

Article



Preservation and Restoration of Roadside Tree Alleys in Line with Sustainable Development Principles—Mission (Im)possible?

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Abstract: The main challenge in the efforts to protect roadside tree alleys is to achieve a balance between the local development and the conservation of biodiversity. The problem of aging and disappearing roadside tree alleys was analyzed based on a critical review of the literature, various types of reports related to this topic and the provisions of international and Polish acts of law on biodiversity conservation and landscape protection. The following research hypotheses were formulated: 1. The preservation and restoration of roadside tree alleys promotes biodiversity conservation and sustainable development, and it constitutes an important social and scientific problem, and 2. detailed guidelines are needed to formulate effective programs for the protection of roadside tree alleys. The results of the study were used to formulate the universal guidelines for designing programs for the protection of roadside tree alleys. The potential barriers and obstacles that can occur in each stage of the proposed algorithm were identified and discussed on the example of Poland. In the summary, the answer to the question used as the title of the article should be affirmative. However, many actions must be taken. Most of them are included in the proposed guidelines and some of them are given as recommendations.

Keywords: environmental quality; green design; natural resources; roadside greenery; sustainable development

1. Introduction

Recent years have witnessed a growing interest in the role played by trees and tree assemblages in rational land management, planning sustainable urban infrastructure and sustainable rural development [1–5]. According to the Nature Conservation Act of 16 April 2004 [6], tree assemblages in open landscapes consist of individual trees and shrubs or small clusters of trees and shrubs that do not constitute forest communities. These include waterside and midfield clusters of trees and shrubs, as well as overgrown mires, ravines, defunct quarries and rubble heaps. In some studies, parks, orchards, tree nurseries, urban and rural green spaces, as well as trees and shrubs growing in church yards and cemeteries, have also been classified as tree assemblages [7,8]. Roadside tree alleys belong to a historical category of tree assemblages, where trees were planted at equal distance on both sides of transport routes in open landscapes. These formations consist of trees of the same species, size and habit, or they are collections of different tree species. In the past, trees were planted mainly in gardens and parks, and over the years, they began to play an even more important role in open spaces and urban landscapes. Unfortunately, at present tree assemblages are often perceived as a problematic element of land management that exerts a negative influence on vehicular traffic and complicates the construction and upgrade of roads. For this reason, the presence of tree alleys can hinder local development.



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Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). At the same time, roadside tree alleys deserve special care because they play key climatic, ecological and esthetic roles. This dilemma poses a significant challenge for local authorities around the world [1–5,7,8].

These considerations suggest that the main challenge in the efforts to protect (preserve and restore) roadside tree alleys is to achieve a balance between the construction and modernization of municipal roads that promote local growth and the conservation of biodiversity, including valuable roadside trees.

The following research hypotheses were formulated:

- 1. The preservation and restoration of roadside tree alleys promotes biodiversity conservation and sustainable development, and it constitutes an important social and scientific problem;
- 2. Detailed guidelines are needed to formulate effective programs for the protection of roadside tree alleys.

The main aim of this study was to develop guidelines that would assist local government departments in designing and implementing programs for the protection of roadside tree alleys. The secondary goal was to identify the problems that can be encountered by professionals who design nature conservation programs and institutions that implement these programs.

The practical implications of the proposed guidelines were presented in view of legal regulations and the experience acquired by the authors in Poland. It should be noted that Poland has a high number of preserved roadside alleys relative to other Member States of the European Union. In Poland, roadside tree alleys differ considerably in conservation status, type (trees lining one or both sides of the road), age, species, health status and location. Roadside tree alleys are most prevalent in northern and north-eastern Poland, including the region of Warmia and Mazury, where all regional roads are lined with tree alleys of different length. The percentage of county roads with historical tree alleys ranges from 30 to 85% (approx. 60% on average) [9]. Numerous protection programs have been initiated with the assistance of EU funding instruments. The above arguments justify the selection of Poland as a suitable object for analyzing the practical implementation of the proposed guidelines.

The term "protection of roadside tree alleys" is regarded as synonymous with the concept of "preservation and restoration of roadside tree alleys", and both terms are used interchangeably in the study.

The article is organized as follows: information sources and data analysis methods are presented in Section 2; Section 3 contains a review of the literature; the results of the study are presented and the practical implications of the proposed guidelines are discussed in Section 4; conclusions and recommendations are formulated in Section 5.

2. Materials and Methods

The problem of aging and disappearing roadside tree alleys was analyzed based on a critical review of the literature, environmental reports developed by the respective institutions in general, road construction reports, biodiversity protection/conservation programs and the provisions of international and Polish acts of law on biodiversity conservation and landscape protection, in particular in the practical stage of research. Websites dedicated to the protection of roadside trees were analyzed as well. The authors had also acquired extensive experience by participating in training programs on arboriculture, conducting tree inventories, developing dendrology reports for local governments and private clients, and coordinating tree planting programs.

A critical literature review was conducted based on the method outlined by Pickering and Byrne [10] and Gruas et al. [11]. The method follows the Preferred Reporting Items for Systematic Review Recommendations (PRISMA) approach. The aim of the literature review was to determine the implications of research into the protection of roadside tree alleys, biodiversity conservation and sustainable development for society and science, and to identify the need for systemic protection measures. The experimental part of the study was conducted in Poland; therefore, not only English-language scientific literature but also valuable Polish studies and reports were analyzed. Keywords were used to search for information in public library catalogs, academic research databases (including Science Direct, Scopus, Web of Knowledge, Google Scholar and Research Gate), reference lists, bibliographies, online repositories and digital libraries. The search focused on academic papers published in the last ten years. Research articles, practical documents (environmental impact reports, plans for the protection of roadside tree alleys, guidelines and recommendations), and the relevant provisions of the EU and Polish law (legal acts, regulations, conventions, etc.) were analyzed to obtain detailed information about the protection (preservation and restoration) of roadside tree alleys and the sustainable development of regions and the smallest units of administrative division (municipalities in Poland). The gathered materials were analyzed, verified and interpreted to validate the formulated research hypotheses.

3. Literature Review

Roadside tree alleys had been originally developed for various reasons. They were a source of fruit and timber; they offered protection against sunlight, wind and snow; they marked the position of snow-covered roads; they enhanced the landscape and were a source of food and timber for marching troops. For these reasons, roadside tree alleys were composed mainly of tree species with utilitarian value, including fruit trees (cherry, apple, pear and plum), willows and lindens. Linden blossoms were a source of nectar for bees, and they were also valued for their medicinal properties. Softwood was used in the production of furniture, tools, sculptures and musical instruments, and flexible willow twigs were woven into baskets. Many tree species were elements of local folklore and traditions. Roadside tree alleys were also established for representative purposes. Monumental oaks, lindens and chestnut trees were planted along roads leading to manors and palaces [12,13].

Roadside tree alleys continue to play these roles today, but their functions have been expanded. At present, considerable emphasis is placed on the natural and ecological role of tree assemblages. Roadside trees promote water retention in the environment, minimize the effects of wind erosion on soil, protect crops against traffic pollution, create a favorable habitat for pollinators, produce oxygen, filter out micropollutants from dust and exhaust gases, and contribute to biodiversity conservation [14–18]. The preservation of roadside tree alleys poses a challenge for modern societies due to intensive land use and the growing scarcity of land resources. Roadside trees are an important element of historical and cultural heritage, and they mark the evolution of landscapes that are often linked with historical figures and events. The preservation and presentation of the cultural heritage are the corner-stone of any cultural policy [19,20]. Trees also play an important role in the regional economy. Roadside tree alleys enhance local landscapes and increase their attractiveness for tourists [21–24]. Trees play vital roles in the web of life, and the preservation of roadside tree alleys should be an important goal on the path toward sustainable development.

Biodiversity conservation is one of the key challenges for the 21st century, not only in Europe but on a global scale. The biological diversity of unique and valuable habitats and natural features requires special protection. These include sites and features that closely resemble natural ecosystems as well as monuments of animate and inanimate nature. Global strategies for biodiversity protection also advocate the rational use of natural resources and the reinstatement of components and resources of animate and inanimate nature (geodiversity) that have been destroyed by human activity. The destruction of natural habitats is the primary cause of species extinction, which is driven by competition for land and human-induced changes in land use. Human activities have led to the transformation of stable ecosystems such as forests and water bodies into unstable ecosystems such as arable land and urban areas. Urbanization, infrastructure development and the intensification of agriculture and forestry also pose a threat to biodiversity. In open landscapes, roadside trees connect forest communities and act as migration (ecological) corridors for numerous wildlife species. In urban areas, attempts are being made to create green spaces that connect parks and municipal forests with woodland outside of cities.

The Convention on Biological Diversity, a multilateral agreement signed on 5 June 1992 in Rio de Janeiro [25], is one of the most important legal instruments for biodiversity protection in the international arena. The main goals of the convention that are linked with the protection of roadside tree alleys are to protect biological diversity and promote the sustainable use of its components. In the European Union, the key legal acts on biodiversity protection are Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds [26] and Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora [27]. The United Nations General Assembly declared 2010 as the International Year of Biodiversity, and the period of 2011–2020 as the Decade on Biodiversity. The new approach to biodiversity conservation focuses not only on unique and threatened components of nature, but also on natural elements that are characteristic of biogeographic regions and smaller areas. In 2012, the European Union adopted a Strategic Plan for Biodiversity 2011–2020 [28]. The new EU Biodiversity Strategy for 2030 to bring back nature into our lives was published by the European Commission on 20 May 2020 [29].

Legal provisions concerning the environmental impacts of linear infrastructure play an important role in the protection of roadside tree alleys. Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (codification) [30] states that the EU countries should identify, describe and evaluate the direct and indirect effects of individual projects on human beings, fauna and flora, soil, water, air, climate, landscape, material assets, cultural heritage and the interactions between these factors.

Roadside tree alleys are a valuable landscape component. The preamble to the European Landscape Convention states that "landscape is a key element of individual and social well-being, and its protection, management and planning entail rights and responsibilities for everyone" [31]. Therefore, roadside tree alleys should be classified as unique landscapes of considerable natural and cultural value. Tree alleys that are skillfully incorporated into the surroundings are ornamental landscape components. In Europe, roadside tree alleys have been established on palace grounds, in royal gardens and parks, and they are important and legible elements of landscape architecture. Roadside trees organize space and introduce order; they are planted for orientation; they indicate transport routes and connect various landscapes. The European Landscape Convention aims to promote landscape protection, management and planning, and to organize European cooperation on landscape issues. Landscape protection involves actions to design and harmonize the significant or characteristic features of a landscape. The aim of landscape management is to ensure the regular upkeep of a landscape based on the principles of sustainable development. Landscape planning involves measures to enhance, create or restore degraded or mismanaged landscapes. Roads and their surroundings, including roadside tree alleys, are natural, cultural and technical components of a landscape that enhance the attractiveness of tourist destinations. Roadside greenery can be regarded as a tourist product for visitors who travel by car, motorcycle or bicycle, in particular in *slow regions* that promote the *slow* tourism concept [32–35]. The Council of Europe regularly analyzes and publishes reports on workshops concerning the implementation of the European Landscape Convention. These reports include information about roadside tree alleys in the context of developing road infrastructure [36]. Workshop participants have arrived at the following conclusions: "Following the golden age of tree-lined roads in the 19th and early 20th centuries, a significant proportion of the trees growing alongside Europe's roads and streets—as much as 90% in some regions—has disappeared due to the natural aging process or as a result of epidemics or pests, but above all because of road schemes and misjudged road safety policies. Replanting has by no means compensated for these losses, due to the introduction of planting distances which are incompatible with landownership realities, through a loss of interest on the part of the relevant managers and through the lack of dedicated budgetary provision. Mistreatment and inappropriate practice are

accelerating the decline of the remaining trees." These reports emphasize that tree-lined roads and streets constitute an important shared heritage in the history of Europe. According to workshop participants, tree-lined roads and streets should be protected by amending legal provisions, retaining and caring for the existing trees, systematically filling gaps and planting new avenues to compensate for past felling. Conservation measures should be delivered by a collective organization bringing together owners and managers, the authority responsible for upholding the protection regulations and other environmental groups. It is a matter of urgency that state governments and public authorities engage in communication, consciousness-raising and education for the public, set up appropriate management systems (inventories, follow-up, etc.), and stop all tree felling until these recommendations are implemented [36]. Several examples of the measures implemented in European countries to protect roadside tree alleys are presented below [36,37]. In Germany, information and educational campaigns were conducted and the relevant laws were amended to protect hundreds of kilometers of tree alleys during efforts to upgrade the road network in the former East Germany. As a result, construction standards may be abandoned during road upgrading projects to protect and preserve trees in the most valuable roadside alleys. Sections of damaged alleys are being restored as part of social programs, in particular along less traveled roads. In Sweden, roadside tree alleys are legally protected as landscape components. New trees are planted along empty roads, and damaged alleys are restored. In the Czech Republic, trees are planted to reinstate alleys on both sides of roads. In Latvia, selected tree alleys are preserved on both sides of local roads, and new transit roads are built in the close vicinity. In Poland, the "Roads for Nature" project was implemented as part of the EU LIFE program, and the "Trees for Green Infrastructure" project was initiated in recent years. The main aim of these projects was to establish cooperation between road authorities and territorial governments and to modify the existing strategies concerning roadside tree alleys. Social campaigns involving educational activities, interventions and publications, such as the "Saving Tree Alleys" program, have also been implemented.

Sustainable development is the dominant paradigm of development not only in the international arena, but also at all levels of governance in many countries. Sustainable development principles have been incorporated in international and Polish acts of law. This concept is embodied by the "think globally, act locally" slogan, which indicates that sustainable development principles should be developed and implemented first at the local level. Territorial governments play a special role in planning sustainable development According to the literature [17,38,39] and the authors' experience, town and village inhabitants are the most ardent supporters of roadside tree alleys. Local support projects are mainly grassroots initiatives that are organized at the lowest level of administrative division, which is represented by municipalities in Poland. Local governments are the sphere of government that is closest to the people. Local departments responsible for environmental protection and greenery are best acquainted with local problems and needs regarding the preservation of roadside tree alleys. However, public opinion on this and other issues is often divided in Polish municipalities. Some residents are reluctant to keep roadside trees, but most inhabitants are in favor of preserving these valuable landscape components [40]. Inhabitants who do not work in agriculture generally display positive attitudes towards roadside tree alleys, in particular along roads leading to residential estates. However, some farmers argue that trees cast large shadows and compete for nutrients with crops. Many of them are unaware that trees provide an excellent habitat for pollinators and therefore contribute to increasing crop yields. Roadside tree alleys play an important role in agricultural landscapes only if they form long ecological corridors without gaps. Tree alleys also enhance the microclimate in cities and open areas. They decrease temperature and increase humidity via three processes: direct shading reduces both heat and UV radiation, evapotranspiration causes cooling, and vegetation does not absorb as much heat as built surfaces. It should also be noted that the cooling effect of trees extends into the surrounding area and can be detected within a radius of up to 80 m

[41–43]. These ecosystems have to be skillfully designed and managed to deliver optimal benefits for local communities.

The importance of the green infrastructure concept that combines biodiversity conservation, landscape protection, ecosystem services and sustainable development cannot be underestimated in the context of protecting and reinstating roadside tree alleys. A uniform definition of green infrastructure has not been formulated to date, and there are no detailed guidelines for identifying green infrastructure elements [44]. The European Union describes green infrastructure as "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, green infrastructure is present in rural and urban settings". The European Commission has funded numerous studies to develop recommendations for designing green infrastructure and to identify green infrastructure components [45], including roadside tree alleys.

Scientific [46–50] as well as technical and practical research [51–55] has demonstrated that roadside alleys pose an obstacle to road traffic, road maintenance and the construction of new roads in municipalities. In this context, roadside tree alleys can compromise local economic growth. Roads that are lined with trees impose restrictions on vehicle parameters (height, width, weight). Other development projects, such as sewer networks, underground power and telecommunication lines, often damage tree roots and pose a threat to roadside trees. Some projects, such as the construction of exits from the main road, require tree felling. A review of the literature, legal acts, websites dedicated to the protection of roadside trees, environmental reports and road construction reports validated the research hypotheses formulated in the study. A survey of decision-makers, their observations and experiences in dendrology and arboriculture confirmed the scarcity of formal guidelines for developing roadside alley protection programs. In many countries, such efforts are undertaken based only on general recommendations and good practices that do not account for the specific characteristics of roadside tree alleys or sustainable development goals [55–58]. This observation has inspired the authors to propose guidelines that would assist the authorities responsible for the protection of these vital landscape components.

4. Results and Discussion

4.1. Guidelines for Designing and Implementing Programs for the Preservation and Restoration of Roadside Tree Alleys—A Proposal

The results of the study were used to formulate guidelines for designing programs for the protection of roadside tree alleys. A complete set of measures (activities) that should be implemented to guarantee the effectiveness of protection programs is presented in Figure 1.

The proposed guidelines in the form of an algorithm were divided into four stages. Stages I and II include tree inventories and analyses that facilitate the selection of the optimal roadside tree protection scenario. Stages III and IV involve an analysis of legal measures and technical requirements relating to selected scenarios for the protection of roadside tree alleys.

Problems that delay the implementation of the protection program or even blight previous efforts and the incurred costs can be encountered in every stage. Some of these threats can be avoided or minimized through early identification.

The guidelines are universal and can be applied in all countries where the competent authorities are tasked with protecting roadside tree alleys or voluntarily undertake such measures. However, it should be noted that the extent to which the proposed solutions can be implemented and the type of the encountered problems are largely dependent on a given country's legal system and land management policies.

The potential barriers and obstacles that can occur in each stage of the proposed algorithm were identified and discussed on the example of Poland in the following subsections of the article.



Figure 1. Guidelines for designing comprehensive programs for the preservation and restoration of roadside tree alleys. Active scenarios are marked in green, and the passive scenario is marked in yellow.

4.2. Practical Aspects of Implementing the Proposed Guidelines on the Example of Poland

According to the provisions of the Polish law [59,60], municipalities are responsible for environmental protection in the public domain (including the protection of municipal green spaces and trees), and they use environmental resources (by intervening in and/or influencing the natural environment) to the extent required for performing their statutory duties. Municipalities represent the lowest level of administrative division, and they perform statutory tasks of local significance that do not constitute the legal responsibility of other agencies and bodies. Municipal authorities are tasked with meeting the needs of local communities. The construction and maintenance of municipal roads is one of such tasks. However, many municipalities are intersected by other categories of roads, including national, regional and county roads. Therefore, the boundaries of the area where a tree protection program is to be implemented have to be clearly identified. Trees can be planted only in green belts on land under roads (Figure 2). The Act of 21 March 1985 on public roads [61] defines land under roads as a delineated strip of land that accommodates a road, including the space above and under land surface, as well as the structures and technical infrastructure for managing, guiding and facilitating vehicular traffic.



Figure 2. Elements of the road lane with a model location of roadside tree alleys.

The above act also states that the ownership of real estate (or parts thereof) that is covered by a road construction permit is transferred to the road owner (central, regional, county or municipal government).

Stage I. Identification of the Problem and Its Severity

Full and reliable information about the location, quantity and quality of the existing tree alleys is required to determine the scope and type of the required protective measures. The main sources of the relevant data are presented in a diagram in Figure 1. The data accumulated in Stage I will also be used to assess the suitability of potential planting sites and to identify road sections where new trees are required. Geographic information systems (GIS) are well suited for this purpose. Municipalities that do not operate a GIS should invest in system development. The system should have access to the geospatial data gathered by territorial self-governments or the existing geoportals in municipalities. In the latter case, the spatial tool for managing tree alleys and other trees (dendroflora) should be implemented in the existing system. The system should also enable local users to submit petitions, express opinions and report problems concerning the management of tree stands in the municipality. The authors' experiences indicate that the development of comprehensive programs for the protection of roadside tree alleys can be problematic for a number of reasons.

Many municipalities suffer from a lack of employees who have degrees in dendrology or arboriculture and are qualified to take stock of the existing resources. In such cases, municipal authorities commission experts to conduct tree inventories. However, the professional qualifications of experts who perform tree inventories are not legally regulated in Poland. In many cases, the main criterion for selecting bidders in public tenders is the price rather than the contractors' experience in performing ecophysiographic analyses of roadside trees. The division of competences regarding the management of roadside greenery may also be unclear at the local level. Many municipalities are intersected by various categories of roads that have different owners who are not interested in professional inventory services. These obstacles can lead to errors in dendrological reports; the resulting decisions are unsound and delay the implementation of successive operations.

The authorities managing different categories of roads (on behalf of road owners) do not cooperate effectively in the process of administering the existing roads and planning road upgrades. The relevant information is difficult to access and share because GIS software has not been implemented by the authorities managing county and regional roads. Road authorities operate separate internal databases to collect information about carriageway width and potential sites for tree planting. The absence of a constructive dialogue between the road owner and the department responsible for environmental protection makes it difficult to reach an agreement on the number of trees and optimal sites for planting trees along roads. Environmental protection departments should account for the technical requirements regarding road safety, whereas road authorities should maximize the area of planting sites along carriageways.

The analytical tasks in Stage I may also be difficult to complete because municipalities lack dedicated GIS software that is based on a well-designed data standard. Not all municipal employees have the skills and qualifications needed to use specialist software. Financial considerations are equally important: some municipalities cannot afford to purchase new software or adapt old software that has access to the existing GIS. The absence of synchronization and communication between different systems and databases can significantly undermine the success of protection programs [62].

Stage II. Selection of the Optimal Scenario for the Protection of Roadside Tree Alleys

The results of the analyses conducted in Stage I provide information about the location and parameters of the existing and planned municipal roads and the quantity and quality of roadside tree alleys. The responsible departments need access to such data in order to identify the existing problems and select the optimal tree protection scenario in consultation with the municipal authorities. For the needs of this study, two potential scenarios were adopted based on a review of the literature, an analysis of reports concerning the preservation and restoration of roadside tree alleys and the authors' experience:

1. A passive scenario which preserves the existing roadside tree alleys and prevents further deterioration in their condition by replacing damaged trees and/or planting new trees.

Realization of this scenario involves the purchase of seedlings, tree planting and the upkeep of all trees in roadside alleys;

2. An active scenario which reinstates the original layout and location of roadside tree alleys that have deteriorated to a varied degree or promotes the establishment of new alleys in identified locations.

Realization of this scenario could be more difficult to implement than the passive scenario, and it could additionally require the delineation of the road lane and/or a new green belt in the field. These tasks require specialist services, including land surveying, and they could entail additional costs. However, the active scenario could be the only feasible solution in cases where roadside trees pose a threat to vehicular traffic or obstruct road upgrades.

A graphic visualization of the above scenarios is presented in Figure 3.



Figure 3. Examples of the proposed scenarios for the protection of roadside tree alleys.

The authorities should bear in mind that trees were planted in European cities and along roads between the 17th and the mid-20th century, when road width and throughput were considerably smaller in comparison with modern transport networks. The Polish region of Warmia and Mazury is a good example, where most local roads were paved with cobblestones and lined with trees in the past centuries. In the second half of the 20th century, very few of those roads were modernized and adapted to modern standards. In most cases, damaged cobblestone roads were simply covered with a layer of asphalt [63]. Therefore, in these or similar cases, trees growing directly along carriageways or within a distance of 3 m from the outer edge of a trafficable lane will probably have to be removed for safety reasons during road upgrade projects (Figure 4. A roadside tree alley in Warmia).

The authors' experience suggests that the clearance between the outermost edge of the carriageway and newly planted trees should not be less than 6 m. This requirement should be observed when reinstating tree lines along unpaved roads or when planting new trees in the existing alleys behind the roadside ditch. If the upgraded road is directly lined by trees or if the clearance is less than 6 m, new trees should be planted behind the roadside ditch, or a new green belt should be designed. This decision should be made in Stage III of the proposed procedure.

Stage III. Legal and Technical Preparations for Selecting Planting Sites and Tree Species

Practical experience indicates that the cadastral boundaries of the existing roads, in particular old municipal roads, may be difficult to identify in Poland. In many cases, green belts along roads have been used for many years by the owners of adjacent property, including farmers. If this is the case, the boundaries of the carriageway have to be redefined. This is a costly process that requires the services of licensed surveyors. The region's history and traditional land patterns should be taken into consideration if new trees are to be planted along field roads to conserve biodiversity.

Due to Poland's turbulent history (wars, resettlement campaigns), the legal status of property adjacent to unpaved field roads often remains unresolved. The legal title to land plots that are directly adjacent to such roads has to be clarified before new trees are planted. In some cases, narrow strips of land will have to be purchased from present owners to restore tree alleys. Not all land owners are willing to sell their land, and plots that are available for sale have to be appraised by a licensed property valuer [64]. According to the Polish law, the price has to correspond to the property's market value [65,66]. The appraisal process is laborious, and the price of land is influenced by the plot's designation

in the local zoning plan. For this reason, new trees should be planted only if the property that needs to be purchased for the project constitutes farmland. This option should not be considered if the plots adjacent to the carriageway are zoned for other purposes.



Figure 4. Tree alley in the road gauge. (source: from Piotr Dynowski).

A plan detailing the most suitable tree species and their layout should be developed in the next step of the process. Trees can be planted on one or both sides of the road, depending on the local landform, land ownership and soil type (Figure 5).

The layout and the planting plan should be designed based on a detailed analysis of the applicable legal regulations. According to the Polish law, the minimum clearance between the tree and the outermost edge of the carriageway is min. 3 m [67]. However, the statutory clearance is not always a safe distance. Traffic safety should always be the priority in tree alley restoration programs, and trees should be optimally planted behind the roadside ditch (this solution was proposed in the developed guidelines). If trees are planted directly along the road, their canopies will ultimately protrude into the vertical clearance. Branches will have to be cut, which could damage the trees. The original tree line can be preserved in the existing alleys. The minimum clearance between newly planted trees and the boundaries of land plots and buildings is not legally regulated in Poland. Project managers should rely on their best judgement and the future dimensions of the planted tree species (canopy width, trunk height and diameter).



Figure 5. An example of the result of the proposed action referred to in the article as of the "active" scenario. (source: from Piotr Dynowski).

Stage IV. Technical Operations Associated with Tree Planting

Field operations could be delayed and the cost of the tree alley protection project could increase due to a number of contingencies. Polish municipalities are legally required to procure goods and services by way of public tender. In itself, public procurement is a sound process, but the criteria for selecting the best tender should be modified. At present, the main criterion is the price, which often leads to the purchase of low-quality trees, and the suppliers do not guarantee the trees' survival in the long term. Road owners and administrators rarely rely on the services of dendrologists or arboriculture experts in the process of selecting and planting trees and preparing the substrate. The planted trees should be managed by contractors who have the required knowledge and experience and are supervised by suitably qualified personnel. Poor maintenance and inadequate trimming can lead to tree damage. The guarantee period covering the purchased trees may also be difficult to establish. Road maintenance works should be adequately supervised and should involve the appropriate equipment to prevent tree damage. Ideally, tree maintenance operations should be planned at the design stage or during a field inspection directly before the beginning of road works [68]. These rules should be observed to avoid or minimize additional operations. The implementation of the developed guidelines increases the probability that model roadside alleys will be incorporated into the landscape in the future (Figure 6).



Figure 6. An example of a model roadside tree alley (trees line both sides of the road behind the drainage ditch). (source: from Piotr Dynowski).

In Polish open landscapes, most tree alleys line both sides of the road (one row of trees on each side of the road), and they comprise trees of similar age and species, mostly deciduous species (lindens, oaks, poplars and maples—the share of different tree species differs across regions) [69]. Tree alleys are frequently located in the clear zone alongside the road. Therefore, the most urgent task facing the local authorities is to restore the most damaged alleys in clear zones by planting new trees behind the drainage ditch. These efforts should be undertaken to minimize the difference in the age of roadside trees. This is a very important consideration because young trees are unable to fully preserve the continuity of ecosystems and habitats of protected and umbrella species for many years or even decades.

5. Summary and Recommendations

Biodiversity conservation and the protection of roadside tree alleys in line with sustainable development principles poses a considerable challenge in all countries around the world. The results of the cited research studies accentuate the weight of this problem. The proposed guidelines were developed in the form of an algorithm to support the operations of departments responsible for designing and implementing programs for the protection of roadside tree alleys, and they can effectively resolve the most of these difficulties. Each stage of the program and the implementation of the required operations have been presented on the example of Poland. The protection and restoration of roadside tree alleys requires detailed analyses and well-planned and organized technical operations taking into account the legal provisions. Unlike trees growing on farmland and in forests, tree alleys occupy carriageways that play numerous roles during road construction and maintenance. The rules and regulations applicable to the repair and upgrade of roads and the maintenance of individual trees and entire tree alleys in the designated green belts should be clearly specified in carriageway maintenance plans. The attempts to implement the proposed guidelines have demonstrated that for such undertakings to be successful, decision makers should closely cooperate, the responsible authorities should have access to the required information that is gathered and distributed via dedicated GIS software

and that trees should be planted and maintained by suitably qualified contractors. Legal regulations in a given country play an important role in the process because national and local laws can resolve competency issues in the institutions and departments responsible for the protection of roadside tree alleys, and eliminate barriers to the selection of suitably qualified personnel responsible for conducting inventories and performing analyses, and administrative decision makers. Municipalities or other units at the lowest level of administrative division should employ dendroflora experts who would be responsible for the protection and maintenance of roadside tree alleys. These experts should be members of teams that develop road upgrade projects and supervise the selection of service providers who plant and maintain trees in good health.

Changes in selected regulations can contribute to reducing the costs associated with the purchase of planting material and tree management and maintenance. Social awareness, a sense of regional and local identity, and sensitivity to the cultural landscape should also be actively promoted. These factors can significantly contribute to the protection of roadside tree alleys, but their importance is often overlooked. An analysis of the practical requirements for the implementation of the proposed guidelines in Poland led to the identification of possible problems that could also be encountered in other countries. The relevant authorities should attempt to eliminate or mitigate such contingencies to ensure that biodiversity conservation projects are effectively implemented. In this context, the answer to the question formulated in the title of the article "Preservation and restoration of roadside tree alleys in line with sustainable development principles—mission (im)possible?" should be affirmative—possible.

The results of the present study are largely theoretical and apply to Poland, but they can also constitute useful and comprehensive material for conducting extensive comparative studies in the international arena.

Despite the fact that biodiversity conservation and the sustainable development of regions have been discussed extensively in the literature, further research is needed to address the protection of roadside tree alleys in the face of modern technical standards in transport and road construction and the implementation of the green infrastructure concept.

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