplifies the perfected Baroque vision of space and perspective [100]. The garden unfolds along a central axis, meticulously designed to create a seamless visual experience, where lawns, parterres, and water features extend in perfect alignment towards an infinite vanishing point. The arrangement of turfgrass within this structured composition was integral to maintaining clarity and continuity, allowing the eye to follow unbroken planes of green that framed the elaborate decorative elements [99].



Figure 6. Vaux-le-Vicomte, designed by André Le Nôtre (mid-17th century). This exemplary Baroque Garden illustrates the geometric precision, axial symmetry, and theatrical spatial composition typical of the French formal style. Turfgrass is used extensively to emphasize visual clarity, structure long perspectives, and create strong contrasts with gravel paths, fountains, and sculptural plantings.

The design principles established at Vaux-le-Vicomte reached their grandest scale at the Palace of Versailles, where Le Nôtre's genius culminated in an unparalleled orchestration of landscape, architecture, and power. Versailles was not merely a garden; it was a statement of absolute control, where nature was disciplined into precise forms, mirroring the centralized authority of Louis XIV's reign [10]. The expansive lawns, structured parterres, cascading fountains, and radiating avenues created a landscape that symbolized order, hierarchy, and the divine right of kings [101].

Within the French formal garden, turfgrass was rigorously maintained and geometrically arranged, serving as a unifying visual element that reinforced symmetry, hierarchy, and spatial organization. Unlike the functional turfgrass of medieval cloisters or the Renaissance 'giardino segreto', Baroque lawns were not designed for direct interaction but rather for aesthetic contemplation. The precision with which they were cultivated reflected the broader Baroque philosophy of mastery over nature, where even the most organic elements were disciplined into artistic compositions [102].

A defining feature of these gardens was the parterre, a level, intricately designed section of the garden, often bordered by clipped hedges and filled with either turfgrass, gravel, or floral embroidery. These elaborate patterns reinforced the decorative function of turfgrass, transforming lawns into living tapestries that complemented the architectural symmetry of the garden. The four primary types of parterre included:

1. Parterre de broderie (embroidery parterre): Delicate, lace-like designs formed with low boxwood hedges, often contrasting against a gravel or sand background.
2. Parterre de compartiment (compartmentalized parterre): Larger, symmetrical compartments that combined turfgrass with floral arrangements, separated by gravel pathways.
3. Parterre à l'Angloise (English-style parterre): A simpler layout consisting of large, continuous green lawns, bordered by flower beds and hedges.
4. Parterre de pièces coupées (cut elements parterre): A more abstract composition, featuring shaped hedges, flowers, and decorative motifs, set against a gravel or sand background [28].

The meticulous maintenance of these lawns was a symbol of refinement and artistic perfection, reinforcing the Baroque desire for theatricality and grandeur. Their smooth, uninterrupted surfaces allowed for breathtaking visual effects, such as mirror-like reflections in water basins, extended perspectives, and an overall sense of harmony and control [103]. Despite the overwhelming emphasis on ornamentation and visual grandeur, the gardens of Versailles also contained a practical component that was deliberately concealed from view. While the visible gardens showcased elaborate parterres, pristine lawns, and sculptural elements, the actual production of food and medicinal plants took place in the King's Kitchen Garden (Potager du Roi), located outside the main garden axis [104].

Designed by Jean-Baptiste La Quintinie, the Potager du Roi was an extraordinary feat of horticultural engineering, supplying the palace with fresh fruits, vegetables, and herbs while remaining visually separate from the ornamental gardens [105]. This deliberate separation reflects the Baroque ideology of spatial hierarchy, where functional landscapes were subordinated to aesthetic concerns, reinforcing the idea that the formal garden was a stage for power, beauty, and artistic perfection [106].

The Baroque Garden revolutionized the role of turfgrass, elevating it from a practical or decorative feature to a critical element in the orchestration of space, perspective, and optical illusion [99]. Through the works of Le Nôtre, turfgrass became a medium for expressing power, order, and artistic mastery, contributing to theatrical landscape compositions that extended beyond their physical boundaries.

As illustrated in Figure 6, the gardens of Vaux-le-Vicomte represent the culmination of these principles, where lawns, parterres, and axial perspectives create a sense of infinite depth and mathematical precision. This model would not only define the gardens of Versailles but also influence landscape architecture across Europe, shaping the formal gardens of the 18th century and laying the groundwork for the transition to naturalistic English landscapes in the following century [107].

3.7. The 18th-Century Landscape Garden: The Naturalization of Turfgrass and the Aesthetic of the Picturesque

By the 18th century, landscape design underwent a radical transformation, moving away from the rigid geometries of the Renaissance and Baroque gardens toward a more naturalistic and emotionally evocative vision. This shift was rooted in a new philosophical and artistic sensibility, which rejected the strict human dominion over nature in favor of an idealized, untouched landscape [108]. The emerging concept of nature as pure, perfect, and artistically complete was influenced by scientific discoveries, Enlightenment ideals, and an increasing fascination with non-European landscapes [109,110]. The growing interest in exotic lands and Eastern philosophies, fueled by 17th-century explorations and expanding global trade, introduced new perspectives on nature and landscape aesthetics. Travelogues and literary accounts of Chinese gardens, in particular, inspired European designers to abandon rigid geometric schemes in favor of irregular, asymmetrical flowing compositions that evoked spontaneity and harmony with the environment [111]. This was not merely a stylistic change, but a cultural and philosophical revolution, seeking to reconcile human intellect with the natural world while emphasizing a new coexistence between science and nature [29].

It was in England that this vision materialized into a completely new form of garden design, one that embraced the landscape itself as a model. The English landscape garden, developed in the early

18th century, quickly influenced France, Germany, and Italy, challenging the formal garden tradition that had dominated European aristocratic estates for centuries [112]. This new approach transformed the role of turfgrass, aligning it with the philosophy of landscape naturalism, where lawns became central visual and functional features, no longer confined to decorative framing. . One of the key figures in this revolution was Charles Bridgeman (1677–1738), whose work at Stowe (1714) marked the transition from formal gardens to a more naturalistic aesthetic [113]. Bridgeman's most significant innovation was the replacement of highly decorative flower parterres with expansive turfgrass lawns, designed for both aesthetic enjoyment and everyday use. This shift responded to the excessive cost and labor of traditional parterres. He introduced , uninterrupted grassy expanses, integrated into broader landscape compositions, framing scenic views and guiding the visitor's experience , [114]. This marked a turning point in garden design: turfgrass, once confined to geometric symmetry and ornamental framing, now became the central compositional element, fostering a greater sense of openness and fluidity. Beyond aesthetic innovations, Bridgeman also revolutionized garden accessibility and spatial perception. Instead of enclosing estates with walls, he introduced the "ha-ha", a sunken that prevented livestock intrusion while preserving continuous sightlines to the countryside. This approach redefined the estate as part of the larger landscape and paved the way for modern public parks. [115]. Bridgeman's approach set the foundation for modern public parks, as lawns were no longer the exclusive privilege of aristocrats but began to be conceptualized as shared spaces for leisure and recreation. His work redefined both the practical and symbolic role of turfgrass, ensuring its place as a fundamental element of modern landscape architecture [116]. The next major development in landscape gardening came with William Kent (1685–1748), an influential landscape architect who, according to Horace Walpole, *"leapt the fence and saw that all nature was a garden."* Kent expanded Bridgeman's ideas by adopting , a more painterly, emotionally resonant approach [114]. Kent's gardens used natural topography and carefully placed elements to create immersive, sequential views . . Turfgrass served as a soft connective tissue between these components, enhancing unity and narrative flow without visual interruption [117]. This romanticization of the landscape reflected the growing cultural fascination with nature as a source of inspiration, nostalgia, and emotional depth [55]. With Capability Brown, the landscape garden reached full maturity. He perfected the manipulation of natural scenery through rolling lawns, reflective lakes, and tree clusters, dispensing with overt architectural elements. Turfgrass here became the primary structuring device, shaping space, guiding movement, and intensifying the perception of depth and scale [32]. In many estates, the lawn extended directly from the house to the ha-ha, blurring the line between private garden and rural landscape [118,119].

Unlike Kent, Brown eliminated architectural elements, relying solely on natural forms—rolling meadows, reflective lakes, and strategically placed tree clusters—to shape the viewer's experience [120]. A defining feature of Brown's designs was the use of expansive turfgrass surfaces, which became the primary structuring element of the garden. These undulating lawns were meticulously maintained and carefully shaped to enhance depth perception, atmospheric effects, and compositional balance [121]. In many cases, Brown brought the ha-ha directly up to the house, creating the illusion that nature extended into the very interiors of the estate. His most iconic projects, such as Petworth and Blenheim Palace, illustrate this seamless fusion of cultivated and wild landscapes, where vast green meadows dissolve into the surrounding countryside. Brown's work exemplified a fully integrated design philosophy in which lawns were no longer static surfaces, but dynamic elements that encouraged interaction and deepened emotional connection to the landscape [118]. By the late 18th century, the English landscape garden had replaced the formal gardens of the Baroque era across much of Europe. In contrast to French and Italian gardens, it emphasized personal engagement with nature, offering open green spaces designed for movement, reflection, and social life [114]. The first major adaptation of the English garden concept in Italy occurred at the Reggia di Caserta, (Figure 7 and Figure 8) where ancient ruins were integrated into a naturalistic composition, evoking grandeur, and timelessness [122]. Elsewhere in Europe, the romanticized vision of nature took on regional variations, incorporating elements from local topographies and cultural traditions

[108]. This transformation laid the groundwork for modern urban parks, and green infrastructure. . The multifunctionality of lawns—visual, ecological, and social—was solidified through the innovations of Bridgeman, Kent, and Brown, making turfgrass a defining feature of contemporary landscape architecture. The 18th-century landscape garden redefined the relationship between humans, nature, and designed spaces, marking a fundamental shift from formal geometry to organic fluidity. The evolution of turfgrass during this period mirrored broader cultural changes, transforming from a decorative element to a central feature of interactive, immersive landscapes [123]. Through the innovations of Bridgeman, Kent, and Brown, the multifunctionality of lawns was solidified, paving the way for their continued relevance in contemporary landscape architecture. This era not only democratized access to green spaces but also established an enduring model for balancing aesthetics, ecology, and public use, shaping modern environmental consciousness and urban planning [124].



Figure 7. English Garden, Reggia di Caserta. This view of the English Garden at the Reggia di Caserta exemplifies the integration of English landscape aesthetics into Italian design. The composition combines turfgrass, romantic ruins, and naturalistic water features to evoke a picturesque and emotionally resonant landscape, reflecting the 18th-century shift from formal geometry to scenic fluidity.

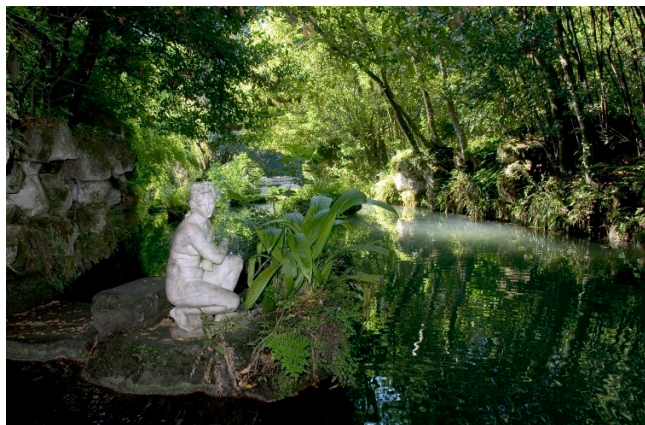


Figure 8. English Garden, Reggia di Caserta. This scene highlights how the English garden movement influenced Italian park design during the late 18th century. The integration of turfgrass with historical ruins, shaded woodland, and reflective water elements creates a naturalistic composition that emphasizes emotional depth, scenic variety, and a cultivated sense of wilderness.

3.8. The Use of Turfgrass from the 19th Century Onwards

With the arrival of the 19th century, the creative momentum that had characterized previous centuries gradually gave way to a more eclectic approach to landscape design [125]. Formal elements continued to play a role, but they were now softened by simpler, nature-inspired compositions, reflecting a growing appreciation for the organic beauty of the landscape. During this period, garden

design and urban planning became increasingly intertwined, giving rise to the concept of the public urban park, which soon became a defining feature of European cities. The emergence of public parks was driven by multiple factors. There was a growing awareness of the needs of the general population, which required livable green spaces within the urban fabric. Concerns about public health and sanitation also played a key role, as did the desire to enhance urban aesthetics and civic prestige [126]. In England, in particular, the public park was conceived not merely as a recreational space, but as a semi-public environment with a clear educational and social function. During previous centuries, the large green lawns of aristocratic villas, often framed by topiary, decorative artifacts, and artistic elements, had been symbols of status and refinement [63]. Even in smaller-scale gardens, flower beds, central green spaces, or bordered lawns were common, reflecting a well-defined way of life. However, in the 19th century, lawns became a more universal feature, gradually incorporated into gardens of all sizes. The idea of a private green space was no longer limited to the nobility; it became an essential component of middle-class homes and urban landscapes. Moreover, historical parks and gardens that had originated before the 18th century were often modified or integrated according to the new aesthetic principles. Newly designed parks were structured around one or more expansive lawns, allowing for pleasant open-air walks and panoramic views. The lawn became the unifying element of these green spaces, reinforcing a sense of cohesion and continuity in the overall composition [127]. The Industrial Revolution further intensified the demand for green public spaces. As cities expanded, the transition from rural to urban life created a sense of disconnection from nature, particularly among workers who had previously lived in agricultural settings. Factory conditions were often bleak and overcrowded, forcing urban populations to seek new forms of outdoor recreation to compensate for their loss of connection with the countryside [128,129]. At the same time, the economic benefits of industrialization were too significant to forgo, leading to a dual necessity: embracing urban modernity while still preserving elements of rural life. This paradox gave rise to a new urban ideology, in which public parks were seen not only as aesthetic improvements but as crucial instruments for health, hygiene, and social progress [130].

As part of this transformation, many former private estates were opened to the public, and historical gardens were repurposed as public parks. This shift was both ideological and practical, symbolizing greater social inclusivity while addressing pressing urban challenges. The creation of large, open green spaces provided an effective response to the need for fresh air, recreation, and community well-being. It soon became evident that simple tree-lined avenues, where the upper classes had once strolled in carriages or on foot, were no longer sufficient. The demand for vast open spaces, where all citizens—regardless of class—could freely engage in outdoor activities, led to the widespread introduction of large, open lawns in public parks. These green areas required minimal infrastructure, reducing maintenance costs while offering maximum accessibility to the general public [131]. The social function of the lawn became increasingly evident. It was perceived as a universal space, equally suited for leisure, play, exercise, and relaxation. Unlike structured gardens, where movement was restricted by pathways and hedges, the lawn encouraged free and spontaneous interaction with nature. Over time, it became a deeply ingrained cultural symbol, associated with health, vitality, and well-being [132]. Beyond its practical and recreational benefits, the lawn took on new aesthetic and symbolic meanings. Its flat, open surface created a sense of spaciousness, making it an ideal backdrop for sculptures, fountains, and urban landmarks. The uniformity of turfgrass accentuated architectural elements, creating a visual podium that enhanced perspective and composition. Unlike trees and shrubs, which had volume and mass, the lawn was purely a surface, adapting to the contours of the land and concealing irregularities in the terrain. As a result, turfgrass became an irreplaceable feature of landscape design, offering a unique blend of simplicity and elegance [133]. Even when compared to luxurious stone pavements or meticulously designed mosaics, the soft, green expanse of a well-maintained lawn remained unparalleled in its ability to create a sense of openness and tranquility [63]. The association between turfgrass and the natural landscape was equally significant. Lawns were not perceived as artificial constructs, but rather as extensions of the countryside, evoking the rolling meadows of rural landscapes. This deep

psychological connection reinforced their appeal, making them an essential element of both urban and suburban environments [134].

As awareness of environmental sustainability grew, turfgrass was also recognized for its ecological contributions. Grass surfaces played a role in:

- Carbon sequestration, helping to mitigate climate change.
- Dust and pollutant filtration, improving urban air quality.
- Water absorption and flood management, reducing soil erosion.
- Biodiversity support, serving as habitats for small organisms and pollinators [135]
- Urban heat island mitigation, by lowering surface temperatures through evapotranspiration.
- Noise reduction, especially in urban environments, due to the sound-dampening properties of dense vegetation.
- Psychological and recreational benefits, contributing to mental well-being, relaxation, and opportunities for physical activity.
- Soil stabilization, preventing compaction and surface degradation in urban green spaces [136].

With technological advancements, turfgrass was no longer treated as a simple natural element but became an engineered surface, cultivated with increasingly sophisticated methods. The introduction of improved grass varieties, advanced irrigation systems, and precise soil management techniques allowed for higher-quality lawns with improved durability and aesthetics [137]. These advancements were particularly evident in specialized environments, such as sports fields, golf courses, horse-racing tracks, airports, and exhibition areas. In these contexts, turfgrass was cultivated not just for beauty but for performance, ensuring optimal conditions for both functional and recreational activities [138]. Within cities, however, the role of turfgrass became more fragmented. Due to land constraints and increasing urban density, green spaces were often reduced to small, enclosed areas, sometimes limited to tiny patches of grass within roundabouts or parking lots. The maintenance of urban lawns was further complicated by water shortages, vandalism, and pollution, making their preservation a growing challenge [139]. Nevertheless, the cultural and psychological value of turfgrass remained strong, reinforcing the idea that green spaces are vital components of the urban fabric. Public parks, even when limited in size, continued to serve as “green lungs” for cities, providing a refuge from concrete-dominated environments and fostering community well-being [140].

In an era of increasing environmental awareness, turfgrass is now recognized not only for its aesthetic value but also for its contributions to sustainability and urban resilience. As Francis Bacon eloquently stated in the early 17th century, “*The garden is the purest of human pleasures... Without it, buildings and palaces are but crude manual works*” [96]. This sentiment remains true today, as lawns continue to symbolize harmony, balance, and the enduring human connection with nature.

4. Bridging Historical Uses and Contemporary Turfgrass Management

The historical trajectory of turfgrass reveals a profound evolution in both function and perception. From its early appearance in the enclosed temple gardens of ancient Egypt to the expansive lawns of Renaissance villas and English landscape parks, turfgrass has long served aesthetic, symbolic, and recreational purposes [141]. However, behind its visual harmony lay practical techniques—often labor-intensive—designed to maintain the appearance and structure of grassy surfaces. In classical antiquity, green spaces were irrigated through sophisticated hydraulic systems, as seen in Roman peristyles and Islamic chahar bagh gardens, where qanats and cisterns ensured consistent moisture levels [142]. In medieval monastic gardens, turf was kept short through grazing by livestock or by hand tools such as scythes, with maintenance tasks integrated into the rhythms of daily religious life.

While not always documented in detail, these early practices reflect a proto-ecological awareness: water was used judiciously, maintenance was manual and cyclical, and turfgrass was often multifunctional—used for reflection, rest, and productive cultivation [143]. The evolution of turfgrass thus mirrors broader shifts in landscape ideology: from controlled geometric order to

romanticized wilderness, from aristocratic privilege to public accessibility. Yet, in all phases, turfgrass remained a material interface between humans and the environment—a soft threshold between architecture, garden, and wider landscape [144].

In the modern era, however, the expansion of urban green spaces, sports fields, and ornamental lawns has placed new demands on turfgrass systems. Mechanized mowing, synthetic fertilizers, pesticides, and large-scale irrigation have become standard in many regions—often without regard to local climate, soil conditions, or biodiversity. These high-input practices, while effective for uniform appearance, have raised critical concerns regarding water use, chemical runoff, and greenhouse gas emissions [145].

Bridging past and present, it becomes clear that historical models of turfgrass care—though limited in scale—offer valuable insights for contemporary management. The transition from symbolic lawns to sustainable systems calls for a rethinking of turfgrass not just as a decorative feature, but as a living, adaptive element within ecological and urban infrastructures [3,140]. The following section explores this shift, analyzing recent innovations in turfgrass science, low-input maintenance strategies, and integrated design approaches that respond to environmental pressures while building on centuries of landscape tradition.

5. The Agronomic and Ecological Functions of Turfgrass in Contemporary Landscapes

Although traditionally valued for its ornamental and recreational functions, turfgrass also contributes significantly to soil conservation, hydrological regulation, carbon sequestration, and biodiversity support. While often criticized for its high-water demand and intensive maintenance requirements, advancements in sustainable turfgrass management have highlighted its potential as an integral element of both urban and rural ecosystems [146]. By enhancing soil stability, moderating climatic extremes, and fostering biodiversity, turfgrass underscores the importance of resource-efficient, environmentally responsible management strategies. One of its most crucial agronomic benefits is erosion control, particularly in urban green spaces, sloped terrains, and riparian buffers, where its dense root system helps bind soil particles, reducing surface runoff and sediment displacement. The dense root system of turfgrass enhances soil structure, binding particles together and reducing sediment loss from surface runoff [147,148]. Research has shown that turfgrass-covered slopes experience up to 90% less erosion compared to bare or sparsely vegetated areas, making it an essential tool in stormwater management and sustainable urban planning [149].

Beyond erosion control, turfgrass contributes significantly to hydrological regulation by enhancing water infiltration, reducing runoff, and filtering pollutants. The porous nature of turfgrass lawns allows water to percolate into the soil, improving groundwater recharge and mitigating flood risks in urban environments. Studies have demonstrated that well-maintained turfgrass areas can retain up to 60% of annual precipitation, reducing non-point source pollution and nutrient runoff into waterways [150,151].

However, water consumption remains a critical concern, particularly in arid and semi-arid regions, where traditional turfgrass species and cultivars require intensive irrigation to maintain their aesthetic and functional qualities. In response, research has focused on developing drought-resistant turfgrass varieties and precision irrigation systems to optimize water efficiency. Technologies such as subsurface irrigation, moisture-sensing systems, and hydrogel amendments have significantly improved water conservation efforts in golf courses, sports fields, and urban parks, reducing unnecessary irrigation while maintaining functional turf performance [152].

Recent research has identified turfgrass as a valuable carbon sink, with the potential to contribute to atmospheric CO₂ reduction and climate regulation [153–155].

While turfgrass has historically been overlooked in global carbon models, studies suggest that managed turfgrass systems can sequester substantial amounts of carbon in the soil, particularly in low-input and well-maintained landscapes [156,157].

The rapid turnover of organic matter in turfgrass root systems promotes long-term carbon storage, with estimates suggesting that turfgrass can sequester between 0.2 and 1.5 metric tons of CO₂ per hectare per year, depending on species selection, soil composition, and maintenance practices [158]. In addition, turfgrass plays a role in urban microclimate regulation, particularly in mitigating the urban heat island (UHI) effect. Through evapotranspiration and surface cooling, grass-covered surfaces can be up to 10°C cooler than impervious surfaces such as asphalt or concrete, significantly improving thermal comfort in densely populated areas [159,160].

Moreover, turfgrass contributes to air quality improvement, acting as a natural filter for particulate matter and absorbing atmospheric pollutants. Studies have shown that well-maintained lawns can capture airborne dust, heavy metals, and volatile organic compounds (VOCs), further supporting their role in climate resilience and public health [161].

Despite these benefits, concerns remain regarding the carbon footprint of turfgrass maintenance, particularly in high-input systems that rely on synthetic fertilizers, frequent mowing, and extensive irrigation. Studies indicate that the emissions from maintenance equipment and chemical inputs can reduce the carbon sequestration potential of turfgrass [158]. To address these challenges, researchers have advocated for low maintenance turfgrass species, organic soil amendments, and electric mowing technologies, which can reduce the environmental impact while preserving carbon storage benefits [162].

Beyond its agronomic and climate functions, turfgrass plays a crucial role in supporting biodiversity, particularly in urban and peri-urban environments. While conventional monoculture turf systems have been criticized for low species diversity, recent shifts towards pollinator-friendly, mixed-species turfgrass have demonstrated significant ecological advantages [163]. Research has shown that low-mow and flowering turfgrass varieties can provide critical resources for native bee populations, butterflies, and other beneficial insects, contributing to urban pollination networks [164,165].

In peri-urban and rural landscapes, turfgrass serves as an important component of wildlife corridors, enhancing habitat connectivity for small mammals, birds, and invertebrates [166]. Studies on golf course roughs and park meadows indicate that minimally managed turfgrass areas can support higher avian diversity compared to intensively maintained lawns [167]. Additionally, turfgrass buffers along waterways play a significant role in nutrient retention and riparian zone restoration, filtering excess nitrogen and phosphorus from agricultural runoff [168].

However, the ecological benefits of turfgrass depend heavily on management practices. Excessive use of herbicides, pesticides, and synthetic fertilizers can disrupt soil microbial diversity, negatively affecting ecosystem resilience [169]. To address these issues, sustainable turfgrass management strategies have focused on integrated pest management (IPM), reduced mowing frequencies, and organic fertilization, all of which contribute to enhancing the ecological function of turfgrass while minimizing negative environmental trade-offs [170].

The agronomic and ecological functions of turfgrass extend far beyond aesthetic and recreational purposes, playing a critical role in soil stabilization, water management, carbon sequestration, and biodiversity support. While traditional high-input turfgrass systems have often been associated with excessive resource consumption, emerging research and sustainable management approaches suggest that low-input, climate-adaptive turfgrass solutions can offer significant environmental benefits [171].

As urbanization and climate change continue to reshape global landscapes, future turfgrass research should prioritize multi-functional landscapes that balance agronomic performance with ecological resilience. By integrating drought-tolerant species, eco-friendly management practices, and innovative turf technologies, turfgrass can remain a valuable component of both urban and rural ecosystems in an era of increasing environmental and climatic challenges.

6. Sustainable Turfgrass Management: Challenges, Innovations, and Future Perspectives

The management of turfgrass systems faces increasing challenges related to sustainability, climate change, and resource conservation. While turfgrass plays a pivotal role in urban landscapes, sports fields, and ecosystem services, conventional high-input maintenance practices have been widely criticized for excessive water consumption, chemical dependency, and greenhouse gas emissions [172]. To ensure the long-term viability of turfgrass within sustainable landscapes, management strategies must prioritize resource efficiency, climate adaptation, and technological innovation. By integrating precision irrigation, optimized fertilization, climate-resilient species selection, and smart maintenance technologies, turfgrass can evolve into a low-input yet functional component of modern landscapes [88].

As climate change exacerbates drought conditions across many regions, water conservation has become a primary objective in sustainable turfgrass management. Efficient irrigation strategies play a crucial role in reducing water waste while ensuring turfgrass viability under arid conditions [173]. Advances in subsurface drip irrigation (SDI), precision irrigation, and soil moisture-sensing technologies have significantly improved water-use efficiency, allowing turfgrass systems to maintain functional performance with reduced inputs [174].

Research has demonstrated that SDI systems can lower water consumption by up to 40% compared to traditional overhead sprinkler irrigation, minimizing evaporation losses and promoting deeper root growth [175,176]. The integration of AI-driven irrigation scheduling, real-time soil moisture sensors, and adaptive irrigation controls further enhances water efficiency, ensuring that turfgrass receives only the precise amount of water necessary while preventing runoff and nutrient leaching [177,178].

In high-maintenance landscapes such as golf courses and sports fields, where water conservation is a priority, innovative technologies have revolutionized irrigation management. Automated weather-based irrigation controllers, linked to evapotranspiration data, dynamically adjust watering schedules based on climatic conditions, optimizing resource use while maintaining optimal turf health [179]. These technological advancements demonstrate how intelligent irrigation management can substantially reduce water demand while ensuring long-term turfgrass sustainability.

Excessive fertilizer and pesticide applications have long been associated with negative environmental impacts, including soil degradation, water contamination, and increased greenhouse gas emissions [180]. Over-application of nitrogen fertilizers contributes to elevated CO₂ and N₂O emissions, negating the potential carbon sequestration benefits of turfgrass systems [158].

To address these challenges, alternative soil fertility and pest management approaches have been developed. Recent studies have shown that optimizing fertilizer regimes—rather than eliminating inputs entirely—can sustain or even improve turfgrass performance in terms of color, density, and resilience, while significantly lowering environmental impacts. Reduced nitrogen inputs, when combined with organic fertilizers or slow-release formulations, enhance nutrient use efficiency and root development, contributing to long-term turf health [181].

Optimizing nitrogen application rates, incorporating organic fertilizers, and utilizing microbial soil amendments have proven effective in reducing the environmental footprint of turfgrass systems while maintaining turf quality and functionality [182–184].

Additionally, integrated pest management (IPM) strategies, which emphasize biological controls, targeted treatments, and reduced reliance on synthetic pesticides, are increasingly recognized as essential for enhancing soil health and ecological resilience [185].

Furthermore, low-input turfgrass management strategies, such as reducing mowing frequencies, implementing slow-release fertilizers, and using natural compost amendments, have been shown to improve soil microbial diversity, reduce nutrient leaching, and minimize chemical dependency [186,187]. These approaches align with the broader goals of sustainable landscape

management, ensuring that turfgrass systems contribute positively to urban ecosystems rather than exacerbating environmental degradation.

As urbanization expands and climatic conditions become more unpredictable, turfgrass management must adapt to environmental stressors, including higher temperatures, prolonged droughts, and extreme weather events [121]. A key component of climate adaptation is the selection of turfgrass species with enhanced drought resistance, salinity tolerance, and reduced maintenance requirements.

Recent breeding programs have focused on developing hybrid warm season turfgrasses, such as advanced cultivars of Bermudagrass (*Cynodon dactylon*) and Zoysia spp., which require less irrigation and demonstrate greater resilience under prolonged heat stress [188,189]. Additionally, research into polycultures and mixed species turfgrass blends has shown promise in increasing genetic diversity and ecological resilience, reducing the risk of widespread turf failure due to disease outbreaks or climate extremes [61].

These climate-resilient turfgrass systems not only offer improved durability under fluctuating environmental conditions but also contribute to reduced chemical inputs and lower water consumption, making them an integral part of future sustainable landscape strategies [190].

Beyond its role in landscape aesthetics, turfgrass is increasingly recognized for its contributions to stormwater management, carbon sequestration, and biodiversity enhancement. Innovative urban planning approaches integrate turfgrass into bioswales, rain gardens, and permeable green spaces, maximizing stormwater retention, mitigating urban heat island effects, and enhancing habitat connectivity for urban wildlife [191].

The incorporation of turfgrass into multifunctional green infrastructure allows urban planners to combine the benefits of traditional turfgrass with ecological resilience, creating adaptive landscapes that respond to climate variability and urbanization pressures [192]. These applications reinforce the idea that turfgrass should not be viewed solely as an ornamental element, but rather as a functional ecosystem component with critical environmental and social benefits.

While historical turfgrass systems were primarily designed for visual harmony and symbolic expression, modern turfgrass management increasingly emphasizes measurable ecological performance. Comparative data highlight this shift: contemporary turfgrass systems can sequester approximately 0.9 to 1.8 tons of carbon per hectare per year, depending on management intensity and grass species [153]. Moreover, irrigated turfgrass surfaces can reduce surface temperatures by 5–10°C compared to adjacent hardscape areas, mitigating urban heat island effects [193]. In terms of water use, traditional ornamental turf required substantial manual irrigation, while current technologies such as subsurface drip irrigation (SDI) can reduce water consumption by up to 40% compared to conventional sprinkler systems [194]. These indicators reinforce the evolution of turfgrass from an aesthetic element to a multifunctional green infrastructure component, bridging cultural heritage with environmental innovation.

Advancements in genomics, molecular breeding, and digital agriculture are reshaping turfgrass science, leading to the development of genetically enhanced turf varieties with improved stress tolerance, disease resistance, and reduced maintenance requirements [195]. In parallel, smart irrigation technologies, such as AI-powered water management systems, enable real-time adjustments to irrigation schedules based on weather forecasts, evapotranspiration rates, and soil conditions, significantly optimizing resource efficiency [196].

Additionally, robotic mowing and autonomous turf monitoring technologies have been introduced to reduce fuel consumption, minimize labor costs, and enhance turfgrass performance. These innovations mark a shift toward precision turf management, ensuring that modern turfgrass systems remain both sustainable and high performing [197,198].

The future of turfgrass science and management lies in the transition toward low-input, climate-resilient, and technologically advanced practices. Continued research efforts should focus on breeding drought-tolerant and disease-resistant cultivars, refining precision irrigation techniques, and integrating turfgrass into sustainable urban design [199,200].

By embracing an evidence-based, resource-efficient approach, turfgrass management can evolve into an ecologically responsible and climate-adaptive practice, ensuring its long-term viability within both urban and rural landscapes. In an era of global environmental challenges, turfgrass remains a valuable component of green infrastructure, supporting ecosystem services, urban resilience, and sustainable land use [201,202]. The transition toward sustainable turfgrass management requires a multifaceted approach that integrates water conservation, reduced chemical inputs, climate adaptation, urban sustainability, and technological advancements. Table 2 summarizes the key challenges facing turfgrass management, alongside innovative strategies and future directions aimed at enhancing its environmental resilience and functionality.

A major limitation of this study is its reliance on historical sources and literature-based analysis, without the inclusion of direct field data or ecological trials. While this approach enables a broad cultural and temporal comparison, future research would benefit from empirical methodologies that incorporate biodiversity surveys, carbon sequestration metrics, and in-situ turfgrass performance indicators across varied geographic contexts.

Table 2. Key Challenges, Innovations, and Future Directions in Sustainable Turfgrass Management.

Key Challenge	Innovations & Strategies	Future Directions
Water Conservation	<ul style="list-style-type: none">- Subsurface drip irrigation (SDI) reduces water use by up to 40%.- AI-driven irrigation and moisture sensors optimize water efficiency.- Weather-based irrigation controllers minimize runoff and evaporation.	<ul style="list-style-type: none">- Expansion of AI and real-time irrigation control [203].- Development of drought-tolerant turf species [204].
Reduction of Chemical Inputs	<ul style="list-style-type: none">- Optimized nitrogen application and slow-release fertilizers reduce environmental impact.- Organic soil amendments improve microbial diversity.- Integrated Pest Management (IPM) minimizes pesticide use.	<ul style="list-style-type: none">- Increased adoption of organic and microbial-based fertilizers [205].- Precision nutrient management via soil testing [199].
Climate Adaptation	<ul style="list-style-type: none">- Breeding of drought-tolerant turf species (e.g., hybrid Bermudagrass, Zoysia spp.).- Polyculture and mixed-species turf systems enhance resilience.- Turfgrass integrated into heat-mitigating green spaces.- Turfgrass integrated into bioswales, rain gardens, and stormwater management systems.	<ul style="list-style-type: none">- Expansion of climate-resilient, low-input turfgrass varieties [206].- Research on adaptive genetic breeding for extreme climates.
Urban Sustainability & Green Infrastructure	<ul style="list-style-type: none">- Carbon sequestration and urban heat island mitigation.- Turfgrass supports pollinators and urban biodiversity.	<ul style="list-style-type: none">- Wider implementation of multifunctional turfgrass landscapes.- Policy-driven incentives for green infrastructure integration [136].
Technological Advancements	<ul style="list-style-type: none">- Genomic and molecular breeding for disease-resistant, low-maintenance turfgrass.- Smart irrigation technologies and AI-powered water management.- Robotic mowing and autonomous turf monitoring reduce emissions.	<ul style="list-style-type: none">- Further development of autonomous maintenance systems [195].- Expansion of precision turf management technologies [69].

7. Conclusions, Considerations and Recommendations

The evolution of turfgrass from a functional agricultural resource to an essential component of urban and ecological landscapes highlights its multifaceted role in modern environmental management. While traditionally valued for its aesthetic and recreational qualities, contemporary research has demonstrated that turfgrass also provides crucial ecosystem services, including soil

stabilization, water filtration, carbon sequestration, and biodiversity support. However, the sustainability of turfgrass systems has been a subject of growing concern, particularly due to the perceived high water demands, chemical dependencies, and greenhouse gas emissions associated with conventional maintenance practices. As climate change and urbanization continue to reshape landscapes, there is an urgent need for a paradigm shift toward resource-efficient, ecologically responsible turfgrass management.

A key priority for future research and practice is the optimization of water conservation strategies. Advances in precision irrigation, subsurface drip irrigation, and AI-driven water management systems have shown significant potential in reducing water consumption while maintaining turfgrass viability. The development and widespread adoption of drought-tolerant turfgrass species further contribute to reducing irrigation needs, making turfgrass a more sustainable option in regions affected by water scarcity. Additionally, a more judicious approach to fertilization and pest management is essential to mitigate the environmental risks associated with excessive nitrogen application and pesticide use. By integrating organic soil amendments, microbial-based fertilizers, and integrated pest management (IPM) strategies, it is possible to enhance soil health while minimizing chemical runoff and pollution.

The impact of climate change on turfgrass performance necessitates a shift toward climate-resilient varieties and adaptive management techniques. Advances in molecular breeding have facilitated the development of turfgrass cultivars with enhanced tolerance to drought, salinity, and temperature extremes. Polyculture and mixed-species turf systems have also emerged as promising solutions for increasing genetic diversity and ecological resilience, reducing the vulnerability of turfgrass to disease outbreaks and environmental stressors. In parallel, urban sustainability initiatives have underscored the value of turfgrass in green infrastructure, where it plays a role in stormwater management, urban cooling, and habitat connectivity. By integrating turfgrass into bioswales, rain gardens, and permeable landscapes, its functionality extends beyond ornamental use, reinforcing its importance in climate adaptation strategies.

Technological innovation will continue to shape the future of turfgrass management, with developments in robotics, AI, and automated maintenance systems playing a crucial role in optimizing resource use and reducing environmental impact. Smart irrigation technologies that adjust water application based on soil moisture levels and weather forecasts exemplify how digital advancements can enhance efficiency while minimizing waste. Similarly, autonomous mowers and remote turf monitoring systems offer sustainable alternatives to traditional maintenance practices, reducing fuel consumption and labor costs.

The future of turfgrass science lies in the integration of agronomic performance with ecological resilience. While traditional turfgrass systems have often been criticized for their environmental footprint, emerging research suggests that with appropriate management, turfgrass can contribute positively to sustainable landscapes. By adopting a multi-disciplinary approach that combines agronomy, environmental science, and technological innovation, turfgrass can be maintained in a way that aligns with contemporary sustainability goals. Future research should continue to explore ways to refine low-input, climate-adaptive management practices, ensuring that turfgrass remains a viable and beneficial component of both urban and rural environments.

Ultimately, the challenge of sustaining turfgrass in the face of global environmental change requires a balanced approach that considers both its functional and ecological roles. The transition from high-maintenance, resource-intensive systems to resilient, low-input alternatives will be critical in ensuring that turfgrass continues to provide valuable services without exacerbating environmental degradation. By embracing evidence-based strategies, turfgrass management can evolve to meet the demands of a changing climate while contributing to healthier, more sustainable landscapes.

Policy Recommendations

In light of these findings, it is essential that policymakers and urban planners recognize the strategic value of turfgrass within broader environmental policies. We recommend the following actions:

- Integrate turfgrass into land restoration and anti-erosion programs, particularly in peri-urban and degraded areas, where root structure can help prevent soil loss and improve infiltration.
- Promote the use of native or climate-adapted turfgrass species in public green spaces to reduce water use and chemical dependency.
- Incentivize sustainable turf management practices—such as precision irrigation, organic fertilization, and autonomous maintenance—through funding schemes and regulatory frameworks.
- Incorporate turfgrass into urban green infrastructure planning, ensuring its use in bioswales, green corridors, stormwater control systems, and urban cooling zones.
- Support interdisciplinary research on turfgrass as a tool for environmental resilience, linking agronomy, ecology, and public health.

These recommendations highlight the importance of transitioning from ornamental to functional turfgrass systems, aligning landscape management with the urgent challenges of climate change, biodiversity loss, and land degradation.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org, Critical Analysis of Selected References.

Author Contributions: Conceptualization, methodology, formal analysis, writing—original draft preparation, writing—review and editing: M.O.; data curation, M.S.; investigation, E.R.; resources, P.V.; validation, A.M.; All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Lindsey, A. J., Schiavon, M., Unruh, J. B., & Kenworthy, K. (2025). Urban Landscapes: Turfgrass Benefits. *Grasses*, 4(1), 3. <https://doi.org/10.3390/grasses4010003>
2. Zhu, L.; Sarah, J.S. History and Evolution of the Healing Gardens: Investigating the Building-Nature Relationship in the Healthcare Setting. *SSM - Qualitative Research in Health* **2024**, 6, 100450, doi:10.1016/j.ssmqr.2024.100450.
3. Monteiro, J.A. Ecosystem Services from Turfgrass Landscapes. *Urban Forestry & Urban Greening* **2017**, 26, 151–157, doi:10.1016/j.ufug.2017.04.001.
4. Boulos, L.; Fahmy, A.G.-E.-D. Grasses in Ancient Egypt. *Kew Bulletin* **2007**, 62, 507–511. <http://www.jstor.org/stable/20443376>
5. Mahmoudi Farahani, L.; Motamed, B.; Jamei, E. Persian Gardens: Meanings, Symbolism, and Design. *LO* **2016**, 46, 1–19, doi:10.3097/LO.201646.
6. Hunt, J.D. *The Making of Place: Modern and Contemporary Gardens*; Reaktion Books, 2015; ISBN 1-78023-566-6.
7. Miller, M. *The Garden as an Art*; Suny Press, 1993; ISBN 0-7914-1378-0.
8. Alberti, L.B. *De Re Aedificatoria*; Ediciones Akal, 1992; Vol. 10; ISBN 84-7600-924-0.
9. Mukerji, C. *Territorial Ambitions and the Gardens of Versailles*; Cambridge University Press, 1997; ISBN 0-521-59959-8.
10. Thompson, I. *The Sun King's Garden: Louis XIV, André Le Nôtre and the Creation of the Gardens of Versailles*; Bloomsbury Publishing USA, 2006; ISBN 1-58234-631-3.
11. Rutherford, S. *Capability Brown: And His Landscape Gardens*; National Trust, 2016; ISBN 1-911358-00-6.
12. Jenkins, V. *The Lawn: A History of an American Obsession*; Smithsonian Institution, 1994; ISBN 1-56098-406-6.
13. Norris, K.D. *New Naturalism: Designing and Planting a Resilient, Ecologically Vibrant Home Garden*; Cool Springs Press, 2021; ISBN 0-7603-6819-8.
14. Ignatieva, M.; Haase, D.; Dushkova, D.; Haase, A. Lawns in Cities: From a Globalised Urban Green Space Phenomenon to Sustainable Nature-Based Solutions. *Land* **2020**, 9, 73.

15. Iqbal, M.A.; Grichar, W.J. *Grasslands: Conservation and Development*; BoD–Books on Demand, 2024; ISBN 0-85014-123-0.
16. Pliny the Younger. *Letters*, Volume I: Books 1-7. Translated by Betty Radice. Loeb Classical Library 55. **1969**, Cambridge, MA: Harvard University Press.
17. Radice, B. *The Letters of the Younger Pliny*; Penguin UK, 2003; ISBN 0-14-191594-3.
18. Priede, K. Aspects of "Genius Loci" and "Hortus Conclusus" in Relation to the Courtyard of the Former Lucerne Central Prison. **2020**.
19. Headrick, D.R. *Humans versus Nature: A Global Environmental History*; Oxford University Press, 2020; ISBN 0-19-086471-0.
20. Valipour, M.; Krasilnikof, J.; Yannopoulos, S.; Kumar, R.; Deng, J.; Roccaro, P.; Mays, L.; Grismer, M.E.; Angelakis, A.N. The Evolution of Agricultural Drainage from the Earliest Times to the Present. *Sustainability* **2020**, *12*, 416.
21. Viollet, P.-L. *Water Engineering in Ancient Civilizations: 5,000 Years of History*; CRC Press, 2007; ISBN 90-78046-05-8.
22. De Arce, R.P. *City of Play: An Architectural and Urban History of Recreation and Leisure*; Bloomsbury Publishing, 2018; ISBN 1-350-03214-X.
23. Olivadese, M.; Dindo, M.L. Water, Ecosystem Services, and Urban Green Spaces in the Anthropocene. *Land* **2024**, *13*, 1948. <https://doi.org/10.3390/land13111948>
24. Hobhouse, P. *Plants in Garden History: An Illustrated History of Plants and Their Influences on Garden Style*; Pavilion, 2004; ISBN 1-86205-660-9.
25. Lattimore, R. *The Odyssey of Homer*; HarperCollins Publishers: New York, 2007; ISBN 978-0-06-124418-6.
26. Hall, E. M. (2008). The Return of Ulysses: A Cultural History of Homer's Odyssey.
27. Pregill, P.; Volkman, N. *Landscapes in History: Design and Planning in the Eastern and Western Traditions*; John Wiley & Sons, 1999; ISBN 0-471-29328-8.
28. Mosser, M., Teyssot, G., *The history of garden design: the Western tradition from the Renaissance to the present day*; Eds.; Thames and Hudson: London, 1991; ISBN 978-0-500-01511-7.
29. Thacker, C. *The History of Gardens*; Univ of California Press, 1985; ISBN 0-520-05629-9.
30. López-Ruiz, C. *Greek Mythology: From Creation to First Humans*; Oxford University Press, 2025; ISBN 0-19-094479-X.
31. Fitter, C. *Poetry, Space, Landscape: Toward a New Theory*; Cambridge University Press, 1995; ISBN 0-521-46301-7.
32. DeWet, J. Grasses and the Culture History of Man. *Annals of the Missouri Botanical Garden* **1981**, 87–104.
33. Hilditch, M. (2016). Kepos: Garden Spaces in Ancient Greece: Imagination and Reality.
34. Castilho, R.M.M.D.; Freitas, R.C.; Santos, P.L.F.D. The Turfgrass in Landscape and Landscaping. *Ornam. Hortic.* **2020**, *26*, 499–515, doi:10.1590/2447-536x.v26i3.2237.
35. Stine, S. *Landscapes for Learning: Creating Outdoor Environments for Children and Youth*; John Wiley & Sons, 1996; ISBN 0-471-16222-1.
36. Hutchison, D.C. *A Natural History of Place in Education*; Teachers College Press, 2004; Vol. 24; ISBN 0-8077-4469-7.
37. Berleant, A. *Living in the Landscape: Toward an Aesthetics of Environment*; University press of Kansas, 1997; ISBN 0-7006-0811-7.
38. Koutsoyiannis, D.; Mamassis, N. From Mythology to Science: The Development of Scientific Hydrological Concepts in Greek Antiquity and Its Relevance to Modern Hydrology. *Hydrology and Earth System Sciences* **2021**, *25*, 2419–2444.
39. Cooper, J.C. *An Illustrated Encyclopaedia of Traditional Symbols*; Thames & Hudson, 2012; ISBN 0-500-77090-5.
40. MacDougall, E.B., Jashemski, W.F., *Ancient Roman Gardens*; Dumbarton Oaks, Eds.; Dumbarton Oaks Trustees for Harvard University: Washington, D.C, 1981; ISBN 978-0-88402-100-1.
41. Aben, R.; De Wit, S. *The Enclosed Garden: History and Development of the Hortus Conclusus and Its Reintroduction into the Present-Day Urban Landscape*; 010 Publishers, 1999; ISBN 90-6450-349-4.

42. Jashemski, W.F., Gleason, K.L., Hartswick, K.J., *Gardens of the Roman Empire*; Cambridge university press: Cambridge (UK), 2017; ISBN 978-0-521-82161-2.
43. Carroll, M. *Earthly Paradises: Ancient Gardens in History and Archaeology*; Getty Publications, 2003; ISBN 0-89236-721-0.
44. Braun, R.C.; Mandal, P.; Nwachukwu, E.; Stanton, A. The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans: Thirty Years Later. *Crop Science* **2024**, *64*, 2909–2944, doi:10.1002/csc2.21383.
45. Fulford, M.; Wallace-Hadrill, A. Towards a History of Pre-Roman Pompeii: Excavations beneath the House of Amarantus (I. 9.11–12), 1995–8. *Papers of the British School at Rome* **1999**, *67*, 37–144.
46. Stewart, P. *The Social History of Roman Art*; Cambridge University Press, 2008; ISBN 0-521-81632-7.
47. Vercelloni, M.; Vercelloni, V.; Gallo, P. *Inventing the Garden*; Getty Publications, 2010; ISBN 1-60606-047-3.
48. Spencer, D. *Roman Landscape: Culture and Identity*; Cambridge University Press, 2010; ISBN 1-107-40024-4.
49. Bellingham, D.C. W. F. Jashemski, The Gardens of Pompeii, Herculaneum and the Villas Destroyed by Vesuvius. New Rochelle: Caratzas Brothers, 1979. Pp. x + 372, 538 Illus. - Ancient Roman Gardens. Ed. E. B. MacDougall and W. F. Jashemski (Dumbarton Oaks Colloquium on the History of Landscape Architecture VII). Washington, D.C.: Dumbarton Oaks, 1981. Pp. 108, 96 Pls. - A. Hoffmann, Das Gartenstadion in Der Villa Hadriana (Deutsches Archäologisches Institut Rom, Sonderschriften IV). Mainz: Von Zabern, 1980. Pp. ix + 87, 60 Pls., 37 Plans. *J. Rom. Stud.* **1983**, *73*, 230–232, doi:10.2307/300107.
50. Hudson, J. *Walled Gardens*; National Trust, 2018; ISBN 1-911358-48-0.
51. Pearson, S.K. *Egyptian Airs: The Life of Luxury in Roman Wall Painting*; University of California, Berkeley, 2015; ISBN 1-339-21666-3.
52. Chen, G. *Landscape Architecture: Planting Design Illustrated*; ArchiteG, Inc., 2011; ISBN 0-9843741-9-1.
53. Coffin, H.G.; Brown, R.H.; Gibson, R.J.; Gibson, L.J. *Origin by Design*; Review and Herald Pub Assoc, 2005; Vol. 152; ISBN 0-8280-1776-X.
54. Lime, E.K. To Stand in Playful Gardens: The Statues of Roman Garden Paintings and Foucault's Heterotopia. **2020**.
55. Leslie, M., A Cultural History of Gardens in the Medieval Age. *Bloomsbury Cultural History* **2013**, doi:10.5040/9781350048102.
56. Quraeshi, S. *Sacred Spaces: A Journey with the Sufis of the Indus*; Harvard University Press, 2010; ISBN 0-87365-859-0.
57. Petruccioli, A.; Pirani, K.K. *Understanding Islamic Architecture*; Routledge, 2013; ISBN 1-136-85131-3.
58. Puerta-Vilchez, J.M. The Alhambra and the Generalife. The Eternal Landmarks of Islamic Granada. In *A Companion to Islamic Granada*; Brill, 2021; pp. 365–406 ISBN 90-04-42581-0.
59. Chamberlain, G. *Troubled Waters: Religion, Ethics, and the Global Water Crisis*; Rowman & Littlefield, 2008; ISBN 0-7425-5245-4.
60. Çalis-Kural, B.D. *Sehrenciz, Urban Rituals and Deviant Sufi Mysticism in Ottoman Istanbul*; Routledge, 2016; ISBN 1-315-60820-0.
61. Clark, E. *The Art of the Islamic Garden*; The Crowood Press, 2010; ISBN 0-7198-4358-8.
62. Ruggles, D.F. *Islamic Gardens and Landscapes*; University of Pennsylvania Press, 2008; ISBN 0-8122-4025-1.
63. Campbell, G. *A Short History of Gardens*; Oxford University Press, 2016; ISBN 0-19-878461-9.
64. Bayard, T. *Sweet Herbs and Sundry Flowers: Medieval Gardens and the Gardens of the Cloisters*; Metropolitan Museum of Art, 1997; ISBN 0-87099-775-0.
65. Landsberg, S. *The Medieval Garden*; University of Toronto Press, 2003; ISBN 0-8020-8660-8.
66. Marcus, C.C.; Barnes, M. *Healing Gardens: Therapeutic Benefits and Design Recommendations*; John Wiley & Sons, 1999; Vol. 4; ISBN 0-471-19203-1.
67. McWilliam, G.H. *The Decameron*; Boccaccio, G.; Penguin classics; Penguin Books Limited, 2003; ISBN 978-0-14-192157-0.
68. Ames-Lewis, F.; Rogers, M. *Concepts of Beauty in Renaissance Art*; Routledge, 2019; ISBN 0-429-86054-4.
69. Mellor, D.R. *Picture Perfect: Mowing Techniques for Lawns, Landscapes, and Sports*; John Wiley & Sons, 2001; ISBN 1-57504-151-0.
70. Ackerman, J.S. *The Villa: Form and Ideology of Country Houses*; Princeton University Press, 2023; ISBN 0-691-25231-9.

71. Miller, N.F.; Gleason, K.L. *The Archaeology of Garden and Field*; University of Pennsylvania Press, 1997; ISBN 0-8122-1641-5.
72. Duple, R.L. *Turfgrasses: Their Management and Use in the Southern Zone*; Texas A&M University Press, 1996; Vol. 20; ISBN 1-58544-161-9.
73. Shearman, R. (Bob) C.; Riordan, T.P.; Johnson, P.G. Buffalograss. *Warm-Season (C4) Grasses* **2004**, 45, 1003–1026.
74. Gazda, E.K.; Haeckl, A.E. *Roman Art in the Private Sphere: New Perspectives on the Architecture and Decor of the Domus, Villa, and Insula*; University of Michigan Press, 1991; ISBN 0-472-08314-7.
75. Gollotte, A.; Van Tuinen, D.; Atkinson, D. Diversity of Arbuscular Mycorrhizal Fungi Colonising Roots of the Grass Species *Agrostis Capillaris* and *Lolium Perenne* in a Field Experiment. *Mycorrhiza* **2004**, 14, 111–117.
76. Ahmed, A.T.; El Gohary, F.; Tzanakakis, V.A.; Angelakis, A.N. Egyptian and Greek Water Cultures and Hydro-Technologies in Ancient Times. *Sustainability* **2020**, 12, 9760.
77. Ford, L. *The Spaces between Buildings*; JHU Press, 2000; ISBN 0-8018-6331-7.
78. Abdul Latif, Z.; Mohd Yunus, M.Y.; Mohd Yaman, M. A discourse on the Persian Chahar-Bagh as an Islamic Garden. *PMJ* **2017**, 15, doi:10.21837/pmjournal.v15.i3.303.
79. Vargas Jr, J.; Turgeon, A.J. *Poa Annua: Physiology, Culture, and Control of Annual Bluegrass*; John Wiley & Sons, 2003; ISBN 0-471-47268-9.
80. Coupland, R.T. A Reconsideration of Grassland Classification in the Northern Great Plains of North America. *The Journal of Ecology* **1961**, 135–167.
81. McBride, J.R. History. In *The World's Urban Forests*; Future City; Springer International Publishing: Cham, 2017; Vol. 8, pp. 27–70 ISBN 978-3-319-52107-7.
82. Phillips, D. *The Truth of Ecology: Nature, Culture, and Literature in America*; Oxford University Press: Oxford, 2003; ISBN 978-0-19-513769-9.
83. Strandberg, M.; Blombäck, K.; Jensen, A.M.D.; Knox, J.W. Priorities for Sustainable Turfgrass Management: A Research and Industry Perspective. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science* **2012**, 62, 3–9, doi:10.1080/09064710.2012.682163.
84. Segre, A. Untangling the Knot: Garden Design in Francesco Colonna's *Hypnerotomachia Poliphili*. *Word & Image* **1998**, 14, 82–108, doi:10.1080/02666286.1998.10443943.
85. Goodchild, K.H. *Towards an Italian Renaissance Theory of Landscape*; University of Virginia, 1998; ISBN 0-599-15108-0.
86. Jellicoe, G.; Jellicoe, S.; Jellicoe, S. *The Landscape of Man: Shaping the Environment from Prehistory to the Present Day*; Thames and Hudson New York, 1987; ISBN 0-500-27431-2.
87. Hunt, J.D. *Greater Perfections: The Practice of Garden Theory*; University of Pennsylvania Press, 2000; ISBN 0-8122-3506-1.
88. VanDerZanden, A.M.; Cook, T.W. *Sustainable Landscape Management: Design, Construction, and Maintenance*; John Wiley & Sons, 2010; ISBN 0-470-88042-2.
89. Lazzaro, C.; Lieberman, R. The Italian Renaissance Garden: From the Conventions of Planting, Design, and Ornament to the Grand Gardens of Sixteenth-Century Central Italy. *(No Title)* **1990**.
90. Hunt, J.D. *Garden and Grove: The Italian Renaissance Garden in the English Imagination*, 16-175; University of Pennsylvania Press, 2016; ISBN 0-8122-9278-2.
91. Laird, M. *The Formal Garden: Traditions of Art and Nature*; Thames and Hudson: New York, N.Y, 1992; ISBN 978-0-500-01542-1.
92. Estienne, C. *L'agriculture et Maison Rustique*; chez André Laurens, Nabu Press; **2014**; ISBN 978-1293863725
93. Hunt, J.D. *Greater Perfections: The Practice of Garden Theory*; University of Pennsylvania Press, 2000; ISBN 0-8122-3506-1.
94. Hunt, J.D. *Gardens and the Picturesque: Studies in the History of Landscape Architecture*; Mit Press, 1992; ISBN 0-262-58131-0.
95. Toman, R.; Bednorz, A. *L'art baroque: architecture, sculpture, peinture*; H. F. Ullmann: Cologne (Allemagne)] [Paris, 2007; ISBN 978-3-8331-3335-0.

96. Delorme, S. RW Gibson, Francis Bacon, A Bibliography of His Works and of Baconiana to the Year 1750, Supplement. *Revue d'histoire des sciences* **1960**, 13, 153–153.
97. Marcus, C.C.; Francis, C. *People Places: Design Guidelines for Urban Open Space*; John Wiley & Sons, 1997; ISBN 0-471-28833-0.
98. Ross, S. *What Gardens Mean*; University of Chicago Press, 1998; ISBN 0-226-72822-6.
99. Conan, M. *Baroque Garden Cultures: Emulation, Sublimation, Subversion*; Dumbarton Oaks, 2005; Vol. 25; ISBN 0-88402-304-4.
100. Weiss, A.S. *Mirrors of Infinity: The French Formal Garden and 17th-Century Metaphysics*; Princeton Architectural Press, 1995; ISBN 1-56898-050-7.
101. Baridon, M. *A History of the Gardens of Versailles*; University of Pennsylvania Press, 2008; ISBN 0-8122-4078-2.
102. Krinke, R. *Contemporary Landscapes of Contemplation*; Routledge, 2005; ISBN 1-135-99471-4.
103. Prévôt, P., *Histoire des jardins*; Ed.; Editions Sud Ouest: Bordeaux, 2006; ISBN 978-2-87901-714-3.
104. Courtois, S., *Le potager du Roi: = The king's vegetable garden*; Ecole Nationale Supérieure du Paysage, Eds.; Nouvelle éd. revue, augmentée.; Actes Sud: Arles, 2003; ISBN 978-2-7427-4505-0.
105. La Quintinie, J. de *Instruction pour les jardins fruitiers et potagers avec un Traité de la culture des orangers suivi de quelques Réflexions sur l'agriculture*; Thésaurus; Actes Sud ENSP: Arles [Versailles], 1999; ISBN 978-2-7427-2496-3.
106. DeLue, R.Z.; Elkins, J. *Landscape Theory*; The art seminar; Routledge: New York, 2008; ISBN 978-0-415-96053-3.
107. Steenbergen, C.M.; Reh, W.; Smienk, G. *Architecture and Landscape: The Design Experiment of the Great European Gardens and Landscapes*; Birkhäuser Berlin, 2003; ISBN 3-7643-0335-2.
108. Grant, S.W. Gardens Are a Physical Manifestation of Culture: Postmodern Public Parks of the Twenty-First Century Will Be Built on the Infrastructure of the Industrial Age. **2013**.
109. Milani, R. *Art of the Landscape*; McGill-Queen's Press-MQUP, 2009; ISBN 0-7735-3508-X.
110. Tang, C. *The Geographic Imagination of Modernity: Geography, Literature, and Philosophy in German Romanticism*; Stanford University Press, 2008; ISBN 0-8047-5839-5.
111. Rinaldi, B.M. *Ideas of Chinese Gardens: Western Accounts, 1300-1860*; University of Pennsylvania Press, 2016; ISBN 0-8122-4763-9.
112. Whyte, I.D. *Landscape and History since 1500*; Reaktion Books, 2004; ISBN 1-86189-453-8.
113. Rutherford, S. *Landscape Gardens*; Amberley Publishing Limited, 2017; ISBN 1-4456-6994-3.
114. Amherst, A. *A History of Gardening in England*; 1st ed.; Cambridge University Press, 2013; ISBN 978-1-108-06208-4.
115. Haynes, S. *Charles Bridgeman (c. 1685-1738): A Landscape Architect of the Eighteenth Century*; Boydell & Brewer, 2023; Vol. 15; ISBN 1-83765-117-5.
116. Haynes, S. Constructing Eighteenth-Century Meaning in a Prehistoric Landscape: Charles Bridgeman's Design for Amesbury Abbey. *Landscapes* **2013**, 14, 155–173.
117. Kellert, S.R.; Heerwagen, J.; Mador, M. *Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life*; John Wiley & Sons, 2011; ISBN 1-118-17424-0.
118. Rutherford, S. *Capability Brown: And His Landscape Gardens*; National Trust, 2016; ISBN 1-911358-00-6.
119. Moore, C.W.; Mitchell, W.J.; Turnbull, W. *The Poetics of Gardens*; Mit Press, 1988; ISBN 0-262-63153-9.
120. Bowring, J. *Landscape Architecture Criticism*; Routledge, 2020; ISBN 0-429-45098-2.
121. Christians, N.; Patton, A.J.; Law, Q.D. *Fundamentals of Turfgrass Management*; Fifth edition.; Wiley: Hoboken, New Jersey, 2017; ISBN 978-1-119-20463-3.
122. Shepherd, J.C.; Jellicoe, G.A. *Italian Gardens of the Renaissance*; Princeton Architectural Press, 1993; ISBN 1-878271-52-0.
123. Casler, M. Perennial Grasses for Turf, Sport and Amenity Uses: Evolution of Form, Function and Fitness for Human Benefit. *The Journal of Agricultural Science* **2006**, 144, 189–203.
124. Stanley, B.W.; Stark, B.L.; Johnston, K.L.; Smith, M.E. Urban Open Spaces in Historical Perspective: A Transdisciplinary Typology and Analysis. *Urban geography* **2012**, 33, 1089–1117.

125. Thompson, I. *Landscape Architecture: A Very Short Introduction*; Oxford University Press, 2014; Vol. 387; ISBN 0-19-968120-1.
126. Lyles-Chockley, A. Building Livable Places: The Importance of Landscape in Urban Land Use, Planning, and Development. *Buff. Envtl. LJ* **2008**, 16, 95.
127. Ignatieva, M.; Haase, D.; Dushkova, D.; Haase, A. Lawns in Cities: From a Globalised Urban Green Space Phenomenon to Sustainable Nature-Based Solutions. *Land* **2020**, 9, 73. <https://doi.org/10.3390/land9030073>
128. Friedman, T.L. *Hot, Flat, and Crowded: Why the World Needs a Green Revolution-and How We Can Renew Our Global Future*; Penguin UK, 2009; ISBN 0-14-191850-0.
129. Pretty, J. *Agri-Culture: Reconnecting People, Land and Nature*; Routledge, 2013; ISBN 1-84977-042-5.
130. Schuyler, D. The New Urban Landscape. *The redefinition of city form in nineteenth century America* **1986**.
131. Richardson, M.; Dobson, J.; Abson, D.J.; Lumber, R.; Hunt, A.; Young, R.; Moorhouse, B. Applying the Pathways to Nature Connectedness at a Societal Scale: A Leverage Points Perspective. *Ecosystems and People* **2020**, 16, 387–401, doi:10.1080/26395916.2020.1844296.
132. Stuart-Smith, S. *The Well-Gardened Mind: The Restorative Power of Nature*; Simon and Schuster, 2021; ISBN 1-4767-9448-0.
133. Tunnard, C. *Gardens in the Modern Landscape: A Facsimile of the Revised 1948 Edition*; University of Pennsylvania Press, 2014; ISBN 0-8122-2291-1.
134. Trancik, R. *Finding Lost Space: Theories of Urban Design*; John Wiley & Sons, 1991; ISBN 0-471-28956-6.
135. Petermann, J.S.; Buzhdygan, O.Y. Grassland Biodiversity. *Current Biology* **2021**, 31, R1195–R1201.
136. Wratten, S.D.; Gillespie, M.; Decourtye, A.; Mader, E.; Desneux, N. Pollinator Habitat Enhancement: Benefits to Other Ecosystem Services. *Agriculture, Ecosystems & Environment* **2012**, 159, 112–122.
137. Leinauer, B.; Serena, M.; Schiavon, M.; Sevostianova, E. Water demands and water conservation strategies in turfgrass management. *Acta Hort.* **2012**, 113–120, doi:10.17660/ActaHortic.2012.938.14.
138. Brede, D. *Turfgrass Maintenance Reduction Handbook: Sports, Lawns, and Golf*; John Wiley & Sons, 2000; ISBN 1-57504-106-5.
139. Egerer, M.; Schmack, J.M.; Vega, K.; Barona, C.O.; Raum, S. The Challenges of Urban Street Trees and How to Overcome Them. *Front. Sustain. Cities* **2024**, 6, 1394056, doi:10.3389/frsc.2024.1394056.
140. Beard, J.B.; Green, R.L. The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans. *Journal of environmental quality* **1994**, 23, 452–460.
141. Ellis, E.C. Land Use and Ecological Change: A 12,000-Year History. *Annual Review of Environment and Resources* **2021**, 46, 1–33.
142. Olivadese, M.; Dindo, M.L. Cultural Landscapes: Exploring the Imprint of the Roman Empire on Modern Identities. *Land* **2024**, 13, 605. <https://doi.org/10.3390/land13050605>
143. Richter, S. Environmental Law: Wisdom from the Ancients. *Bulletin for biblical research* **2014**, 24, 307–329.
144. Singh, H. Landscape Gardening for Ecological and Aesthetic Gains. *Floriculture and landscape gardening* **2017**, 1–10.
145. Braun, R.C.; Straw, C.M.; Soldat, D.J.; Bekken, M.A.H.; Patton, A.J.; Lonsdorf, E.V.; Horgan, B.P. Strategies for Reducing Inputs and Emissions in Turfgrass Systems. *Crop Forage & Turfgrass Mgmt* **2023**, 9, e20218, doi:10.1002/cft2.20218.
146. Petrovic, A. & Easton, Zachary. (2005). The Role of Turfgrass Management in the Water Quality of Urban Environment. *Intl. Turfgrass Soc. Res. J.* 10.
147. Frantzeskaki, N.; McPhearson, T.; Collier, M.J.; Kendal, D.; Bulkeley, H.; Dumitru, A.; Walsh, C.; Noble, K.; Van Wyk, E.; Ordóñez, C.; et al. Nature-Based Solutions for Urban Climate Change Adaptation: Linking Science, Policy, and Practice Communities for Evidence-Based Decision-Making. *BioScience* **2019**, 69, 455–466, doi:10.1093/biosci/biz042.
148. Hejl, R. Improving Irrigation Efficiency in Sand-Capped Turfgrass Systems and Urban Lawns. **2021**.
149. Cheng, Z.; McCoy, E.L.; Grewal, P.S. Water, Sediment, and Nutrient Runoff from Urban Lawns Established on Disturbed Subsoil or Topsoil and Managed with Inorganic or Organic Fertilizers. *Urban ecosystems* **2014**, 17, 277–289.
150. Romero, C.C.; Dukes, M.D. Review of Turfgrass Evapotranspiration and Crop Coefficients. *Transactions of the ASABE* **2016**, 59, 207–223.

151. Stier, J.C.; Steinke, K.; Ervin, E.H.; Higginson, F.R.; McMaugh, P.E. Turfgrass Benefits and Issues. *Turfgrass: Biology, use, and management* **2013**, *56*, 105–145.
152. Lakhari, I.A.; Yan, H.; Zhang, C.; Wang, G.; He, B.; Hao, B.; Han, Y.; Wang, B.; Bao, R.; Syed, T.N.; et al. A Review of Precision Irrigation Water-Saving Technology under Changing Climate for Enhancing Water Use Efficiency, Crop Yield, and Environmental Footprints. *Agriculture* **2024**, *14*, 1141. <https://doi.org/10.3390/agriculture14071141>
153. Qian, Y.; Follett, R. Carbon Dynamics and Sequestration in Urban Turfgrass Ecosystems. *Carbon sequestration in urban ecosystems* **2012**, 161–172.
154. Selhorst, A.; Lal, R. Net Carbon Sequestration Potential and Emissions in Home Lawn Turfgrasses of the United States. *Environmental management* **2013**, *51*, 198–208.
155. Guertal, E. Carbon Sequestration in Turfed Landscapes: A Review. *Carbon sequestration in urban ecosystems* **2011**, 197–213.
156. Pornaro, C.; Novello, A.; Fidanza, M.; Macolino, S. Grasscycling: A Key Practice for Sustainable Turfgrass Management. *Grasses* **2022**, *1*, 45–52, doi:10.3390/grasses1010005.
157. Flude, C.; Ficht, A.; Sandoval, F.; Lyons, E. Development of an Urban Turfgrass and Tree Carbon Calculator for Northern Temperate Climates. *Sustainability* **2022**, *14*, 12423, doi:10.3390/su141912423.
158. Wang, R.; Mattox, C.M.; Phillips, C.L.; Kowalewski, A.R. Carbon Sequestration in Turfgrass–Soil Systems. *Plants* **2022**, *11*, 2478, doi:10.3390/plants11192478.
159. Phillips, C.L.; Wang, R.; Mattox, C.; Trammell, T.L.E.; Young, J.; Kowalewski, A. High Soil Carbon Sequestration Rates Persist Several Decades in Turfgrass Systems: A Meta-Analysis. *Science of The Total Environment* **2023**, *858*, 159974, doi:<https://doi.org/10.1016/j.scitotenv.2022.159974>.
160. Faragallah, R.N.; Ragheb, R.A. Evaluation of Thermal Comfort and Urban Heat Island through Cool Paving Materials Using ENVI-Met. *Ain Shams Engineering Journal* **2022**, *13*, 101609, doi:10.1016/j.asej.2021.10.004.
161. Yadav, A.; Khare, P. The Role of Volatile Organic Compound Emissions from Aromatic Crops in the Management of Bioaerosols at Agricultural Sites: An Overview. *Journal of Hazardous Materials Advances* **2025**, *17*, 100574, doi:10.1016/j.hazadv.2024.100574.
162. Lerman, S.B.; Contosta, A.R.; Milam, J.; Bang, C. To Mow or to Mow Less: Lawn Mowing Frequency Affects Bee Abundance and Diversity in Suburban Yards. *Biological Conservation* **2018**, *221*, 160–174, doi:10.1016/j.biocon.2018.01.025.
163. Baldock, K.C. Opportunities and Threats for Pollinator Conservation in Global Towns and Cities. *Current Opinion in Insect Science* **2020**, *38*, 63–71, doi:10.1016/j.cois.2020.01.006.
164. Larson, J.L.; Dale, A.; Held, D.; McGraw, B.; Richmond, D.S.; Wickings, K.; Chris Williamson, R. Optimizing Pest Management Practices to Conserve Pollinators in Turf Landscapes: Current Practices and Future Research Needs. *Journal of Integrated Pest Management* **2017**, *8*, doi:10.1093/jipm/pmx012.
165. Snep, R.P.H.; Opdam, P.F.M.; Baveco, J.M.; WallisDeVries, M.F.; Timmermans, W.; Kwak, R.G.M.; Kuypers, V. How Peri-Urban Areas Can Strengthen Animal Populations within Cities: A Modeling Approach. *Biological Conservation* **2006**, *127*, 345–355, doi:10.1016/j.biocon.2005.06.034.
166. Aziz, H.A.; Rasidi, M.H. The Role of Green Corridors for Wildlife Conservation in Urban Landscape: A Literature Review. *IOP Conf. Ser.: Earth Environ. Sci.* **2014**, *18*, 012093, doi:10.1088/1755-1315/18/1/012093.
167. Sorace, A.; Visentin, M. Avian Diversity on Golf Courses and Surrounding Landscapes in Italy. *Landscape and Urban Planning* **2007**, *81*, 81–90, doi:10.1016/j.landurbplan.2006.10.014.
168. Saleh, I.; Kavian, A.; Habibnezhad Roushan, M.; Jafarian, Z. The Efficiency of Vegetative Buffer Strips in Runoff Quality and Quantity Control. *International Journal of Environmental Science and Technology* **2018**, *15*, 811–820.
169. Carey, R.O.; Hochmuth, G.J.; Martinez, C.J.; Boyer, T.H.; Nair, V.D.; Dukes, M.D.; Toor, G.S.; Shober, A.L.; Cisar, J.L.; Trenholm, L.E.; et al. A Review of Turfgrass Fertilizer Management Practices: Implications for Urban Water Quality. *hortte* **2012**, *22*, 280–291, doi:10.21273/HORTTECH.22.3.280.
170. Patton, A.J. Why Mow?: A Review of the Resulting Ecosystem Services and Disservices from Mowing Turfgrass. *Crop Science* **2025**, *65*, e21376, doi:10.1002/csc2.21376.

171. Von Thaden, J.; Badillo-Montaño, R.; Lira-Noriega, A.; García-Ramírez, A.; Benítez, G.; Equihua, M.; Looker, N.; Pérez-Maqueo, O. Contributions of Green Spaces and Isolated Trees to Landscape Connectivity in an Urban Landscape. *Urban Forestry & Urban Greening* **2021**, *64*, 127277, doi:10.1016/j.ufug.2021.127277.
172. Winkler, J.; Pasternak, G.; Sas, W.; Hurajová, E.; Koda, E.; Vaverková, M.D. Nature-Based Management of Lawns—Enhancing Biodiversity in Urban Green Infrastructure. *Applied Sciences* **2024**, *14*, 1705, doi:10.3390/app14051705.
173. Sarni, W.; Pechet, T. *Water Tech: A Guide to Investment, Innovation and Business Opportunities in the Water Sector*; Routledge, 2013; ISBN 0-203-12729-3.
174. Colaizzi, A. D. Schneider, S. R. Evett, T. A. Howell Comparison of SDI, LEPA, and spray irrigation performance for grain sorghum. *Transactions of the ASAE* **2004**, *47*, 1477–1492, doi:10.13031/2013.17628.
175. Chen, Y.; Zhang, J.-H.; Chen, M.-X.; Zhu, F.-Y.; Song, T. Optimizing Water Conservation and Utilization with a Regulated Deficit Irrigation Strategy in Woody Crops: A Review. *Agricultural Water Management* **2023**, *289*, 108523, doi:10.1016/j.agwat.2023.108523.
176. Ercan Oğuztürk, G.; Murat, C.; Yurtseven, M.; Oğuztürk, T. The Effects of AI-Supported Autonomous Irrigation Systems on Water Efficiency and Plant Quality: A Case Study of Geranium Psilostemon Ledeb. *Plants* **2025**, *14*, 770, doi:10.3390/plants14050770.
177. El-Naggar, A.G.; Hedley, C.B.; Horne, D.; Roudier, P.; Clothier, B.E. Soil Sensing Technology Improves Application of Irrigation Water. *Agricultural Water Management* **2020**, *228*, 105901, doi:10.1016/j.agwat.2019.105901.
178. Lee, Y.; Ha, S.; Wang, X.; Hahm, S.; Lee, K.; Park, J. An Automatic Irrigation System Based on Hourly Cumulative Evapotranspiration for Reducing Agricultural Water Usage. *Agriculture* **2025**, *15*, 308, doi:10.3390/agriculture15030308.
179. Fu, Z.; Zhang, K.; Zhang, J.; Zhang, Y.; Cao, Q.; Tian, Y.; Zhu, Y.; Cao, W.; Liu, X. Optimizing Nitrogen Application and Sowing Date Can Improve Environmental Sustainability and Economic Benefit in Wheat-Rice Rotation. *Agricultural Systems* **2023**, *204*, 103536, doi:10.1016/j.agsy.2022.103536.
180. Tripathi, S.; Srivastava, P.; Devi, R.S.; Bhadouria, R. Influence of Synthetic Fertilizers and Pesticides on Soil Health and Soil Microbiology. In *Agrochemicals detection, treatment and remediation*; Elsevier, 2020; pp. 25–54.
181. Smith, T. Climate Change Impacts on Agriculture: A Global Perspective. *Annual Review of Environment and Resources* **2020**, *45*, 17–38.
182. Carrow, R.N.; Waddington, D.V.; Rieke, P.E. *Turfgrass Soil Fertility & Chemical Problems: Assessment and Management*; John Wiley & Sons, 2002; ISBN 1-57504-153-7.
183. Wolf, B.; Snyder, G. *Sustainable Soils: The Place of Organic Matter in Sustaining Soils and Their Productivity*; CRC Press, 2003; ISBN 1-56022-917-9.
184. Guertal, E.A.; Green, B.D. Evaluation of Organic Fertilizer Sources for South-Eastern (USA) Turfgrass Maintenance. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science* **2012**, *62*, 130–138, doi:10.1080/09064710.2012.683201.
185. Yadav, A.; Khare, P. The Role of Volatile Organic Compound Emissions from Aromatic Crops in the Management of Bioaerosols at Agricultural Sites: An Overview. *Journal of Hazardous Materials Advances* **2025**, *17*, 100574, doi:10.1016/j.hazadv.2024.100574.
186. Kroeck, S. *Crop Rotation and Cover Cropping: Soil Resiliency and Health on the Organic Farm*; Chelsea Green Publishing, 2004; ISBN 1-60358-345-9.
187. Aguiar Jr., T.R.; Rasera, K.; Parron, L.M.; Brito, A.G.; Ferreira, M.T. Nutrient Removal Effectiveness by Riparian Buffer Zones in Rural Temperate Watersheds: The Impact of No-till Crops Practices. *Agricultural Water Management* **2015**, *149*, 74–80, doi:10.1016/j.agwat.2014.10.031.
188. Wherley, B.; Heitholt, J.; Chandra, A.; Skulkaew, P. Supplemental Irrigation Requirements of Zoysiagrass and Bermudagrass Cultivars. *Crop Science* **2014**, *54*, 1823–1831.
189. Patton, A.J.; Schwartz, B.M.; Kenworthy, K.E. Zoysiagrass (*Zoysia* Spp.) History, Utilization, and Improvement in the United States: A Review. *Crop Science* **2017**, *57*, S-37.
190. Chouhan, S.; Kumari, S.; Kumar, R.; Chaudhary, P.L. Climate Resilient Water Management for Sustainable Agriculture. *International Journal of Environment and Climate Change* **2023**, *13*, 411–426.

191. Barnes, M.R.; Nelson, K.C.; Meyer, A.J.; Watkins, E.; Bonos, S.A.; Horgan, B.P.; Meyer, W.A.; Murphy, J.; Yue, C. Public Land Managers and Sustainable Urban Vegetation: The Case of Low-Input Turfgrasses. *Urban Forestry & Urban Greening* **2018**, *29*, 284–292, doi:10.1016/j.ufug.2017.12.008.
192. Wang, D.; Xu, P.-Y.; An, B.-W.; Guo, Q.-P. Urban Green Infrastructure: Bridging Biodiversity Conservation and Sustainable Urban Development through Adaptive Management Approach. *Front. Ecol. Evol.* **2024**, *12*, 1440477, doi:10.3389/fevo.2024.1440477.
193. Stewart, I.; Krayenhoff, E.; Voogt, J.; Lachapelle, J.; Allen, M.; Broadbent, A. Time Evolution of the Surface Urban Heat Island. *Earth's Future* **2021**, *9*, e2021EF002178.
194. Schiavon, M. *Turfgrass Establishment and Maintenance under Deficit Irrigation and Saline Soil Conditions*; New Mexico State University, 2013; ISBN 1-303-51153-3.
195. Zhang, Y.; Mian, M.; Bouton, J. Recent Molecular and Genomic Studies on Stress Tolerance of Forage and Turf Grasses. *Crop Science* **2006**, *46*, 497–511.
196. Braun, R.C.; Bremer, D.J.; Ebdon, J.S.; Fry, J.D.; Patton, A.J. Review of Cool-season Turfgrass Water Use and Requirements: I. Evapotranspiration and Responses to Deficit Irrigation. *Crop Science* **2022**, *62*, 1661–1684.
197. Milesi, C.; Running, S.W.; Elvidge, C.D.; Dietz, J.B.; Tuttle, B.T.; Nemani, R.R. Mapping and Modeling the Biogeochemical Cycling of Turf Grasses in the United States. *Environmental management* **2005**, *36*, 426–438.
198. Sidhu, R.K.; Kumar, R.; Rana, P.S.; Jat, M.L. Automation in Drip Irrigation for Enhancing Water Use Efficiency in Cereal Systems of South Asia: Status and Prospects. In *Advances in Agronomy*; Elsevier, 2021; Vol. 167, pp. 247–300 ISBN 978-0-12-824588-0.
199. Zhou, W.; Arcot, Y.; Medina, R.F.; Bernal, J.; Cisneros-Zevallos, L.; Akbulut, M.E.S. Integrated Pest Management: An Update on the Sustainability Approach to Crop Protection. *ACS Omega* **2024**, *9*, 41130–41147, doi:10.1021/acsomega.4c06628.
200. Bouri, M., Arslan, K. S., & Şahin, F. (2023). Climate-Smart Pest Management in Sustainable Agriculture: Promises and Challenges. *Sustainability*, *15*(5), 4592. <https://doi.org/10.3390/su15054592>
201. Simeone, V.A. *Grow More With Less: Sustainable Garden Methods: Less Water-Less Work-Less Money*; Cool Springs Press, 2013; ISBN 1-59186-551-4.
202. Chai, B.; Sticklen, M.B. Applications of Biotechnology in Turfgrass Genetic Improvement. *Crop Science* **1998**, *38*, 1320–1338.
203. Talaviya, T.; Shah, D.; Patel, N.; Yagnik, H.; Shah, M. Implementation of Artificial Intelligence in Agriculture for Optimisation of Irrigation and Application of Pesticides and Herbicides. *Artificial intelligence in agriculture* **2020**, *4*, 58–73.
204. Kanapeckas, J.; Lemežienė, N.; Stukonis, V.; Tarakanovas, P. Drought Tolerance of Turfgrass Genetic Resources. *biologija* **2008**, *54*.
205. Patil, H.J.; Solanki, M.K. Microbial Inoculant: Modern Era of Fertilizers and Pesticides. *Microbial inoculants in sustainable agricultural productivity: vol. 1: research perspectives* **2016**, 319–343.
206. Kowalewski, A.; Schmid, C.; Wang, R.; Braithwaite, E. Advances in Managing Organic Matter in Turfgrass Ecosystems. **2023**.

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