

Review

Classification Systems Applied to Forest Road Planning: Research Gap Analysis

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Abstract: Forest road planning incorporates crucial strategies essential for sustainable timber extraction, minimizing environmental impacts and ensuring safe access to forest regions. This paper presents a literature review conducted to examine publications related to forest roads to ultimately filter and evaluate the information on the incorporation of classification systems in the planning strategies for forest roads. Using the Scopus database to gather publications, various data points were mapped, such as temporal distribution of publications, citation metrics, keyword inputs and other bibliometric markers. Through the bibliometric visualization software VOSviewer 1.6.19, this study determined that over the years, the forest road research subject has gained increasing attention with different shifts in focus. However, upon investigating the application of systems of classification implemented on forest road networks, it became evident that this approach is not a recent innovation and there is scarce documentation and development regarding this planning strategy. The information collected also reveals that this type of classification can be found more in technical documents, like design manuals. This outcome suggests that the subject under study is not relevantly covered in forest-related journals, but rather by institutions aiming to identify region-specific needs and develop corresponding systems accordingly.

Keywords: forest road network; classification systems; road hierarchy; bibliometric analysis; Scopus; VOSviewer



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1. Introduction

In addition to being one of the primary renewable energy sources, forests also offer significant opportunities for employment and economic development. Approximately 45% of the EU-27's land area consists of forests, with the majority being actively managed, contributing to the economic development of the regions [1].

Forest roads are the primary infrastructure for assessing and exploring forest resources. The sustainability awareness that this sector requires is a key element that must be considered when planning a road network. Furthermore, forest roads can offer a possible economic benefit for rural areas that want to market their goods and services by connecting them to urban areas [2].

Despite being intrinsically linked to technical, economic and social factors, forest roads can lead to erosion and sedimentation, harming wildlife and compromising water resources [3]. Further investigation shows that the establishment of roads in this environment imposes a great concern regarding sustainability and the environmental impacts of their construction and use. The insertion of a roadway system can disturb local ecosystems, fragment habitats and alter the natural composition of the soil [4].

Given these considerations, it is important to promote the development of economically, socially, environmentally and technically conscious solutions [3].

Additionally, the road network within forest areas significantly affects forest fire prevention and fighting activities, dictating control strategies employed during a forest

fire outbreak [5]. Therefore, it is essential to approach forest road design and construction with thorough planning of strategies that can mitigate the impacts described and ensure a balance between access needs and environmental preservation [4].

For effective forest management, the road network is crucial in maintaining connectivity and access throughout the forest [6]. Moreover, forest roads are essential to preventive forest fire activities, emphasizing the importance of comprehensive forest road planning and network analysis [5].

In the field of road planning, various strategies have been implemented, including the establishment of classification systems. This strategy is highly valued in national road systems. In Portugal, with the rapid development of the automobile industry, it became important to update the road network to match evolving requirements, ensuring applicability to the increased demand, fostering economic development and facilitating the movement of people and goods. The Portuguese National Road Plan 2000 (PRN 2000) [7] was updated with the necessity of ensuring certain criteria in regard to functionality, operability and accessibility. The definition of a road hierarchy classifies roads given their entailed role [8]. This function is defined by given parameters such as capacity, speed of the traffic stream, accessibility and the relation between the road system and the surrounding environment. By establishing a road hierarchy, the conception of roads for each hierarchy level is predefined to ensure that the performance requirements are met [7,9].

In relation to forest road networks, these systems would also define road specifications based on their intended functions, ensuring that each road is designed and developed according to specific operational and safety requirements. Once design measures are established, it is possible to study more thoroughly the economical inputs and even plan maintenance strategies that can be used throughout the life cycle of the road network, ensuring the longevity and functionality of the road structure [9].

Above all, the concept of classification systems appears as a viable instrument to ensure that developing forest road networks satisfy requirements that must be guaranteed to establish good circulation conditions in forest activities. Based on the functions that each road is expected to fulfill, a variety of recommendations to help with the road's design and construction are provided. This paper aims to characterize the current state of knowledge regarding classification systems for forest roads, used as planning strategies for this type of road network. Through an evaluation of the existing literature, the goal is to identify possible research gaps in this topic.

First, the topic is introduced, and the main objective of the paper is presented. Then, the methods and materials are presented, to contextualize the approach used to collect all information on forest road classification. In the following sections, the documents related to forest roads are identified in the chosen database. Using bibliometric parameters, the information is characterized with the aim of determining which filters to apply to collect documents that may address systems that categorize and classify forest roads.

After identifying and applying the chosen filtering parameters, the documents identified are explored and analyzed, and the classification systems found are described.

2. Materials and Methods

The analysis of other articles, following similar a methodology, revealed that only one database is usually used for the application of bibliometric tools (e.g., [10,11]). The use of multiple databases can influence the results as the same article is likely to be found in multiple databases. Thus, to gather relevant information, the search was conducted using the Scopus database, given its wide range of sources and user-friendly interface.

Given the difficulty in identifying exact keywords that would encompass every document associated with forest road classification systems, a different strategy was used. At first, all the information on the main subject of forest roads was gathered and analyzed. With the prospect of viewing the wide scope of information regarding forest roads, bibliometric tools were employed. To analyze the information collected, in addition to the tool for statistics from the Scopus database, when necessary, the bibliometric visualization

software, VOSviewer 1.6.19, was used [12]. This tool serves as an intuitive software to create and visualize bibliometric information such as journals, researchers and publications using relationships such as citations, bibliographic coupling, co-authorship and co-citation.

Subsequently, keywords that could identify documents about classification systems were identified. Following the application of these filters, the results obtained were thoroughly examined to determine whether each document indeed referenced a classification system and, if so, in what context. From this analysis, a brief description of each document was made, allowing the characterization of the main topic approached. The representation of the strategy followed is presented in Figure 1.

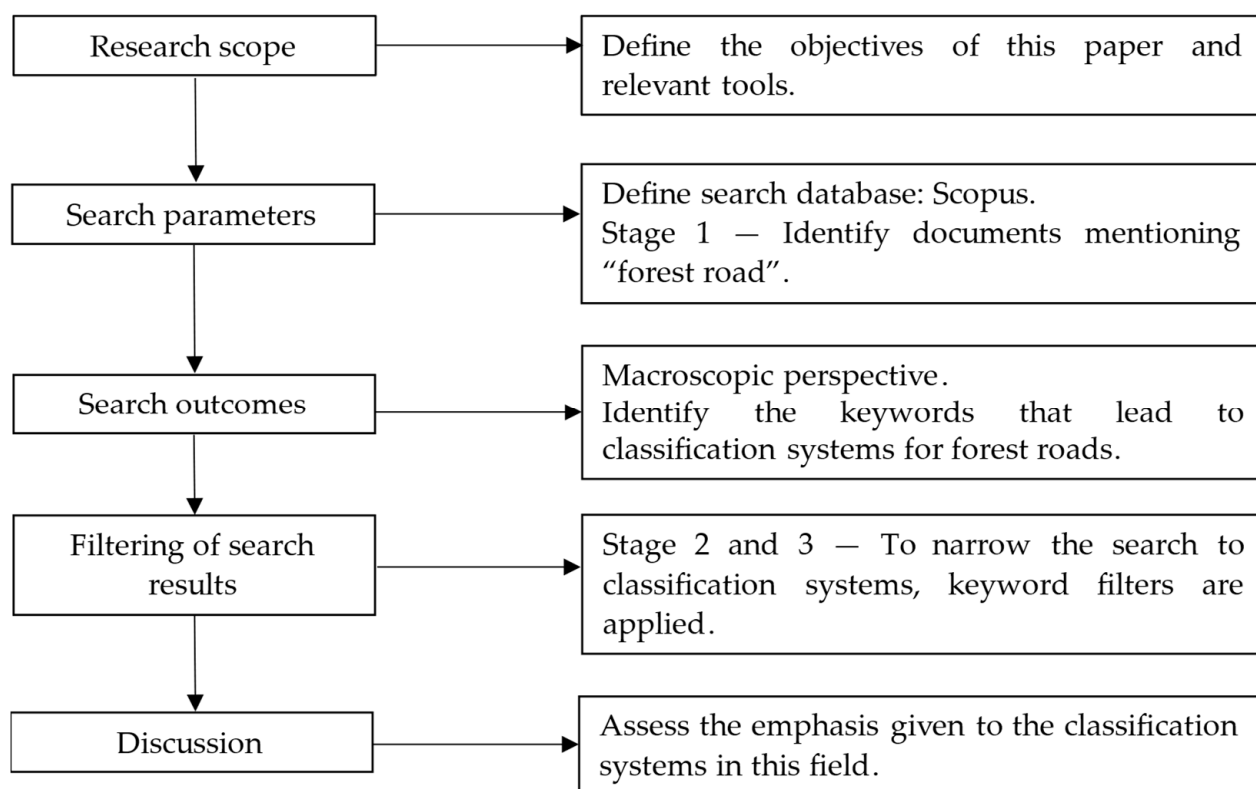


Figure 1. Methodology followed for the assessment of classification systems for forest roads.

3. Results

3.1. Overview of Results

The first assessment of information was performed using the same keywords in multiple databases. As the Scopus database had a higher number of results, it was chosen as the database to use for the review. The filters used for the search of documents by “title, abstract, keywords” using the Scopus database were initially chosen with the intention of assembling comprehensive information about forest roads from a macro perspective, for an overview of the spectrum of research on this topic.

The aggregation of results on the Scopus search bar using the keyword “Forest Road*” (the symbol “*” is used in the Scopus database to search words derived from the base word, in this case plural form which is Forest roads) resulted in 1831 documents published between 1939 and 2023. The search was conducted on 9 October 2023, and no filters, such as document type, year of publication or language, were applied to the search. These initial results covered a broad spectrum of research topics and included a diverse range of studies, allowing the characterization of the subject trends.

Various types of documents were found in the results: 80% of the documents are articles; the remaining documents are mostly conference papers (around 14%). Therefore,

most of the information collected comes from reliable (peer-reviewed) sources, such as scientific journals.

Assessing the number of publications per year, as shown in Figure 2, it is noticeable that between 1939 and 1995, the number of publications was less than 15 per year. However, in the early 2000s, a significant increase in publications regarding forest roads was registered.

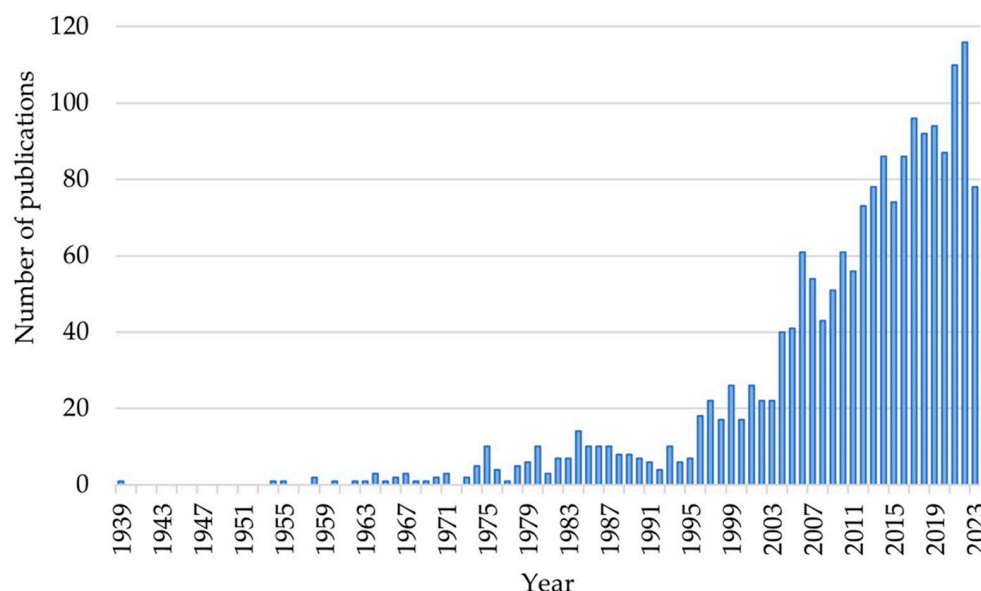


Figure 2. Number of publications on “Forest Road” per year, adapted from Scopus (on 9 October 2023).

The result analysis allowed the conclusion that, based on the data from the Scopus database, the number of publications on forest roads has been actively increasing over the years. This upsurge can be justified by the use of the internet becoming more relevant in the field of investigation, increasing the number of researchers and publications on a digital level. Furthermore, there is currently a greater emphasis on developing innovative and efficient techniques that optimize resource and time management for logging and exploration activities.

With the objective of focusing on the information on classification systems, using the software VOSviewer, all keywords used were gathered directly from Scopus. The program algorithm creates clusters based on the similarity of the group of keywords from each document. In this way, it is possible to analyze the thematic connection between results. Using this tool, a visualization map was obtained, as shown in Figure 3. The software gathers all the keywords associated with the different documents and creates clusters based on the correlation between publications. Keywords from the same cluster share the same main topic. The analysis in VOSviewer collected a total of 4449 keywords; upon restriction to a minimum of five occurrences, 164 keywords were obtained, based on the schematic shown in Figure 3. The number of occurrences of each keyword is identified between brackets; the most used keywords are summarized in Table 1, to identify the theme from each cluster. The analysis returned up to 30 keywords for each cluster. From these results, the keywords that better distinguish clusters were selected, also considering the frequency of each keyword.

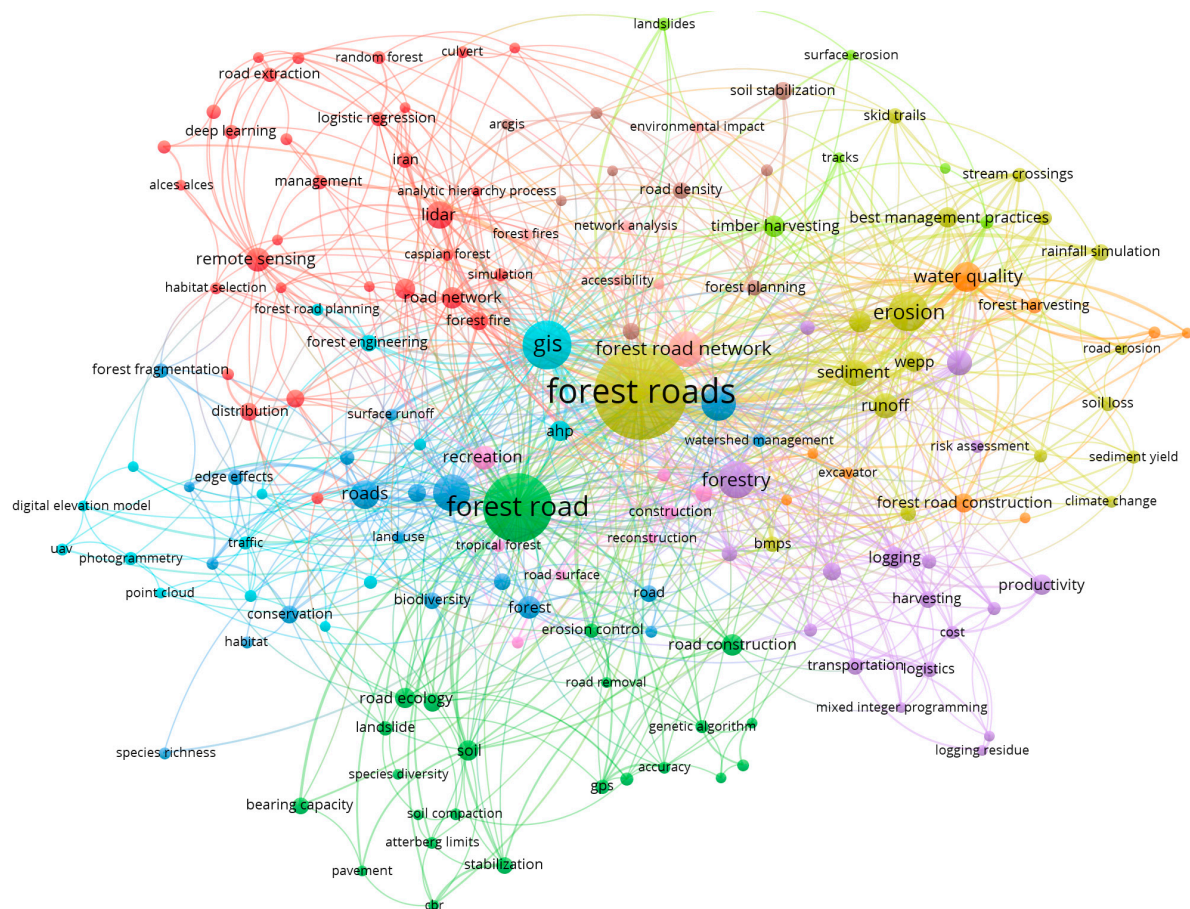


Figure 3. Co-occurrence map of authors' keywords, from VOSviewer (on 9 October 2023).

Table 1. Keyword analysis presenting cluster distribution (number of occurrences of each keyword in brackets) (on 9 October 2023).

Cluster	Keywords
1	LIDAR (26); remote sensing (20); geographic information system (15); forest fire (12); ecology (11)
2	Forest road (141); road construction (16); road ecology (15); soil (14); sustainable forest management (12); bearing capacity (10); stabilization (10); erosion control (8)
3	Forest management (44); soil erosion (38); conservation (12); silviculture (12); biodiversity (10)
4	Forest roads (245); erosion (50); sediment (24); runoff (22); sediment delivery (17); best management practices (14); rainfall simulation (10); forest hydrology (8)
5	Forestry (44); forest operations (22); logging (16); productivity (14); optimization (12); harvesting (10); transportation (10)
6	GIS (73); forest engineering (10); forest road maintenance (7); photogrammetry (7); forest road planning (6); terrestrial laser scanning (6)
7	Water quality (30); forest road construction (13); forest harvesting (9); suspended sediment (6); environmental impacts (5); slope stability (5)
8	Soil stabilization (11); planning (10); road density (10); forest planning (9); forest transportation (6); logging roads (6); ArcGIS (5)
9	Recreation (20); design (10); construction (8); maintenance (7)
10	Forest road network (41); wood transport (7); environmental impact (6); forest fires (6); network analysis (6)
11	Timber harvesting (16); landslides (7); sedimentation (7); ecosystem services (5); surface erosion (5)

With this overview of the theme, it is possible to identify which keywords point to potential records approaching system classification for forest roads. Given that classification systems are a tool applied to the planning phase of forest roads, while analyzing the clusters, the ones that stood out regarding this information were clusters 8, 9 and 10 (Table 1).

3.2. Result Refinement

The refinement of the results implemented is described in Figure 4. Given the main objective of identifying the search significance given to classification systems on this field, the chosen keyword clusters (8, 9 and 10 in Table 1) were applied, in Stage 1 (Figure 4). From this filtering, 697 results were obtained. Given the wide scope of results, a new stage of refinement was considered (Stages 2 and 3, Figure 4). To ensure the road classification topic is mentioned in each document that resulted from this filtering, new words were incorporated into the search. The filtering stages applied, on the Scopus search bar, in an attempt to gather relevant information, appear in Figure 4.

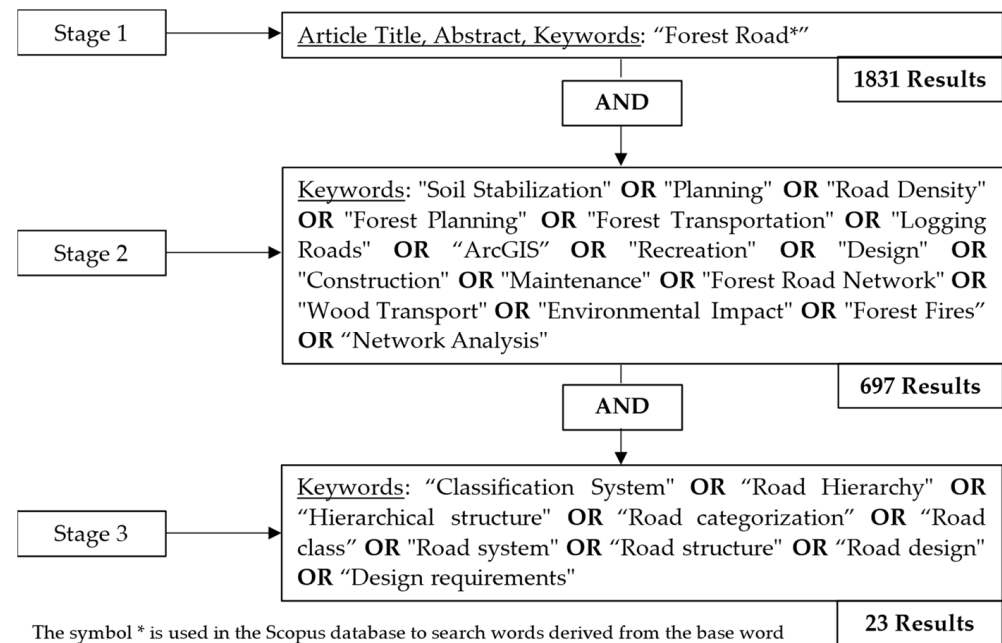


Figure 4. Refinement of results: filtering stages of the search.

With these requirements, 23 results were obtained, representing approximately 1.3% of the results from the first analysis on the main topic. The documents identified from this filtering were mainly journal articles (78.3%); the remaining documents were conference papers (13.0%), book chapters (4.3%) and notes (4.3%). The assessment of each document helps determine the extent of the use of classification systems in studies of this area of research.

Reviewing the entire content of these documents allows the determination of whether any reference was made to classification systems for forest roads. From this full-content review, Table 2 was created to consolidate the information gathered (the order in which the documents are listed is based on their number of citations). Table 2 presents an overview of the content of each paper and highlights any mentions of classification systems.

Table 2. Content analysis of results on classification systems, after the refinement of results described in Figure 4, by number of citations (on 9 October 2023).

Selected Document	Year	Type of Document	Citations	Title	Q *
1 Akay, A. and Sessions, J. [13]	2005	Journal Article	55	Applying the decision support system, TRACER, to forest road design	No
Brief Description		The model TRACER facilitates the decision-making process in regard to road pathways. It aims to minimize costs regarding construction, maintenance and transportation while considering design specifications, environmental requirements and driver safety standards.			

Table 2. Cont.

Selected Document	Year	Type of Document	Citations	Title	Q *
2 Akay, A. [14]	2006	Journal Article	44	Minimizing total costs of forest roads with computer-aided design model	No
Brief Description	Evaluates different alignment alternatives with computer-based road design systems to facilitate the comparison between alignment solutions. This model considers road costs, design specifications, environmental requirements and driver safety.				
3 Aruga et al. [15]	2005	Journal Article	32	Heuristic planning techniques applied to forest road profiles	No
Brief Description	Compares different approaches designed with embedded linear programming routine and a manually designed forest road profile. With the fundamentals of these approaches, the construction and maintenance costs can be minimized, and soil sediment from soil erosion on forest roads can be assessed.				
4 Aruga et al. [16]	2005	Journal Article	29	Application of an airborne laser scanner to forest road design with accurate earthwork volumes	No
Brief Description	Program uses a high-resolution digital elevation model (DEM) sourced from a light detection and ranging (LIDAR) system. Generates cross-section and estimates earthwork volumes for curved roadways, ultimately aiming to optimize the vertical alignment of roadways.				
5 Contreras et al. [17]	2012	Journal Article	24	Improving accuracy in earthwork volume estimation for proposed forest roads using a high-resolution digital elevation model	No
Brief Description	Using a high-resolution digital elevation model (DEM), a computerized model accurately estimates the amount of earthwork given the proposed forest roads. Three possibilities of forest roads were analyzed considering diverse configurations with different terrain roughnesses and ground slopes.				
6 Aruga et al. [18]	2005	Journal Article	22	Forest road design with soil sediment evaluation using a high-resolution DEM	No
Brief Description	Uses software to optimize both horizontal and vertical alignments, while predicting the amount of soil sediment that moved from roads to streams in a portion of the Capitol State Forest in Washington State (US). It was examined how overall road costs and soil sediment transported to streams are affected by the type of road surface material, the distance between the near-stream culvert and the stream and the out-sloped forest road template.				
7 Heralt, L. [19]	2002	Journal Article	18	Using the ROADENG system to design an optimum forest road variant aimed at the minimization of negative impacts on the natural environment	-
Brief Description	Finds the best forest road route with ROADENG, which uses a digital elevation model of terrain to recommend the best road variables given the environmental aspects of the construction.				
8 Saito et al. [20]	2013	Journal Article	14	Study of automatic forest road design model considering shallow landslides with LiDAR data of Funyu experimental forest	-
Brief Description	A model that designs forest roads considering shallow landslides was analyzed. With the knowledge of the landslide risk areas, the software determines the best solution given the earthwork costs and environmental aspects.				

Table 2. Cont.

Selected Document	Year	Type of Document	Citations	Title	Q *
9 Akay, A. [21]	2004	Journal Article	12	A new method of designing forest roads	No
Brief Description	This new method offers two techniques for designing forest roads, facilitating the evaluation of different solutions given the costs while conforming to the design and environmental requirements, as well as driver safety standards.				
10 Vanhanen et al. [22]	2014	Note	11	Utilization of wood ash as a road construction material-sustainable use of wood ashes	-
Brief Description	Studies the use of fly ash as road construction material. Considers the chemical and physical properties of this byproduct and studies the environmental impacts of road construction incorporating this material. The case study assesses the associated environmental impacts over a two-year period.				
11 Czerniak et al. [23]	2021	Journal Article	4	Bearing capacity standards for forest roads constructed using various technologies from mechanically and chemically stabilised aggregate	No
Brief Description	Given the necessity of ensuring adequate bearing capacity, this study proposes criteria for the definition of the bearing capacity standards in regard to forest roads. Parameters such as traffic intensity, operation time and road structure are predefined.				
12 Lindroos et al. [24]	2019	Journal Article	4	Leaching of heavy metals and barium from forest roads reinforced with fly ash	No
Brief Description	Studies the effects of the incorporation of fly ash into the forest road structure. The incorporation of fly ash into forest roads can have leaching problems. The water quality was studied by varying the solutions for the incorporation of this byproduct into the road structure.				
13 Skels et al. [25]	2017	Conference Paper	4	Wood fly ash stabilization of unbound pavement layers	No
Brief Description	Uses wood fly ash for soil stabilization; various mixtures with different levels of incorporation were studied. Parameters such as the optimal moisture content, unconfined compression strength and unconfined modulus of elasticity were determined.				
14 Jalali et al. [26]	2022	Journal Article	3	Potential evaluation of forest road trench failure in a mountainous forest, Northern Iran	No
Brief Description	Assesses the trench failure risk relying on three statistical models. The main objective is to be able to predict the risk before the construction phase. Cost analysis was performed for the different solutions defined.				
15 Hosseini et al. [27]	2019	Journal Article	3	Forest road network design based on multipurpose forestry management in hyrcanian forest	No
Brief Description	Evaluates the potential of a certain area to bear a road structure, based on GIS and satellite data, potentializing the concept of multipurpose forestry management. The experience of experts and scholars was gathered to define the required criteria for an efficient road design.				
16 Keller et al. [28]	2015	Journal Article	3	Overview of Amazon Basin forest roads manual	Yes
Brief Description	Overviews a forest road manual with developed standards, guidelines and operation information for the management of these regions. Analyzes the different components relevant for the design, construction and management phases of the forest road network.				

Table 2. Cont.

Selected Document	Year	Type of Document	Citations	Title	Q *	
17	Slinco et al. [29]	2012	Journal Article	2	Risks assessment in forest roads design	-
Brief Description		Presents the risk management importance, defining the risk associated with each phase of the designing process of forest roads. Mentions tools and processes to help manage and minimize the consequences and maximize the positive events.				
18	Aricak et al. [30]	2023	Book Chapter	1	State of the art on airborne LiDAR applications in the field of forest engineering	-
Brief Description		Refers to tools that help in planning and designing forest roads. Refers to LiDAR technology in this field for data collection helping forest road design of landing areas, skid roads and cable corridors. LiDAR-based 3D point clouds allow the identification of ground surfaces and facilitate the forest road design, construction, earthwork, transportation, forest operation, sediment production and logging impact assessment.				
19	Farabi et al. [31]	2005	Conference Paper	1	Using GIS, terrain attributes and hydrologic models to predict the risk of soil erosion and stream water deterioration caused by forest roads	No
Brief Description		Soil erosion risk from unpaved road structures is acknowledged, and the hydrological connection between the sediment course and the stream can help mitigate this negative impact. The prediction of soil erosion and stream water deterioration can be mapped using GIS techniques, terrain attributes and hydrologic models.				
20	Elliot et al. [32]	2023	Journal Article	0	Measuring and modelling impacts of gravel road design on sediment generation in the southeastern U.S.	-
Brief Description		The Water Erosion Prediction Project (WEPP) is the basis for the prediction of sediments generated on high-traffic gravel roads. The erodibility of two designs of high-traffic gravel roads is estimated.				
21	Muşat et al. [33]	2022	Journal Article	0	Evaluating the forest road systems subjected to different loadings by using the finite element method	No
Brief Description		Evaluates the effects of layer thickness and material types that influence the behavior of the road systems under different loads. Nine solutions were considered, and the finite element method was used to predict the behaviors.				
22	Kim et al. [34]	2022	Journal Article	0	Optimal road design using genetic algorithm to improve biodiversity and risk of soil loss	No
Brief Description		Considers soil erosion and habitat destruction as criteria for the route definition of forest roads. Considering an existing road, a new solution was proposed, using a new road route planning method considering a genetic algorithm and assessing the impacts mentioned.				
23	Grace, J. M. [35]	2008	Conference Paper	0	Determining the range of acceptable forest road erosion	No
Brief Description		Summarizes the losses due to forest road erosion and how they affect forest systems across different geographic regions, while taking road design, climate and management practices into account. It also provides information on the range of erosion losses that can be considered acceptable.				

* Question: Uses a system of classification for forest roads? Only the accessible documents have an answer in this column.

4. Discussion

The review of the search results allowed identifying different topics of research. The majority of the reviewed documents consider some form of computer-based analysis,

potentializing the decision-making process given by simulations that can be assessed before construction. This is the case of Akay and Sessions [13] and Akay [14], who consider TRACER and a forest optimization model to evaluate the best alignment solution in specific cases, aiming to minimize economic and environmental impacts. Genetic algorithms are also referred to as tools for comparing various solutions, aiming to enhance biodiversity, minimize soil loss [15] and reduce associated costs in forest road operations [33].

Accordingly, authors such as Akay [21], Hosseini et al. [27] and Farabi et al. [31] use other computer-based tools, namely linear programming, GIS and GIS with additional satellite data, to respectively optimize road alignments, assess land suitability for road network, and predict environmental impacts, such as soil erosion and stream water deterioration. Trench failure prediction is also studied by Jalali et al. [26], through three statistical models.

Also in this topic, various sources rely on digital elevation models (DEMs) to study different variables in the construction of forest roads and to optimize the road alignment. Aruga et al. [16] consider a light detection and ranging (LiDAR) that supports DEMs, ultimately assessing earthwork volumes from DEM-generated cross-sections. Aruga et al. [18] perform soil sediment evaluation based on high-resolution DEMs, rendering optimized solutions for road alignment.

The bearing capacity of forest road networks is explored and developed by Czerniak et al. [23] and Muşat et al. [33], who consider different road structure solutions using the finite element method to assess the response of the structure to different loads.

The environmental impacts of the construction of this type of road also hold relevance, as most authors study impacts such as soil erosion, sedimentation, leaching problems and habitat destruction.

Supporting sustainable practices, Lindroos et al. [24] and Skels et al. [25] evaluate the incorporation of fly ash, from the incineration of wood and peat, regarding the impacts on leaching of heavy metals, water quality and soil stabilization potential.

From the documents studied, only Keller et al. [28] consider a clear form of forest road classification. Keller et al. [28] analyze the content of the Amazon Basin Forest Roads Manual, which aims to develop standards and guidelines for forest road operations. This manual gives information on transportation planning, road design and road maintenance strategies and includes main issues such as slope stabilization, road deterioration, environmental and erosion.

In [28], the functional aspects of forest road classification are presented and divided into four classes. These classes were defined in accordance with the function they are expected to fulfill. Primary roads support higher traffic volumes and, therefore, must follow more/stricter design requirements to ensure capability throughout the period of use. The area that they serve is larger than the other types of roads and can be linked to the national road system. Secondary roads have less strict requirements, as the traffic volumes are minor and are only used in certain seasons. Temporary roads are developed to the minimum standard possible, allowing only log trucks for a limited period. Skid trails have the same design patterns and consist of cleared paths defined to only accommodate skidders in the organization of logs to be transported. The road surface uses organic materials that can promote revegetation after the periods of use.

In addition to this functional description, Keller et al. [28] define design requirements associated with each class, as summarized in Table 3. These requirements ensure that each road has the conditions to support the activities assigned to it, given the road class function.

Refining the search to find any mention of the use of classification systems for this type of road (Figure 4) primarily revealed that this topic does not hold significant prominence in the publications records analyzed. The scarce information on this topic reveals a significant gap in the existing research. It is worth noting that none of the documents focuses on the study or development of such systems, which would point to current developments. This determines that there is not in fact a current advance in this research field regarding the development or study of classification systems for forest roads. This lack of information potentiates the need for investment in this possible field of research.

Table 3. Design standards of the classification system, adapted from Keller et al. [28].

Class	Primary Roads	Secondary Roads	Temporary Roads	Skid Roads
Parameter				
Number of lanes	Double lane	Single lane		
Width	[5.5; 7] ⁽¹⁾	[3.5; 5]		
Use	All-weather	Seasonal	Minimum standards	Minimum standards
Design Speed	[45; 60]	[25; 35]		
Type of Surface	Surfaced	Both		

⁽¹⁾ Plus shoulders.

While this topic is not on the trends of research on forest roads, it does not certainly indicate a total absence of information on the subject. As a potential source of information, forest road manuals [28] stand out, meaning this type of document can in fact incorporate classification systems. Questioning this argument, a focused research effort was undertaken on forest road manuals, involving the analysis of six design manuals (Table 4).

Table 4. Search results focused on forest road manuals.

	Institution	Year	Location
1	Food and Agriculture Organization of the United Nations, FAO [36]	1977	-
2	State Forests NSW [37]	1999	New South Wales, Australia
3	Ministère des Forêts de la Faune et des Parcs, MFFP [38]	2002	Québec, Canada
4	Minnesota Department of Natural Resources [39]	2007	EUA
5	Austroroads [40]	2009	Australia/New Zealand
6	New Zealand Forest Owners Association [41]	2020	New Zealand

From the search, it was found that all documents included information on classification systems for forest roads. This outcome suggests that the subject under study may not be extensively covered in forest-related journals, as previously expected, but rather by institutions aiming to identify region-specific needs and develop corresponding systems accordingly.

The manuals presented are developed by governmental institutions aiming to provide detailed information to facilitate all tasks associated with the forest engineering process. This entails all planning, construction and maintenance. Regarding planning strategies, considering critical economic, environmental and safety aspects, these manuals consider that a key part of this process is the consideration of road specification. According to the expected level of use, certain requirements are defined, such as road width, maximum grade and curve radius. Additionally, considering the need to allow for non-standard vehicles, these road networks have to fulfill geometrical requirements different from standard information found in traditional road design manuals.

5. Conclusions

This paper presents a literature review conducted to examine publications related to forest roads, to ultimately filter and evaluate the information on the incorporation of classification systems in the planning strategies for forest roads. Using the Scopus database to gather publications, various data points were mapped, such as temporal distribution of publications, citation metrics, keyword inputs and other bibliometric markers.

This paper presents an overview of the publications on forest roads, a field in which there have been various developments, mostly after the 2000s. This reflects the growing recognition of the value given to forest road planning and strategizing. Further in the

search, after restricting the scope of information on forest road classification systems through keyword filtering, the results were analyzed and compared.

The different shifts in theme allowed the characterization of the current concerns regarding this topic, such as the environmental impacts related to the response of the surrounding environment to the disturbance of the natural order. They also revealed the current interest in developing software to allow the prediction of potential outcomes, given predefined criteria. These shifts predispose the field's adaptability and evolution to respond to the challenges of the present day.

The focus on classification systems shows that although this is not an area with extensive documentation in constant development, it is important to consider the analysis of this planning strategy. Classification systems present advantages in relation to the planning of these road networks, facilitating the decision-making process by incorporating predefined requirements of different types of roads, in relation to the function that they are expected to fulfill. For this specific topic, this review identified the need to analyze information from other non-scientific sources, such as government entities. The information found on these systems was presented, initially, from an overview of a forest road design manual. Focusing the research on these design manuals, six examples of manuals that consider classification systems for forest roads were collected. This aspect suggests that these development strategies may be discussed within more technical literature dedicated to forest road design. Future works could focus on detailing the information regarding this topic. This gap ultimately identifies a potential area of research and development, as the existing information may come from older sources and may need updating or reassessing. Collecting this information may help the development of more standardized and effective road planning strategies. As the world evolves and changes priorities, it becomes important to evaluate the techniques that can be used or adjusted to the necessities, paving the way for more efficient and environmentally aware planning strategies.

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