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# Global Overview of the Application of the Braun-Blanquet Approach in Research

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**Abstract:** Environmental classifications are of paramount importance for assessing the impacts of land-use changes, for prioritizing conservation efforts, and for developing effective management strategies to mitigate the negative impacts of human activities. The aim of our research was to provide as complete an analysis as possible of the studies that have been carried out using the Braun-Blanquet approach. The global review of studies based on the Braun-Blanquet approach includes 1168 papers and was conducted using the PRISMA 2009 methodological recommendations, strict criteria for the selection/quality of papers, and modern methods of data analysis and visualization using VOSviewer software developed by Nees Jan van Eck and Ludo Waltman (Centre for Science and Technology Studies (CWTS) of Leiden University in the Netherlands) (version 1.6.18), which ensures a representative sample, minimization of subjective judgements, and reliability of conclusions. It was noted that the number of publications on Braun-Blanquet is growing exponentially. This is an indication of the scientific interest in this methodology and its continuous further development. Based on a detailed analysis of the keywords, the main research directions and challenges are identified. These include improving the conceptual and methodological foundations of the Braun-Blanquet approach; improvement in regional vegetation classifications, synthesizing them and producing a comprehensive classification for large areas as a basis for biodiversity conservation and sustainable land use; expansion of the geography; compilation and updating of databases of phytosociological data; management of dynamics and vegetation; discussion of the important problem of continuity and discreteness of vegetation in the context of ecological classifications; and vegetation mapping. The top 20 journals publishing the most cited articles were identified, as well as the top 20 most cited journals whose high citation rate is due to the large number of high-quality articles. The analysis of the bibliographic network of papers in dynamics has shown that the structure of relationships is not constant and has changed significantly. The analysis of the authors' publication activity showed that the vast majority of researchers have a low publication activity and have published only one to three papers. A peculiarity also emerges: if all the most cited authors are concentrated in Eurasia, then most of the most actively published authors are outside Eurasia. The importance of the Braun-Blanquet approach for the study and classification of forest vegetation should be emphasized. In this case, the Braun-Blanquet approach is integrated into forest typologies, increasing their ecological validity and environmental relevance.

**Keywords:** plant community; ecological classification; vegetation classification; phytosociology; syntaxonomy



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## 1. Introduction

The rapid changes in environmental conditions caused by increasing anthropogenic impact and multiplied by global climate change require increased efforts by the scientific community to study various aspects of the biota's response to disturbance in order to preserve it and ensure favorable conditions for human existence [1–4]. The increasing frequency and intensity of extreme natural phenomena and the likelihood of regional and global environmental crises are also of concern to the scientific community [5,6]. This will help to understand the importance of developing an effective natural resource management strategy, finding appropriate solutions to mitigate the effects of regional manifestations of global climate warming, restoring disturbed ecosystems, and developing appropriate models of the bio-economy [7]. It is generally recognized that the success of solving these problems depends to a large extent on the classification system of the natural ecosystems used [8–10]. It is very important that ecosystems that are part of a group respond in the same way to external disturbances and to environmental measures or management strategies [9,11,12]. Environmental classifications are therefore of paramount importance for the transition to sustainable management of natural resources, for assessing the impacts of land-use changes, for prioritizing conservation efforts, and for developing effective management strategies to mitigate the negative impacts of human activities. Of course, complex ecological classifications already exist and are successfully used to solve a variety of tasks, including providing a better understanding of the spatial distribution, composition, functioning, transformation, and restoration characteristics of natural ecosystems. So, examples include the Biogeoclimatic Ecosystem Classification developed in British Columbia, Canada [13]; habitat-type classifications developed in the Western United States [14]; the Geobiocoenological Classification System developed in the former Czechoslovakia [12]; ecological forest classification based on the zonal concept [15–17]; the EUNIS habitat classification designed for Europe [18]; the European Forest Types designed for Europe [19]; the Forest Classification System of the Forest Management Institute [20]; geobotanical cartography [21]; the worldwide bioclimatic classification system [22]; the ecological–silvicultural classification developed in southern regions of the Russian Federation, Ukraine, and Belarus [23,24]; and the genetic typologies developed in the Russian Federation [25–27].

Nevertheless, human activity continues to alter and fragment the natural habitat, and regional manifestations of global warming are becoming more and more noticeable. At the same time, natural ecosystems are changing and are becoming more fragmented and more dynamic. Therefore, even the best existing ecological classifications need to be further developed to take account of the changes taking place in native ecosystems. At present, all the conditions are in place for its successful development. With the help of remote sensing methods, the territories continuously provide large-scale data on the structure and dynamics of the various ecosystems. These data can and should be exploited. However, the scientific community is also faced with the problem of big data analysis and the need for effective environmental classifications. The revision of traditional concepts and theories to improve environmental classifications is becoming acutely relevant [12,28]. This problem is particularly acute in the science of vegetation and in forestry [29]. Various botanical and forest typological schools are active as part of the solution [12,29–35]. However, due to the complexity and diversity of forests, grasslands, and other plant communities, this problem has not yet been solved. In order to successfully improve the environmental classifications, it is necessary to first summarize the results of modern research, identify actively working scientific schools and research leaders, identify new strong developments, and outline the range of the most pressing problems.

Considering the assumption that the adaptation of plant communities to disturbance and climate change will be accompanied by a change in species composition towards species that are better adapted to new conditions and able to rapidly restore the structure and functions of their populations [36–38], then it is advisable to take this trend into account in environmental classifications. For these purposes, an appropriate methodology is needed to analyze the species composition of plant communities and its changes in space and time. In this context, the approach should be considered.

This approach was developed in Europe in the early decades of the twentieth century. The Swiss botanist and ecologist Braun-Blanquet is the founder of this ecological classification [39–43]. In addition, it is possible to identify a number of papers that can be considered fundamental in terms of the presentation of conceptual foundations and methodological approaches [21,22,44–48].

In the last century, a large amount of phytosociological literature has been published and many scientific schools have been formed with different approaches to vegetation classification, especially in southern and eastern Europe [49,50], North America [51], Russia [52], and Japan [53]. At the same time, the conversion of the Braun-Blanquet indices r, +1, . . .5 into numerical indices allows for reliable statistical analysis [43]. The Braun-Blanquet approach has been widely adopted for classifying the most diverse vegetation due to its versatility, advanced methodology, flexibility of classification criteria, and perfect nomenclature. However, in forest typologies (e.g., the Russian genetic typology) this approach is still mistrusted and used less than it could be [27]. Of course, many years of experience in this area can be extremely useful in the development of modern ecological classifications of vegetation. For forest typology, the Braun-Blanquet approach has long been of interest and there are numerous examples of its success in forest typologies: European [49,50], North American [13,54], and Russian [27,55,56]. However, ignorance of the subtleties of the methodology and misunderstanding of the advantages of this approach for ecological analysis of plant communities still prevent its wider application. Therefore, providing positive examples of the use of the Braun-Blanquet approach will undoubtedly have a positive impact on its further development and broaden the geography of its application.

In the European classifications, the use of the Braun-Blanquet approach is implemented in the classification of phytocenological syntax hierarchy and is a link between the classification of EUNIS habitats and international scientific environmental studies based on the Braun-Blanquet approach [49,50]. Also, the Braun-Blanquet approach is one of the main analytical methods used in the Worldwide Bioclimatic Classification [22]. This approach is effective for identifying the influence of climatic drivers on the spread of potential vegetation at various time and spatial scales [57].

In North American forest typologies, the ecological and floristic approach is most fully applied in the Biogeoclimatic Ecosystem Classification (BEC) developed by V.J. Krajina [58] for British Columbia (Canada). The basic unit of the BEC is the plant community in the Braun-Blanquet sense, or more precisely, its culminating developmental stage (climax stage), which predicts the biogeoclimatic subzone. The associations (including those that have been disturbed and transformed by human activity) are named on the basis of the plant species characteristic of the climax stage, which makes it possible to maintain the link between indigenous and derived phytocenoses in the classification. The bioclimatic classification has found wide application in land use decision-making and currently serves as a common framework for a wide range of land management, conservation, and scientific research applications in British Columbia [54].

In the Russian Federation, the Braun-Blanquet approach is also attracting the attention of forest typologists. A small but rather comprehensive review of the use of this approach for the classification of forest vegetation is given by L.B. Zaugunova [55]. Particularly noteworthy is the determinant of forest types in European Russia, which is made public and easy to use [59]. This determinant is based on a large amount of factual material collected in the FORUS database. It presents a typological scheme of the main syntaxons, keys for determining sections and subsections, as well as prodromes of syntaxons within botanical and geographical zones and characteristics of forest types with an indication of the association and reference books for diagnostic species [59].

The systematic reviews that preceded this research analysis emphasize that the Braun-Blanquet approach developed as an interdisciplinary science. At the same time, priorities have gradually shifted from analyzing the diversity of associations to large landscape units or geosigmeta [60]. Biondi identifies three main levels of analysis: the first level corresponds to the plant association, the second level includes the analysis of the dynamics of plant communities and allows you to identify and study the dynamic series of vegetation (sigmet), and finally, the third level corresponds to geosynphytosociology or catenal phytosociology, which allows you to identify and study phytogeographic units. Simultaneously, all these levels are based on a single phytoindication method [60].

Plant association (plantassociation or coenotaxon) is the main unit of vegetation in classifications based on the Braun-Blanquet approach [41,43]. According to Braun-Blanquet, the plant association is a fundamental level in the hierarchical classification of the biosphere. It is an abstract unit characterized by a combination of species, called characteristic species, which can be defined by various rules [41,43]. The remaining species are responsible for connecting other associations that give a plant continuum in space and time.

Similar associations are grouped into a set of higher hierarchical levels called Alliances, which are grouped into Orders and then into Classes [61]. Currently, such a hierarchical classification is created according to the rules of the International Code of Phytosociological Nomenclature [62,63]. The key concept is fidelity, which helps to assess the species concentration in the selected syntaxon. It is used to highlight and describe the units of vegetation cover.

Initially, the Braun-Blanquet classification used only vegetation features to isolate syntaxons. At present, however, due to the need to develop vegetation maps at different scales and the use of GIS technologies, the geographical principle is beginning to prevail as the basis of classifications [64].

The recognition of the dynamic totality of species in communities, whose composition and structure are subject to fluctuations and anthropogenic transformations, is of great importance for the study and classification of modern vegetation. This is because stable climax communities are now very rare. Modern vegetation is subject to various natural and anthropogenic disturbances and represents dynamic systems. In the Braun-Blanquet approach, this fact formed the basis for the development of a methodology for analyzing spatial and temporal patterns. The concept of a successional system is introduced—a set of climax vegetation and all secondary communities that form in the future, serving as stages in its restoration. Thus, the vegetation series consists of all the communities in the same habitats, linked by dynamic relationships and representing different stages of regenerative or digressive successions. At the same time, a vegetation series represents a biogeographical and ecological unit. It is the basic unit of dynamic phytosociology. The number of associations belonging to the same vegetation series is not constant and depends on climatic and anthropogenic factors. Moreover, it is the anthropogenic impact that is the main driver of vegetation differentiation within its dynamic series [65]. In the context of vegetation dynamics, the concept of potential vegetation developed in phytosociology is important. Current potential vegetation characterized by the plant community that represents the most advanced succession stage within a homogeneous biogeographic area [60]. This concept makes it possible to predict future scenarios for the development of plant communities and to develop dynamic models that can be used for land-use management. The Braun-Blanquet approach thus provides the necessary methodology for analyzing successions and classifying disturbed vegetation, as well as vegetation in different stages of restoration. In developing the conceptual foundations of dynamic phytosociology, Salvador Rivas-Martinez has made a major contribution [65].

The above brief overview of the Braun-Blanquet approach allows us to conclude that the field is actively developing and that there are interesting and important achievements. However, the available literature reviews do not reflect the current state of development of the Braun-Blanquet approach, which limits further improvement of ecological classifications of vegetation.

The aim of our research was to provide as complete an analysis as possible of the studies that have been carried out using the Braun-Blanquet approach.

A total of 1168 articles were reviewed. Our research analysis included analysis of the distribution of papers by year, keyword analysis, analysis of the bibliometric relationship of papers, and analysis of the citation of authors, papers and journals.

I have been looking for the answers to the following questions:

1. What are the tasks for which the Braun-Blanquet approach is used?
2. How effective is the Braun-Blanquet approach in addressing different problems?
3. What kind of plant communities can this approach be applied to?

4. What are the problems that remain unresolved?
5. What trends can be identified in developing the Braun-Blanquet approach?

Are there any trends towards an expansion of the scope of the application?

I also tried to identify the most important papers and active researchers, the journals in which the most papers in this research area were published, and the journals in which the most-cited papers were published. The scientific novelty lies in the completeness and versatility of the analysis of modern studies carried out on the basis of the Braun-Blanquet approach, in the application of effective modern methods of data analysis, and, as a result, in obtaining answers to a whole range of questions that are important for improving the theory and practice of vegetation classification.

This research review will be useful to researchers specializing in ecology, vegetation science, forestry and biodiversity conservation, as well as to natural resource management authorities and environmental organizations involved in the conservation and restoration of ecosystems. I also hope that our research review will contribute to the consolidation of researchers from different countries and scientific schools and give impetus to the further active development of effective ecological classifications of vegetation, which will become a reliable basis for solving the most difficult urgent tasks of the modern changing world, which poses serious challenges to human society.

## 2. Materials and Methods

### *2.1. Data Collection*

Data collection was carried out for the period from 1929 to 2022. We used the PRISMA guidelines [66,67] and guidelines for environmental science studies [68] in conducting this research. "Braun-Blanquet approach", "Braun-Blanquet method", "phytosociology", "syntaxonomy" were used as search terms. Google Scholar, ScienceDirect, Mendeley, and SciProfiles were selected to search for information. The search engines have been selected to retrieve as many relevant records as possible with the least amount of time and effort. For writing systematic reviews, this is the recommended approach for organizing the search for information [69]. Books are rarely indexed in Web of Science and Scopus and are not available for analysis based on these databases. Of course, the requirement for a DOI identifier also limits the inclusion of books in research analysis, especially those published before 1997. However, many of the most important and cited books now have a DOI identifier and can be included in the analysis. Therefore, a quality criterion such as the DOI is more acceptable than indexing in Web of Science and Scopus when it comes to covering a wider range of publications. Web of Science and Scopus are therefore not used in the research analysis.

Google Scholar, like Web of Science and Scopus, is convenient to use, covers a much wider range of journals and books than Web of Science and Scopus, and its search engine provides good searching facilities [70]. Therefore, Google Scholar is useful for finding even the most diverse information and reflecting it as fully as possible [71]. The disadvantage of using Google Scholar is that the citation information is inadequate and updated less frequently [70]. However, this is not an issue when using VOSviewer, which eliminates this drawback. Google Scholar is also publicly available. However, as a primary search engine, Google Scholar is not the best option despite its benefits [72]. For this reason, Google Scholar has been chosen as an additional source of information.

From personal experience, Mendeley is the most convenient way to search for and analyze papers. This resource is characterized by good precision (or specificity), the percentage of relevant records in the result set. As a result, the amount of time spent on the relevance check of records is minimal. It is for this reason that this resource has been chosen as the main source of information.

Different search engines work in different ways [72]. It is possible that the same query used with a different search system will result in a different sample. The reasons for this are not always clear [72]. However, it is for this reason that several search engines must be used to fully cover the available relevant research that meet the selected quality criteria.

We therefore extended the study and used two additional search engines: ScienceDirect and SciProfiles. ScienceDirect is characterized by high recall (or sensitivity), which is the percentage of relevant article records returned in the result set out of all relevant records known to exist [72]. However, the precision (or specificity) is significantly inferior to Mendeley, based on personal experience. Checking the relevance of records therefore takes a lot of time and effort. SciProfiles was chosen as the search engine to verify its recall (or sensitivity) and precision (or specificity) for the purposes of our research.

This research stage was conducted in the period from May 2023 to August 2023. The total number of records examined was 86,580. A schematic diagram of our research analysis is shown in Figure 1.

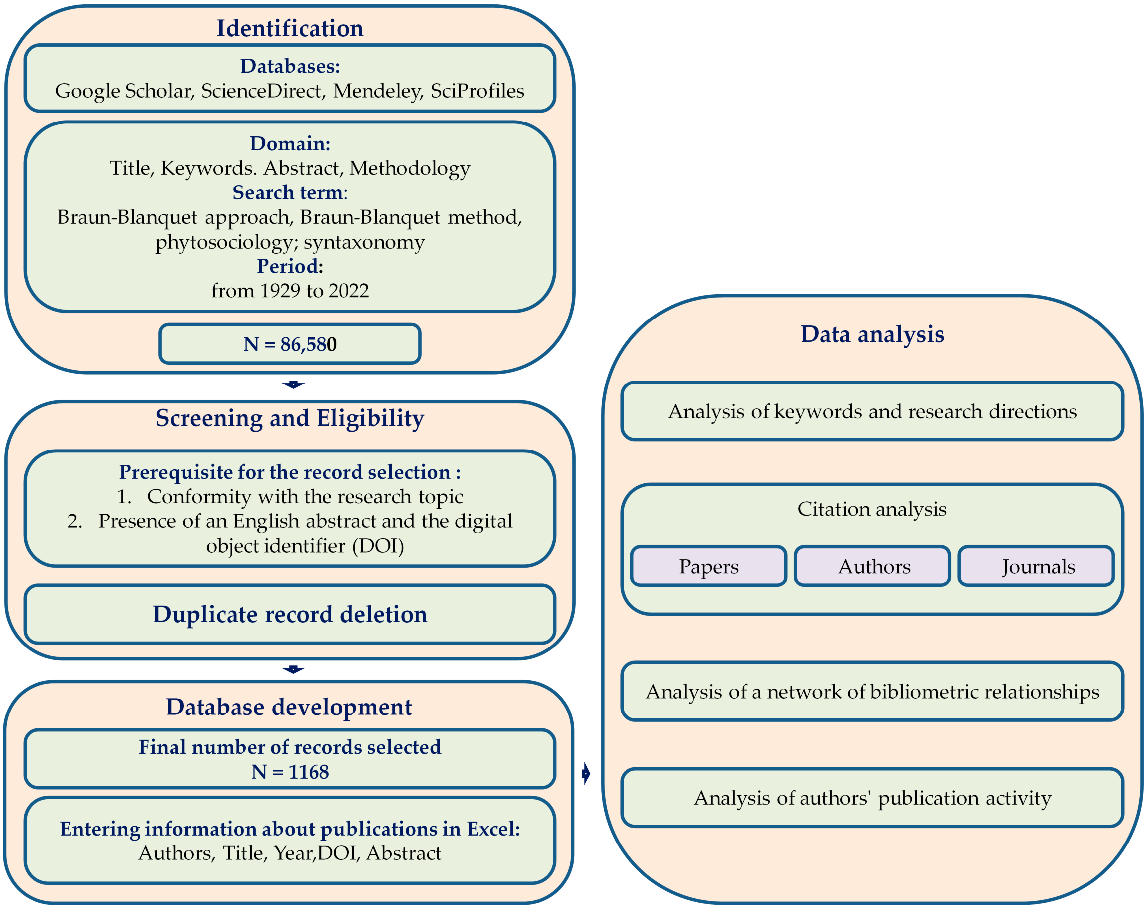


**Figure 1.** Schematic diagram of the research analysis.

### *2.2. Selecting Studies to Include in a Systematic Review*

In order for the results to be scientifically valid, it is necessary to have strict criteria for the selection of data sets and a minimum of subjective decisions. An objective criterion of publication quality was needed to exclude "grey" publications. In our opinion, the DOI identifier is the best option. Crossref publications are many times more numerous than publications indexed in Web of Science and Scopus, especially for the national literature. Therefore, the coverage of non-English publications, as well as books and conference materials in our research analysis, is significantly higher than if we had used Web of Science and Scopus, which are very popular for writing systematic reviews [73–77]. This makes our study more comprehensive than other studies based on automated searches.

However, when the authors of the paper did not indicate that they used Braun-Blanquet method, or ecological classification developed on the basis of it, then these papers were not included in our research analysis. In addition, the presence of the English abstract was a prerequisite for the selection of the records. This is sufficient for search engines to find papers in Italian, French, Polish, Russian, Chinese, Japanese, and other languages and include them in the research analysis. These restrictions allowed us to automatically exclude conference abstracts and articles in journals of low scientific quality. There were no restrictions on the date of publication and geolocation of the research conducted. In controversial cases, we read the full text of the paper to make a final decision on whether to include or exclude the entry in the research analysis. Duplicate records were excluded at the final stage. The number of records selected was 1168 (Figure 2).

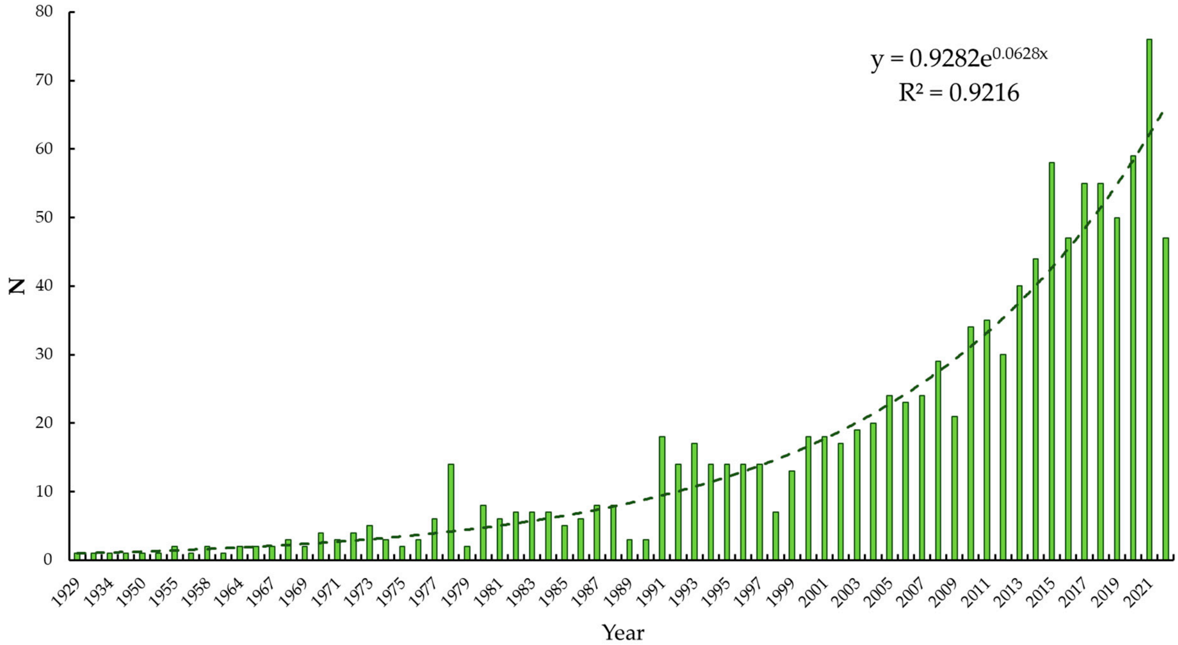


**Figure 2.** Trends in the quantity of publications with DOIs related to the Braun-Blanquet approach from 1929 to 2022.

*2.3. Data Extraction, Management, Analysis, and Visualization*

An Excel spreadsheet was used to structure the information on the selected records. We have recorded the year of publication, the authors, the title, the citation information, the DOI, and the abstract. Data analysis was carried out using the VOSviewer software. VOSviewer is recognized as an effective and convenient tool for analyzing bibliographic data and visualizing research results in a variety of scientific areas [74,78–80]. In this study, VOSviewer was used to analyze keywords, bibliographic relationships, a network of co-authors, citation of articles, authors, and journals. The loading of the data into the VOSviewer was carried out on the basis of the DOI. Any text file containing a DOI is suitable for this purpose. After identifying all DOIs in the text file, VOSviewer downloads data for all available documents with that DOI. Once this was completed, the data analyses of were selected and carried out. The method used in the VOSviewer allows efficient clustering of large numbers of records and the creation of visual maps of the relationship network. These maps are highly visual and intuitive. When creating a map from bibliographic data, Map Wizard offers a choice between two counting methods. The full count has been used. As the main attribute weight, we used the number of citations. When displaying a map, VOSviewer uses a special algorithm to determine which labels can be displayed and which cannot, so that labels do not overlap. The more you zoom in on a particular area of the map, the more labels you will see. This is very useful when working with large maps. The relationship network maps produced by the VOSviewer have been supplemented with tabular information in order to improve the understanding of the maps and to detail and strengthen the results.

### 2.4. Study Limitations

This scientific analysis was limited to articles with DOIs. The inclusion/exclusion criteria are chosen to minimize the subjectivity of the assessments. It was a guarantee of the representativeness of the sample. However, the use of the PRISMA guidelines [66,67] and the guidelines for environmental science research [68], as well as the strict selection/quality criteria for reviewing the publications and the use of modern methods of data analysis and visualization, enabled us to carry out our research analysis at a high scientific level and to achieve the set objective. All of this ensures that the research results are sound and reliable.

## 3. Results

### 3.1. Analysis of the Distribution of the Publications According to Year

Figure 2 shows the distribution of the number of selected papers by year. It is clear from Figure 2 that there has been an exponential increase ($R^2$ = 0.92) in the number of papers. This is an indication of the scientific interest in this methodology and its continuous further development. The first significant single jump in the number of publications was recorded in 1978. The second significant single jump in the number of publications occurred in 1991. Since 2000, the number of publications has continued to increase rapidly. This process is still ongoing.

### 3.2. Analysis of Keywords and Research Directions

To identify areas of research and the relationships between them, keyword analysis was used. Two hundred and nine key words have been grouped into five clusters that reflect the key directions of the research. The results of this analysis are shown in Figure 3. The font size indicates the frequency of occurrence of the keyword. The larger the size, the more common the term is. The lines show the relationships. The strength of the relationship is indicated by the thickness of the lines and their number.

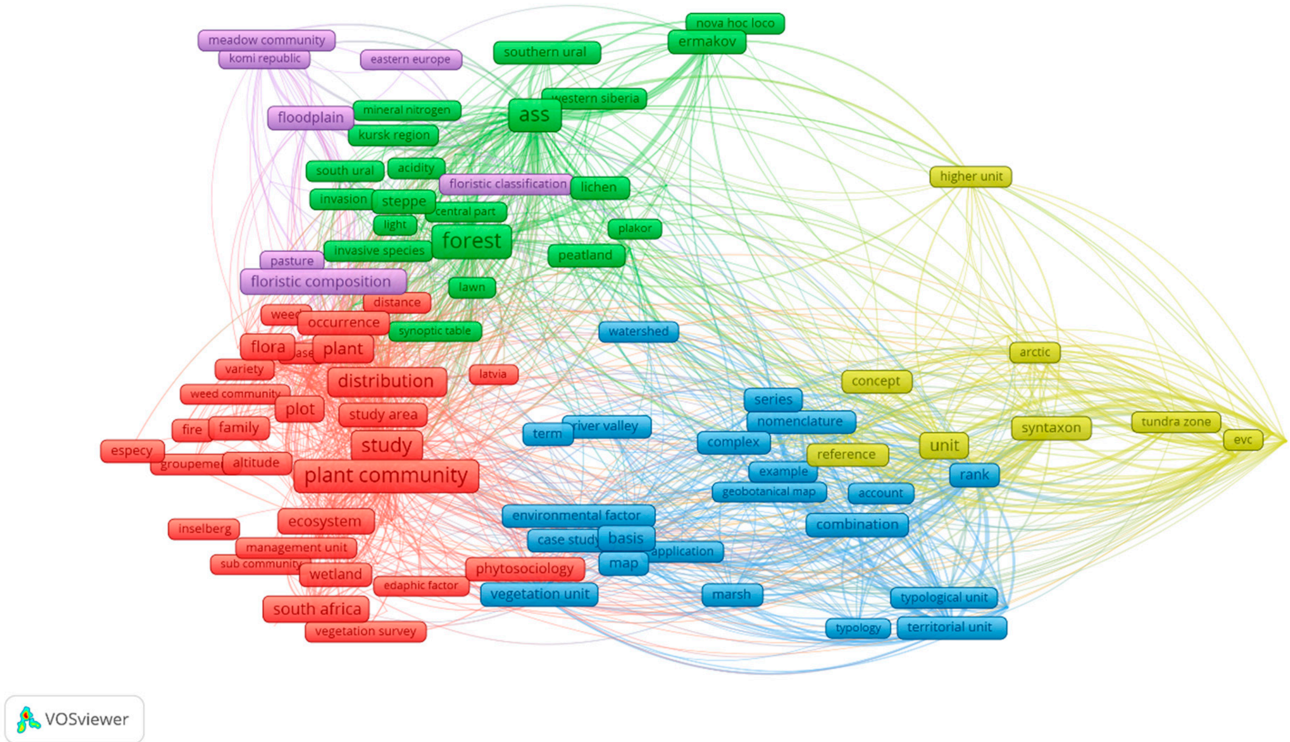


**Figure 3.** Analysis of the keyword relationship network.

#### 3.2.1. Cluster 1

Cluster 1 is highlighted in red and contains 118 keywords. This cluster is very dense, with a large number of intra-cluster relationships. On the contrary, inter-cluster relationships are weakly expressed, indicating the isolation of this cluster from the rest. The keywords with the most links and the most occurrences are described in more detail in Table 1. It is clear from this table that Cluster 1 brings together the key words of a whole range of inter-related fields of vegetation science. The first thing that needs to be noted is the methodological aspect. Keywords: phytosociology, distribution, Braun-Blanquet method, and Braun-Blanquet procedure are associated with publications devoted to improving the conceptual and methodological foundations of the Braun-Blanquet approach.

**Table 1.** Most significant keywords of cluster 1.

| Keyword | Links | Occurrence |
|---|---|---|
| *Methodology improvement and methods of numerical classification and ordination* | | |
| Phytosociology | 110 | 56 |
| Distribution | 192 | 163 |
| Braun-Blanquet method | 168 | 99 |
| Braun-Blanquet procedure | 81 | 40 |
| Ordination | 138 | 50 |
| Correspondence analysis | 109 | 24 |
| Twinspan | 102 | 35 |
| DCA | 82 | 15 |
| Numerical classification | 53 | 15 |
| Decorana | 52 | 13 |
| *Vegetation types, biodiversity and conservation* | | |
| Plant community | 196 | 329 |
| Plant | 184 | 148 |
| Grassland | 141 | 133 |
| Vegetation type | 134 | 64 |
| Species richness | 147 | 54 |
| Tree | 118 | 45 |
| Ecosystem | 125 | 75 |
| Conservation | 123 | 64 |
| Biodiversity | 112 | 34 |
| Wetland | 105 | 45 |
| Forest communities | 94 | 23 |
| Floristic diversity | 76 | 25 |
| Conservation | 123 | 64 |
| *Vegetation dynamics and management* | | |
| Management | 125 | 40 |
| Transformation | 102 | 46 |
| Fire | 91 | 30 |
| Degradation | 67 | 15 |

In terms of the number of citations, van der Maarel's 1979 paper in the journal *Vegetation* stands out [81] (Table 2). The importance of this study to the development of the Braun-Blanquet approach is evidenced by one thousand forty-four citations. This paper is devoted to a comparative analysis of various cover and cover-abundance scales and draws attention to the problem of transformation, including angular transformation and logarithmic transformation. In addition to this article, another paper by the same author called "The Braun-Blanquet Approach", which has been reprinted several times, is of great importance [43,82]. Its main advantage is a complete description of the basics of the Braun-Blanquet approach. Researchers actively refer to it and use it in their research.

**Table 2.** Most cited methodological improvement papers.

| Rank | Authors | Title | Year of Publication | Crossref Citations | References |
|---|---|---|---|---|---|
| 1 | van der Maarel, E. | Transformation of cover-abundance values in phytosociology and its effects on community similarity | 1979 | 1044 | [81] |
| 2 | Westhoff, V.E.; van der Maarel, E. | The Braun–Blanquet Approach | 1973, 1978 | 796 | [43,82] |
| 3 | Mucina, L.; Bültmann, H.; Dierßen, K.; Theurillat, J.; Raus, T.; Čarni, A.; Šumberová, K.; Willner, W.; Dengler, J.; García, R.G.; et al. | Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities | 2016 | 769 | [50] |
| 4 | Barkman, J.J.; Doing, H.; Segal, S. | Kritische bemerkungen und vorschläge zur quantitativen vegetations analyse | 1964 | 308 | [83] |
| 5 | Pojar, J.; Klinka, K.; Meidinger, D.V. | Biogeoclimatic ecosystem classification in British Columbia | 1987 | 290 | [13] |
| 6 | Chytrý, M.; Otýpková, Z. | Plot sizes used for phytosociological sampling of European vegetation | 2003 | 216 | [84] |
| 7 | Poore, M.E.D. | The Use of Phytosociological Methods in Ecological Investigations: I. The Braun-Blanquet System | 1955 | 144 | [85] |
| 8 | Lepš, J.; Hadincová, V. | How reliable are our vegetation analyses? | 1992 | 139 | [86] |
| 9 | Biondi, E. | Phytosociology today: methodological and conceptual evolution | 2011 | 127 | [60] |
| 10 | van der Maarel, E.; Janssen, J.G.M.; Louppen, J.M.W. | TABORD, a program for structuring phytosociological tables | 1978 | 127 | [87] |
| 11 | Moreno-Casasola, P., Espejel, I. | Classification and ordination of coastal sand dune vegetation along the Gulf and Caribbean Sea of Mexico | 1986 | 99 | [88] |
| 12 | Kočí, M.; Chytrý, M.; Tichý, L. | Formalized reproduction of an expert-based phytosociological classification: a case study of subalpine tall-forb vegetation | 2006 | 64 | [89] |
| 13 | Podani, J. | Braun-blanquet's legacy and data analysis in vegetation science | 2006 | 91 | [90] |
| 14 | Moore, J.J.; Fitzsimons, S.J.P.; Lambe, E.; White J. | A comparison and evaluation of some phytosociological techniques | 1970 | 61 | [91] |
| 15 | Poore, M.E. | The use of phytosociological methods in ecological investigations: ii. practical issues involved in an attempt to apply the braun-blanquet system | 1955 | 61 | [85] |
| 16 | Biondi, E., Feoli, E., Zuccarello, V. | Modelling environmental responses of plant associations: A review of some critical concepts in vegetation study | 2004 | 39 | [61] |

An article by a large an international team of authors from 15 countries published in 2016 in the journal *Applied Vegetation Science* [50] is the next outstanding study I would like to mention. The authors have developed a complex hierarchical syntaxonomic system of unions, orders, and classes based on the Braun-Blanquet approach for communities of vascular plants, mosses, lichens and algae of Europe. This paper provides an explanation of the terms used and the syntaxonomic units distinguished, as well as a list of diagnostic species. This makes it an indispensable tool for both scientific research and the management of natural ecosystems.

The study by Dutch researchers Barkman, Doing, and Segal, published in 1964, is still relevant today [83]. The authors carried out a study to improve the methodology for describing vegetation and to reduce the errors in the results associated with the inaccuracy of the scales and the subjective component. This work is recognized as important for the development of the Braun-Blanquet approach, which is confirmed by the high citation rate of this study.

Canadian researchers have tested and adapted the Braun-Blanquet approach to classify North American plant communities [13]. They combined the strengths of several scientific methodologies: European and North American. The result of this painstaking research is a unique, powerful tool for classification and prediction that undoubtedly has significance for practical value for sustainable forest management. This classification is called the Biogeoclimatic Ecosystem Classification.

To describe and classify the vegetation, the approach and nomenclature of J. Braun-Blanquet [43] is combined with landscape ecology and Clements' concept of climax [92]. The developed classification has three hierarchical levels: regional, landscape, and ecosystem. The Biogeoclimatic Ecosystem Classification system is designed to allow users to classify a site based on key features, such as diagnostic species and soil properties, regardless of the stage of digressive–demutational changes. The association is the main unit of the Biogeoclimatic Ecosystem Classification. The names of associations (including anthropogenically disturbed and transformed ones) are given on the basis of plant species characteristic of the climax stage. A system of alphabetical and numerical designations has been developed for a brief description of the classification units. The code of the forest type indicates the zone, subzone, and floral complex. It is also possible to reflect the type and intensity of anthropogenic impact in the code. This development is of great importance for land use management.

Sample plot size is the next important and much debated issue in the study and classification of vegetation. The problem is that phytosociology researchers traditionally use plots of different sizes to study different vegetation. This creates a problem when it comes to creating databases and, if necessary, using the data of many researchers to obtain large-scale data. The authors from the Czech Republic have carried out a thorough analysis of this issue [84]. The authors collected and analyzed information about more than 68 thousand relevés. The results of this analysis are very interesting and the main conclusion is that, due to the differences in the size of the sample plot size, the same vegetation can be assigned to different phytosociological classes or habitat types. This study draws attention to an important issue and forces researchers to take a more serious approach to the choice of sample size and to be more critical when comparing research results. This study also helps to avoid false conclusions, which is undoubtedly very important for both researchers and land-use managers. However, this question is still open for study and discussion. And this scientific direction can be considered one of the most relevant for modern vegetation science.

In general, the description of approaches and their applications in environmental research is well represented in the literature [61,85,86]. Papers dedicated to this strand of science are actively read and cited, indicating the importance of the research results.

The combined use of the Braun-Blanquet approach and numerical methods of vegetation classification usually gives excellent results, which are the basis for the detailed development of regional classification systems and the identification of factors determining landscape and forest type differentiation of vegetation [87–89]. However, there is an opposing view on the correctness of using most traditional methods for multidimensional data analysis [90]. At the same time, a comparative analysis of several methodological approaches showed that the Braun-Blanquet method was the most effective. At the same time, this approach has clear economic advantages [91].

Research to develop the conceptual and methodological underpinnings of the approach is currently ongoing [93].

Table 3 shows the most-cited papers on vegetation type characteristics and the development of regional classifications. The most cited paper [94] of this group presents the first complete organic synthesis of the vegetation of Italy at the Alliance syntaxonomic level. The strength of this prodromus is unified and comprehensive national framework. The description and classification of vegetation in the European Union has greatly benefited from this prodromus, as it has been linked to the European Biodiversity Strategy, the European Habitats Directive, and the European working groups on ecosystems and their services.

**Table 3.** Most-cited papers on the peculiarities of vegetation types, the development of regional classifications, biodiversity, and conservation.

| Rank | Authors | Title | Year of Publication | Crossref Citations | References |
|---|---|---|---|---|---|
| 1 | Biondi, E.; Blasi, C.; Allegrezza, M.; Anzellotti, I.; Azzella, M.M.; Carli, E.; Casavecchia, S.; Copiz, R.; Del Vico, E.; Facioni, L.; Galdenzi, D.; Gasparri, R.; Lasen, C.; Pesaresi, S.; Poldini, L.; Sburlino, G.; Taffetani, F.; Vagge, I.; Zitti S.; Zivkovic L. | Plant communities of Italy: The Vegetation Prodrome | 2014 | 153 | [94] |
| 2 | Mucina, L. | Conspectus of classes of European vegetation | 1997 | 104 | [95] |
| 3 | Hemp, A. | The Banana Forests of Kilimanjaro: Biodiversity and Conservation of the Chagga Homegardens | 2006 | 104 | [96] |
| 4 | Chytry, M. | Phytosociological Data Give Biased Estimates of Species Richness | 2001 | 62 | [97] |
| 5 | Feoli, E.; Lagonegro, M. | Syntaxonomical analysis of beech woods in the apennines (italy) using the program package IAHOPA | 1982 | 48 | [98] |
| 6 | Cilliers, S.S; Bredenkamp, G.J. | Vegetation of road verges on an urbanisation gradient in potchefstroom, South Africa | 2000 | 44 | [99] |
| 7 | Cowling, R.M.; Campbell, B.M.; Mustart, P.; McDonald, D.J.; Jarman, M.L.; Moll, E.J. | Vegetation classification in a floristically complex area: The Agulhas Plain | 1988 | 37 | [100] |
| 8 | Blasi, C.; di Pietro, R.; Fortini, P.; Catonica, C. | The main plant community types of the alpine belt of the Apennine chain | 2003 | 37 | [101] |
| 9 | Furness, H.D.; Breen, C.M. | The vegetation of seasonally flooded areas of the Pongolo River Floodplain | 1980 | 34 | [102] |
| 10 | Mostert, T.H.C.; Bredenkamp, G.J.; Klopper, H.L.; Verwe, C.; Mostert, R.E.; Hahn, N. | Major vegetation types of the Soutpansberg conservancy and the blouberg nature reserve, South Africa | 2008 | 34 | [103] |
| 11 | Tomaselli, M. | The snow-bed vegetation in the Northern Apennines | 1991 | 34 | [104] |
| 12 | Bonyongo, M.C., Bredenkamp, G.J., Veenendaal, E. | Floodplain vegetation in the Nxaraga Lagoon area, Okavango Delta, Botswana | 2000 | 26 | [105] |

A conspectus of classes of European vegetation should also be noted here [95]. The authors confirmed 73 classes of European vegetation. The greatest achievement of this research, which is undoubtedly of great practical importance, is the analysis of all available class names and the verification of their nomenclatural accuracy. The list of synonyms and related class names provided allows researchers to more accurately assess the biodiversity of plant communities and avoid confusion in class names. Of course, this publication dramatically reduces the risk of nomenclature inaccuracies in future research and misleading environmental management researchers and practitioners.

The application of the Braun-Blanquet method to the study of the banana forests of Kilimanjaro aroused great interest among readers and researchers [96]. The author has demonstrated the effectiveness of this method for classifying and identifying the biodiversity of banana forest plant communities on a large empirical material. Coffee–banana plantations on Kilimanjaro are agroforestry systems that are similar to a tropical montane forest. More than 1400 plots were examined by the authors. At the same time, a great diversity of plant species has been revealed, dominated by non-cultivated plants. The fact that the plant communities studied by the authors are threatened with destruction is also of value.

The application of the Braun-Blanquet approach to a large dataset of beech forests in the Apennines (Italy) is an interesting example [98], as are the vegetation of road verges on an urbanization gradient in Potchefstroom [99]; vegetation of seasonally flooded areas of the Pongolo River Floodplain [102]; and vegetation types of the Soutpansberg conservancy and the Blouberg nature reserve (South Africa) [103].

Table 4 presents the most frequently cited papers on the dynamics and management of vegetation. This area of research is less popular with researchers using the Braun-Blanquet approach than those discussed above. It can be assumed that this is due to insufficient elaboration of the methodology for identifying and assessing vegetation dynamics. Among these, the following five can be mentioned in particular [106–110]. For the study of vegetation dynamics, additional data analysis methods are usually in use, such as DCA and PCA.

**Table 4.** Most-cited papers on vegetation dynamics and management.

| Rank | Authors | Title | Year of Publication | Crossref Citations | References |
|---|---|---|---|---|---|
| 1 | Hermy, M.; Stieperaere, H. | An indirect gradient analysis of the ecological relationships between ancient and recent reiverine woodlands to the south of Bruges (Flanders, Belgium) | 1981 | 63 | [106] |
| 2 | Godefroid, S.; Rucquoij, S.; Koedam, N. | To what extent do forest herbs recover after clearcutting in beech forest? | 2005 | 45 | [107] |
| 3 | Czerepko, J. | A long-term study of successional dynamics in the forest wetlands. Forest Ecology and Management | 2008 | 34 | [108] |
| 4 | Dzwonko, Z.; Loster, S. | Vegetation differentiation and secondary succession on a limestone hill in southern Poland | 1990 | 31 | [109] |
| 5 | Vacek, S., Cerný, T., Vacek, Z., Podrázský, V., Mikeska, M., Králíček, I. | Long-term changes in vegetation and site conditions in beech and spruce forests of lower mountain ranges of Central Europe | 2017 | 25 | [110] |

### 3.2.2. Cluster 2

Cluster 2 is highlighted in green and contains 44 keywords. This cluster is looser. In addition to a large number of intra-cluster relationships, inter-cluster relationships are also well expressed. This cluster is associated with the study of forest vegetation and related problems. The keywords with the most links and the most occurrences are described in more detail in Table 5.

**Table 5.** Most significant keywords of cluster 2.

| Keyword | Links | Occurrence |
|---|---|---|
| Forest | 172 | 357 |
| Forest-steppe zone | 77 | 12 |
| Pine forest | 77 | 34 |
| Association (ass) | 153 | 294 |
| Differentiation | 118 | 29 |
| Dominance | 121 | 27 |
| Grass | 126 | 37 |
| Herb layer | 93 | 13 |
| Invasion | 80 | 24 |
| Invasive species | 79 | 18 |

Forest classification in the context of vegetation classification is essential for sustainable forest management and the conservation of forest biodiversity. We have revealed that the Braun-Blanquet approach is widely used for forest classification (Table 6).

Such classifications are based on an ecological analysis of plant communities and aim to identify the main factors determining forest structure and diversity. This approach can therefore provide an essential scientific basis for the development of decisions that contribute to the conservation of unique forest types and the long-term ecological and socio-economic sustainability of forest ecosystems.

A major study devoted to the classification of complex forest vegetation on Mt. Kilimanjaro is of particular interest to readers [111]. This study is not only carried out at a high scientific level but is also interesting from the point of view of discussing the important problem of ecological classifications regarding the continuity and discreteness of vegetation. The author convincingly demonstrated the existence of well-defined boundaries between elevation zones, which are manifested for all layers of forest vegetation studied. This allowed the author to confirm the high efficiency of the Braun-Blanquet approach even for very complex, multi-layered tropical mountain forests. Of course, this study played a positive role in the Braun-Blanquet application of the approach to the study and classification of forests and the development of forest typologies.

A study of the forest vegetation of the Killarney area is the second most cited [112]. The authors presented a comprehensive review of quantitative forest floristic data in tabular form, accompanied by a description of the edaphic drivers. Other papers on forest classification have significantly fewer citations. This is probably due to the fact that these studies were carried out at a regional level and are mainly relevant to the region studied.

**Table 6.** Most-cited papers related to the second cluster keywords.

| Rank | Authors | Title | Year of Publication | Crossref Citations | References |
|---|---|---|---|---|---|
| 1 | Hemp, A. | Continuum or zonation? Altitudinal gradients in the forest vegetation of Mt. Kilimanjaro | 2006 | 241 | [111] |
| 2 | Kelly, D.L. | The native forest vegetation of killarney, south-west Ireland: an ecological account | 1981 | 70 | [112] |
| 3 | Härdtle, W., Von Oheimb, G., Westphal, C. | Relationships between the vegetation and soil conditions in beech and beech-oak forests of northern Germany | 2005 | 31 | [113] |
| 4 | Navarro, G.; Molina, J.A.; De La Barra, N. | Classification of the high-Andean Polylepis forests in Bolivia. Plant Ecology | 2005 | 31 | [114] |
| 5 | Eshaghi Rad, J.; Manthey, M.; Mataji, A. | Comparison of plant species diversity with different plant communities in deciduous forests | 2009 | 28 | [115] |
| 6 | Peinado, M.; Aguirre, J.L.; Delgadillo, J. | Phytosociological, bioclimatic and biogeographical classification of woody climax communities of western North America | 1997 | 27 | [116] |
| 7 | Cano, E.; Musarella, C.M.; Cano-Ortiz, A.; Piñar Fuentes, J.C.; Rodríguez Torres, A.; Del Río González, S.; Pinto Gomes, C.J.; Quinto-Canas, R.; Spampinato, G. | Geobotanical Study of the Microforests of *Juniperus oxycedrus* subsp. *badia* in the Central and Southern Iberian Peninsula | 2019 | 24 | [117] |
| 8 | Li, C. F., Zelený, D., Chytrý, M., Chen, M. Y., Chen, T. Y., Chiou, C. R., Hsia, Y.J.; Liu, H.Y.; Yang, S.Z; Yeh, C.L.; Wang, J.C.; Yu, C.F.; Lai, Y.J.; Guo, K.; Hsieh, C. F. | Chamaecyparis montane cloud forest in Taiwan: ecology and vegetation classification | 2015 | 23 | [118] |
| 9 | Çoban, S., Willner, W. | Numerical classification of the forest vegetation in the western Euxine region of Turkey. | 2019 | 20 | [119] |
| 10 | Krestov, P. V., Ermakov, N. B., Osipov, S. V., Nakamura, Y. | Classification and phytogeography of larch forests of northeast Asia | 2009 | 16 | [120] |

One key importance of regional forest classifications is their contribution to biodiversity conservation and habitat preservation. Different regions possess specific combinations of tree species, vegetation communities, and wildlife habitats. By classifying forests at a regional scale, researchers can identify areas of high biological diversity, critical ecological corridors, and rare or endemic species habitats. This classification facilitates the development of conservation strategies that address region-specific challenges and ensure the long-term integrity of the region's unique forest ecosystems [111,112,115]. Regional forest classifications also play a critical role in understanding and managing the impacts of climate change on forest ecosystems. The vulnerability of different forest types to climate-related stressors such as drought, pest outbreaks, or invasive species can be assessed and monitored using regional forest classifications [116,120]. By taking into account the unique ecological, climatic and geological conditions of a given region, regional forest classifications provide valuable insights into the distribution, composition and functioning of forests, promote regionally tailored approaches to address the challenges associated with each region's forest resources and thereby promote the long-term sustainability of forest ecosystems and the provision of ecosystem services. It also provides a framework for the conservation, planning, and sustainable management of forests.

In summary, the Braun-Blanquet approach provides an excellent methodology for environmental analysis and is well suited to identifying forest diversity. Therefore, this approach is of exceptional importance for conservation purposes. This can be seen as a unique feature and strength of this approach. This strength of the Braun-Blanquet approach is highly valued by researchers, and the Braun-Blanquet methodology is actively involved in the development of forest typologies that serve as the basis for forest management [13,27,49,50,56].

#### 3.2.3. Cluster 3

Cluster 3 is highlighted in blue and contains 22 keywords. Intra- and inter-cluster relationships are quite well expressed. This cluster is related to vegetation mapping and related issues. The keywords with the most links and the most occurrences are described in more detail in Table 7. There are several interesting publications (Table 8).

**Table 7.** Most significant keywords of cluster 3.

| Keyword | Links | Occurrence |
|---|---|---|
| Map | 130 | 49 |
| Geobotanical map | 57 | 11 |
| Vegetation unit | 131 | 45 |
| Territorial unit | 43 | 28 |
| Typological unit | 52 | 15 |
| Typology | 58 | 12 |
| Combination | 136 | 55 |
| Environmental factor | 132 | 39 |
| Nomenclature | 117 | 27 |
| Series | 139 | 45 |
| Basis | 158 | 69 |
| Marsh | 90 | 25 |

Vegetation mapping, also known as geobotanical mapping or phytogeographic mapping, is a systematic approach used to classify and represent the spatial distribution of plant communities within a particular geographic region. It combines botanical knowledge, ecological principles, and spatial analysis techniques to create detailed maps that depict the composition, structure, and variability of vegetation types.

The primary objective of vegetation mapping is to provide a comprehensive understanding of the vegetation patterns and processes at different scales, ranging from local to regional and global levels. This mapping approach relies on the collection and analysis of various data sources, including field surveys, remote sensing imagery, environmental variables (e.g., climate, soil properties), and existing vegetation classification systems.

One of the primary significances of vegetation mapping lies in its ability to provide accurate and detailed information about the distribution, composition, and structure of vegetation types. Furthermore, vegetation mapping serves as a fundamental tool for land managers, policymakers, and conservationists, helping them develop appropriate strategies for sustainable resource management and land-use planning. By understanding the spatial distribution of different vegetation types, land managers can make informed decisions regarding land allocation, restoration initiatives, and the protection of critical ecological areas. Vegetation maps also contribute to the assessment of ecosystem services, such as carbon sequestration, watershed protection, and wildlife habitats, aiding in the design and implementation of conservation initiatives. Overall, vegetation mapping is an indispensable tool in advancing scientific understanding, promoting effective land management practices, and preserving the Earth's biodiversity. Its multidisciplinary nature ensures its relevance across various academic disciplines, including ecology, conservation biology, geography, and environmental science [121,122].

The theoretical and practical importance is stimulating the development of this scientific direction. However, in this field, the Braun-Blanquet approach is clearly inferior to other scientific approaches based on remote sensing of territories [123–126].

The development of vegetation maps required a mandatory consideration of climatic and other environmental factors and a corresponding revision of the diagnostic signs of syntaxons. This provided a strong impetus for further development of the approach. The identification of syntaxons and cartographic representations begin to combine biogeography and the assessment of factors affecting the potential and actual structure of vegetation. The geographical principle becomes one of the most important in the assignment of both associations and syntaxons of higher rank. At the same time, the importance and the level of detail of each factor differ at different hierarchical levels of classification [64]. The set of factors and their role in vegetation classification can vary significantly in different countries and regions, as the factors limiting plant distribution have regional specificities [127–129]. Classifications are becoming more regional, although they are based on general principles. At the same time, the correct integration of phytosociology and ecological analysis is considered key to the hierarchical classification of ecosystems [130].

Successful examples of vegetation mapping are given in Table 8. The interdisciplinary nature of this scientific field requires special training of scientific specialists, which is currently insufficient. Therefore, despite the importance of this scientific direction, research results are still scarce and there is a need to further develop the conceptual and methodological basis for the production of vegetation maps. We can mark the mapping vegetation of Italy [130] and of the Etosha National Park [131].

**Table 8.** Most-cited papers related to the third cluster keywords.

| Rank | Authors | Title | Year of Publication | Crossref Citations | References |
|---|---|---|---|---|---|
| 1 | Capotorti, G.; Guida, D.; Siervo, V.; Smiraglia, D.; Blasi, C. | Ecological classification of land and conservation of biodiversity at the national level: the case of Italy | 2012 | 54 | [130] |
| 2 | le Roux, C.J.G.; Grunow, J.O.; Bredenkamp, G.J.; Morris, J.W.; Scheepers, J.C. | A classification of the vegetation of the Etosha National Park | 1988 | 48 | [131] |
| 3 | Biondi, E.; Casavecchia; S., Pesaresi, S. | Phytosociological synrelevés and plant landscape mapping: From theory to practice | 2011 | 44 | [132] |
| 4 | Galdenzi, D.; Pesaresi, S.; Casavecchia, S.; Zivkovic, L.; Biondi, E. | The phytosociological and syndynamical mapping for the identification of High Nature Value Farmland | 2012 | 25 | [133] |
| 5 | Jalilian, A.M.; Shayesteh, K.; Danehkar, A.; Salmanmahiny, A. | A new ecosystem-based land classification of Iran for conservation goals | 2020 | 14 | [129] |
| 6 | Malfasi, F., Cannone, N. | Phytosociology of the vegetation communities of the Stelvio Pass area | 2021 | 3 | [134] |

3.2.4. Cluster 4

Cluster 4 is highlighted in yellow and contains 14 keywords. This is a small, loose cluster. The connections within and between the clusters are quite well expressed. This cluster is associated with the study of Arctic territories and related problems. The keywords with the most links and the most occurrences are described in more detail in Table 9. The publications with the highest number of citations are listed in Table 10.

**Table 9.** Most significant keywords of cluster 4.

| Keyword | Links | Occurrence |
|---|---|---|
| Arctic | 74 | 23 |
| Russian Arctic | 48 | 15 |
| Tundra zone | 74 | 17 |
| Syntaxon | 144 | 57 |
| Higher unit | 73 | 14 |
| Checklist | 69 | 20 |
| Evc | 39 | 21 |

**Table 10.** Most-cited papers related to the fourth cluster keywords.

| Rank | Authors | Title | Year of Publication | Crossref Citations | References |
|---|---|---|---|---|---|
| 1 | Matveyeva, N.V. | Floristic classification and ecology of tundra vegetation of the Taymyr peninsula, Northern Siberia | 1994 | 49 | [135] |
| 2 | Walker, D.A.; Daniëls, F.J.A.; Matveyeva, N.V.; Šibík, J.; Walker, M.D.; Breen, A.L.; Druckenmiller, L.A.; Raynolds, M.K.; Bültmann, H.; Hennekens, S.; Buchhorn, M.; Epstein, H.E.; Ermokhina, K.; Fosaa, A.M.; Heiðmarsson, S.; Heim, B.; Jónsdóttir, I.S.; Koroleva, N.; Lévesque, E.; MacKenzie, W.H.; Henry, G.H.R.; Nilsen, L.; Peet, R.; Razzhivin, V.; Talbot, S.S.; Telyatnikov, M.; Thannheiser, D.; Webber, P.J.; Wirth, L.M. | Circumpolar arctic vegetation classification | 2018 | 36 | [136] |
| 3 | Koroleva, N. E. | Phytosociological survey of the tundra vegetation of the Kola Peninsula, Russia | 1994 | 25 | [137] |
| 4 | Matveyeva, N.V. | Vegetation of the southern part of Bolshevik Island (Severnaya Zemlya Archipelago) | 2006 | 23 | [138] |
| 5 | Kholod, S.S. | Classification of Wrangel Island vegetation | 2007 | 23 | [139] |

The Arctic region, characterized by extreme cold, short growing seasons, and fragile ecological balance, exhibits distinct vegetation patterns and adaptations to these harsh environmental conditions. One prominent importance of studying and classifying Arctic vegetation lies in its role as a sensitive indicator of climate change.

According to the number of citations, a study dedicated to tundra vegetation of the Taymyr Peninsula [135] has the highest number of citations. The author presented the first systematic description is presented of tundra plant communities using the Braun-Blanquet approach. Simultaneously, the author described for the first time five associations for this region. A phytosociological survey of the tundra vegetation of the Kola Peninsula, Russia, according to the Braun-Blanquet approach was conducted by Koroleva [137]. Later, a large international team of authors presented a survey of circumpolar Arctic vegetation [136]. The strength of this study is also the analysis of the advantages and disadvantages of the Braun-Blanquet classification approach compared to EcoVeg (US), originally developed for the US National Vegetation Classification (US-NVC) [140] and the Biogeoclimatic Ecological Classification (Canada) used in British Columbia [13]. The authors point out that it is difficult to make transitions between classifications above the level of the plant community.

There is still a lot of work to be performed to synchronize research and classification results, which is undoubtedly extremely important for the practical management of Arctic ecosystems. In terms of the advantages of using the Braun-Blanquet approach, the authors point out that this approach has already been widely used in all regions of the Arctic and that many of the described, well-accepted vegetation classes have a pan-Arctic distribution. The authors also highlight the prospects of the Braun-Blanquet approach for the classification of Arctic vegetation, recommend it for wide use, and hope that the Braun-Blanquet approach may continue to be the dominant classification approach for most Arctic countries.

### 3.2.5. Cluster 5

Cluster 5 is highlighted in purple and contains 11 keywords. This cluster is also very loose. Among the inter-cluster interactions, the relationships with cluster 1 are the most pronounced. This cluster is associated with the study of floodplains, meadows, and riparian and aquatic vegetation and related problems. The keywords with the most links and the most occurrences are described in more detail in Table 11.

**Table 11.** Most significant keywords of cluster 5.

| Keyword | Links | Occurrence |
|---|---|---|
| Floodplain | 107 | 44 |
| Pasture | 76 | 23 |
| Meadow community | 51 | 21 |
| Meadow vegetation | 40 | 11 |
| Aquatic vegetation | 48 | 15 |
| Floristic composition | 157 | 67 |
| Floristic classification | 97 | 20 |

The most-cited papers are listed in Table 12. The floristic composition and geographical distribution of the peatland [141] and grasslands are surveyed in detail by the authors [142].

**Table 12.** Most-cited papers related to the fifth cluster keywords.

| Rank | Authors | Title | Year of Publication | Crossref Citations | References |
|---|---|---|---|---|---|
| 1 | Glaser, P.; Wheeler, G.; Gorham, E.; Wright, H.E. | The patterned mires of the red lake peatland, northern Minnesota: vegetation, water chemistry and landforms | 1981 | 179 | [141] |
| 2 | Willems, J.H. | Phytosociological and geographical survey of mesohromion communities in western Europe | 1984 | 49 | [142] |
| 3 | Murray-Hudson, M., Wolski, P., Cassidy, L., Brown, M. T., Thito, K., Kashe, K., Mosimanyana, E. | Remote Sensing-derived hydroperiod as a predictor of floodplain vegetation composition | 2015 | 29 | [143] |
| 4 | Taylor, H.C. | A vegetation survey of the Cape of Good Hope Nature Reserve. I. The use of association-analysis and Braun-Blanquet methods | 1984 | 26 | [144] |
| 5 | Kavgaci, A., Carni, A., Tecimen, H., Ozalp, G. | Diversity of floodplain forests in the Igneada region (NW Thrace—Turkey) | 2011 | 15 | [145] |

Floodplain vegetation plays critical roles in stabilizing riverbanks, regulating water flows, enhancing water quality, and providing habitat for a diverse range of species. Floodplain ecosystems are characterized by dynamic hydrological regimes, including regular flooding events, water level fluctuations, and sediment deposition. These ecohydrological processes shape the composition, structure, and distribution of floodplain vegetation [143].

By classifying floodplain vegetation, land managers can identify areas with high ecological value, such as those with diverse and well-preserved vegetation communities, and prioritize their protection and restoration. Understanding the vegetation composition and structure enables the identification of critical habitats for endangered or vulnerable species [144,145].

Floodplain vegetation classifications also play a crucial role in assessing and managing the ecological services provided by floodplain ecosystems. Vegetation in floodplains helps mitigate the impacts of flooding by slowing down water flows, reducing erosion, and storing water. These ecosystem services are critical for flood regulation and mitigating the risks associated with floods. Additionally, understanding the spatial distribution and connectivity of vegetation communities helps identify potential corridors for wildlife movement and supports landscape-level conservation planning.

In summary, floodplain and meadow vegetation classifications are of significant importance as they provide a deeper understanding of floodplain and meadow ecosystem dynamics, support the assessment and management of ecosystem services, and guide conservation and restoration efforts. By classifying floodplain and meadow vegetation, researchers and land managers can effectively plan land use, prioritize habitat conservation, and implement restoration strategies aimed at maintaining the ecological integrity and resilience of ecosystems.

#### 3.2.6. Analysis of Keywords and Research Directions for the Period 2018–2022

In addition to the general keyword analysis, a similar analysis has been carried out for 2018–2022. In general, the results of this analysis of research are similar to the results of the analysis for the whole period (Figure 4).

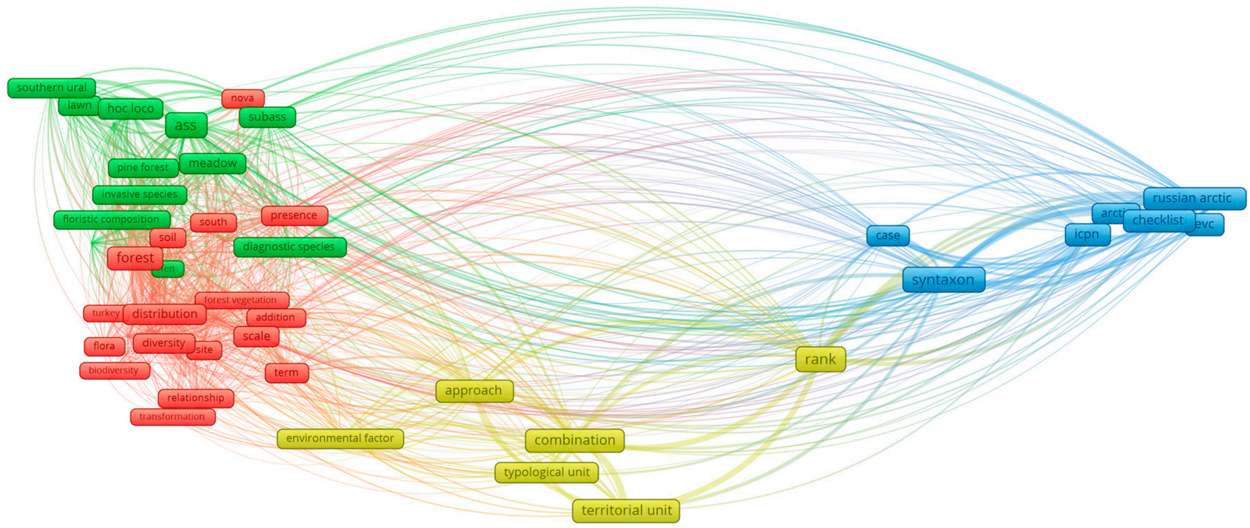


**Figure 4.** Analysis of the keyword relationship network for the period 2018–2022.

Cluster 1 (red) also brings together keywords from a number of interrelated areas of vegetation science. Keywords: phytosociology, distribution, Braun-Blanquet method, and Braun-Blanquet procedure are associated with publications devoted to improving the conceptual and methodological foundations of the Braun-Blanquet approach. The conceptual framework is being refined on the basis of large-scale studies of regional vegetation characteristics in different countries. The first to be mentioned is the large-scale study on the classification of bog vegetation [146], carried out by a large international team. This study is based on extensive material, has an excellent design, and the research findings are perfectly illustrated. Based on the Braun-Blanquet approach, Nowak et al. [147] carried out the first juniper classification of Tajikistan's forests. A group of authors developed a detailed classification of Palestine's vegetation [148]. For the first time in Bulgaria, the syntaxonomy of the class *Polygono-Poetea* has been developed and analyzed [149]. New results have been obtained in the syntaxonomy of the East African wetlands [150] and of the South Africa Nature Reserve [151–153] and mountainous grassland ecosystem [154]. The approach has been successfully used to study and classify rocky vegetation of the Iberian Peninsula [155]. It also describes some new associations [156,157]. Special mention should be made of the studies devoted to the compilation and updating of databases of phytosociological data [158,159]. This suggests that interest in the study of plant community diversity, as well as methodological problems and improvements, continues to this day. On the one hand, there is an understanding of the unresolved methodological problems, and on the other, there is a desire on the part of researchers to develop the approach further. This can be seen as a positive development.

Cluster 2 (green) is associated with the study of forest vegetation and the problems associated with it [160–168]. The retention of research interest in forests and the separation of keywords related to their study into a separate large cluster indicates an understanding of the importance of the problems of preserving their biodiversity and organizing sustainable forest management. The analysis showed that researchers from Russia have been actively involved in solving this problem in recent years [160–162,165–168].

Cluster 3 is highlighted in blue. This cluster is associated with the study of Arctic territories and related problems [169–172]. It should be noted that despite the fact that this cluster has numerous inter-cluster relationships, its isolation from other clusters has increased in the modern period. This probably indicates a deepening of the analysis of the regional characteristics of Arctic vegetation and the formation of a separate scientific direction for the study of the Arctic.

Cluster 4 is highlighted in yellow. This cluster is related to vegetation mapping and related issues [173–176]. The cluster is very loose. This indicates the diversity of research devoted to geobotanical mapping.

### *3.3. Citation Analysis*

Based on the above analysis of the main research areas based on the Braun-Blanquet approach, it can be concluded that the most-cited papers are those on methodological aspects. Among these papers, we would like to mention seven that have been cited more than 200 times [13,43,49,81–84]. Highly cited studies also include papers on forests [96] and peatlands [141].

It is necessary to mention the most-cited authors in addition to the most-cited papers. Table 13 shows the top 20 most-cited authors. More than 33% of all citations are by these authors. This reflects her outstanding contribution to the development of this scientific approach. The most-cited authors include Braun-Blanquet, van der Maarel, and Chytrý. There are more than 1300 citations for these authors (Table 13). Mucina, Dengler, and Di Pietro have more than 900 citations. The high citation rate of these authors proves their influence on the development of the Braun-Blanquet approach, which is manifested in the development and improvement of the methodology of ecological classification of vegetation or in the development of detailed regional classification systems that have been recognized, widely used, and selected as the basis for further research in this field.

It is an interesting exercise to trace the journals in which these papers have been published. We have carried out such an analysis and have identified the top 20 journals that have published the most highly cited papers (Table 14). In this table, three journals stand out: *Classification of Plant Communities, Ordination and Classification of Communities*, and *Acta Botanica Neerlandica*. In these journals, papers have been published with an average of more than 300 citations. It should be noted here that the first two places are occupied by *Classification of Plant Communities*, and *Ordination and Classification of Communities*. These are not journals but the titles of books published under the editorship of Robert H. Whittaker. However, it was decided to include them in the table in view of the high citation rate of the papers published in these books. This is important because it shows that even a single book with several chapters can successfully compete in terms of scientific importance (based on citations) with scientific journals that publish a large number of papers. Unfortunately, the lack of a DOI for most books published before 1997 does not allow us to identify all the most important ones. We can only assume that there are many more such books.

**Table 13.** Most Crossref cited authors.

| Rank | Author | Institute | Country | Number of Papers | Number of Citations |
|---|---|---|---|---|---|
| 1 | Braun-Blanquet, J. | International Station for Alpine and Mediterranean Geobotany, SIGMA | France, Switzerland | 8 | 2096 |
| 2 | van der Maarel, E. | Division of Geobotany, Toernooiveld | Netherlands | 5 | 1889 |
| 3 | Chytrý, M. | Masaryk University | Czech Republic | 16 | 1317 |
| 4 | Mucina, L. | Department of Vegetation Ecology and Biological Conservation, University of Vienna; School of Plant Biology, The University of Western Australia | Austria, Australia | 5 | 923 |
| 5 | Dengler, J. | University of Bayreuth, Germany German Centre for Integrative Biodiversity Research | Germany | 7 | 908 |
| 6 | Di Pietro, R. | Section Environment and Landscape, Sapienza University of Roma | Italy | 8 | 905 |
| 7 | Daniëls, F.J.A. | Institute of Plant Biology and Biotechnology, University of Münster | Germany | 9 | 878 |
| 8 | Willner, W. | Vienna Institute for Nature Conservation and Analyses; Department of Botany and Biodiversity Research, University of Vienna | Austria | 8 | 878 |
| 9 | Tichý, L. | Department of Botany and Zoology, Masaryk University | Czech Republic | 3 | 869 |
| 10 | Čarni, A. | Institute of Biology, Scientific Research Center of the Slovenian Academy of Sciences and Arts; University of Nova Gorica; Macedonian Academy of Sciences and Arts | Slovenia, Republic of Macedonia | 6 | 862 |
| 11 | Schaminée, J.H.J. | Institute for Water and Wetland Research, Radboud University | Netherlands | 5 | 839 |
| 12 | Ermakov, N. | Laboratory of Ecology and Geobotany, Central Siberian Botanical Garden; Nikitskiy Botanical Garden | Russian Federation | 6 | 835 |
| 13 | Hennekens, S.M. | Alterra | Netherlands | 5 | 834 |
| 14 | Pignatti, S. | Department of Environmental Biology, University of Rome L'a Sapienza' | Italy | 5 | 827 |
| 15 | Hájek, M. | Department of Botany and Zoology, Masaryk University | Czech Republic | 5 | 826 |
| 16 | Bültmann, H. | - | Germany | 2 | 823 |
| 17 | Valachovič, M. | Institute of Botany, Slovak Academy of Sciences | Slovakia | 3 | 808 |
| 18 | Westhoff, V. | Groesbeek | Netherlands | 2 | 805 |
| 19 | Bergmeier, E. | Department of Vegetation and Plant Diversity Analysis, Albrecht von Haller Institute of Plant Sciences, University of Göttingen | Germany | 3 | 800 |
| 20 | Dimopoulos, P. | Faculty of Environmental and Natural Resources Management, University of Patras | Greece | 2 | 792 |

**Table 14.** Journals that publish the most-cited papers.

| Rank | Journal | Documents | Citations | Avg. Citations | Avg. Norm. Citations |
|---|---|---|---|---|---|
| 1 | *Classification of Plant Communities* | 1 | 476 | 476.0 | 6.00 |
| 2 | *Ordination and Classification of Communities* | 1 | 329 | 329.0 | 4.67 |
| 3 | *Acta Botanica Neerlandica* | 1 | 311 | 311.0 | 0.26 |
| 4 | *Environmental Management* | 1 | 159 | 159.0 | 2.00 |
| 5 | *Applied Vegetation Science* | 6 | 840 | 140.0 | 8.45 |
| 6 | *Forest Ecology and Management* | 5 | 403 | 80.6 | 3.20 |
| 7 | *The Journal of Ecology* | 8 | 493 | 61.6 | 1.19 |
| 8 | *Vegetatio* | 40 | 2354 | 58.9 | 1.10 |
| 9 | *Landscape and Urban Planning* | 2 | 116 | 58.0 | 3.00 |
| 10 | *Biodiversity and Conservation* | 2 | 110 | 55.0 | 2.04 |
| 11 | *Encyclopedia of Ecology* | 2 | 99 | 49.5 | 3.54 |
| 12 | *Ecography* | 1 | 45 | 45.0 | 7.37 |
| 13 | *Ecosphere* | 1 | 41 | 41.0 | 4.69 |
| 14 | *Journal of Vegetation Science* | 31 | 1239 | 40.0 | 2.23 |
| 15 | *Critical Reviews in Plant Sciences* | 1 | 39 | 39,0 | 2.38 |
| 16 | *Plant Ecology* | 12 | 440 | 36.7 | 1.49 |
| 17 | *Rodriguésia* | 2 | 56 | 28.0 | 4.92 |
| 18 | *International Journal of Environmental Science and Technology* | 1 | 28 | 28.0 | 3.61 |
| 19 | *Bulletin du Jardin Botanique de l'Etat a Bruxelles* | 1 | 27 | 27.0 | 1.00 |
| 20 | *Plant Biosystems—an international journal dealing with all aspects of plant biology* | 24 | 552 | 23.0 | 2.13 |

In addition, the most-cited journals should be noted (Table 15). This list differs from the list in Table 13. The high citation rate of the journals in Table 14 is due to the large number of papers published on the Braun-Blanquet approach, which have a relatively high citation rate. In this table, there are two journals that deserve a special mention. In the journal *Vegetatio*, articles based on the Braun-Blanquet approach have been cited more than 2300 times, and in the *Journal of Vegetation Science* articles based on the Braun-Blanquet approach have been cited more than 1200 times. Such a high number of published papers and their high citation rate prove the importance of the contribution of these scientific journals to the development of the Braun-Blanquet approach. The list of scientific journals in Table 15 will be of interest to researchers both when choosing a scientific journal for publication and when searching for high-quality papers on vegetation classification problems.

**Table 15.** Most cited journals.

| Rank | Journal | Documents | Citations | Avg. Citations | Avg. Norm. Citations |
|---|---|---|---|---|---|
| 1 | *Vegetatio* | 40 | 2354 | 58.9 | 1.10 |
| 2 | *Journal of Vegetation Science* | 31 | 1239 | 40.0 | 2.23 |
| 3 | *Applied Vegetation Science* | 6 | 840 | 140.0 | 8.45 |
| 4 | *Phytocoenologia* | 78 | 840 | 10.8 | 1.23 |
| 5 | *Plant Biosystems—an international journal dealing with all aspects of plant biology* | 24 | 552 | 23.0 | 2.13 |
| 6 | *The Journal of Ecology* | 8 | 493 | 61.6 | 1.19 |
| 7 | *Classification of Plant Communities* | 1 | 476 | 476.0 | 6.00 |
| 8 | *Plant Ecology* | 12 | 440 | 36.7 | 1.49 |
| 9 | *Forest Ecology and Management* | 5 | 403 | 80.6 | 3.20 |
| 10 | *South African Journal of Botany* | 45 | 359 | 8.0 | 0.69 |
| 11 | *Ordination and Classification of Communities* | 1 | 329 | 329.0 | 4.67 |
| 12 | *Acta Botanica Neerlandica* | 1 | 311 | 311.0 | 0.26 |
| 13 | *Bothalia* | 27 | 277 | 10.3 | 1.57 |
| 14 | *Koedoe* | 49 | 267 | 5.4 | 0.96 |
| 15 | *Vegetation of Russia* | 80 | 251 | 3.1 | 0.47 |
| 16 | *Folia Geobotanica et Phytotaxonomica* | 14 | 214 | 15.3 | 0.96 |
| 17 | *Environmental Management* | 1 | 159 | 159.0 | 2.00 |
| 18 | *Folia Geobotanica* | 13 | 159 | 12.2 | 1.43 |
| 19 | *Landscape and Urban Planning* | 2 | 116 | 58.0 | 3.00 |
| 20 | *Biodiversity and Conservation* | 2 | 110 | 55.0 | 2.04 |

A citation-based network of journals is shown in Figure 5. This figure clearly shows the heterogeneity of the network of relationships. A total of 373 journals were recorded. Only 147 of these were clustered. The journal network consists of 24 clusters. The clusters vary in size and density.

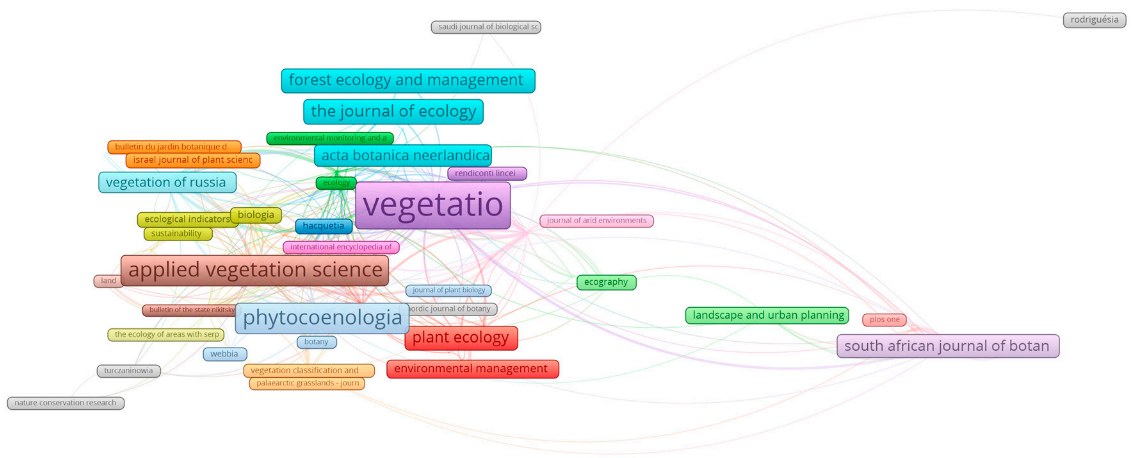


**Figure 5.** Citation-based network of journals.

The network is centered on the purple cluster, which includes eight journals. This cluster contains *Vegetatio*, which has the maximum number of links (51) in this network. The largest cluster is highlighted in red and contains 10 journals. In terms of number of links, *Plant Ecology* dominates. This cluster also includes the forests log. The cluster highlighted in brown contains six journals. This cluster contains *Applied Vegetation Science*, with 33 links. The light blue cluster also contains six journals. This cluster contains *Phytocoenologia*, with 24 links. The turquoise cluster contains seven journals. This cluster contains *Forest Ecology and Management*, which is well cited but has a low number of links (3).

### *3.4. Bibliographic Relationship Analysis*

The bibliographic-based network of papers is a structure that shows how scientific articles relate to each other based on the references they contain. The results of this analysis are shown in Figure 6. In this figure, each scientific paper is represented by a node (point) and the lines show the relationships between the papers. Here, we have focused our research analysis on the change in the structure of relationships over time. Figure 6 clearly shows that the structure of the relationships has changed significantly. At present, authors are more active in citing modern research, and the link with earlier papers is lost. On the one hand, this is a positive point, as it proves the active development of this scientific direction and the good orientation of the authors in the current state of the problem. On the other hand, the decline in the relationship with the first studies according to the Braun-Blanquet approach indicates a lack of appreciation of the importance of continuity in scientific research. It seems to us that modern authors should pay attention to this.

The largest nodes in the network of bibliographic relationships are modern papers [50,61,148,157,169,177–182]. Of the early papers, it is possible to note six of them [43,49,61,82,183,184].

Thus, the analysis of the bibliographic network of interrelationships of papers has made it possible to identify key papers and new trends. In general, this analysis has proved useful for understanding the structure and dynamics of the scientific community as a whole.

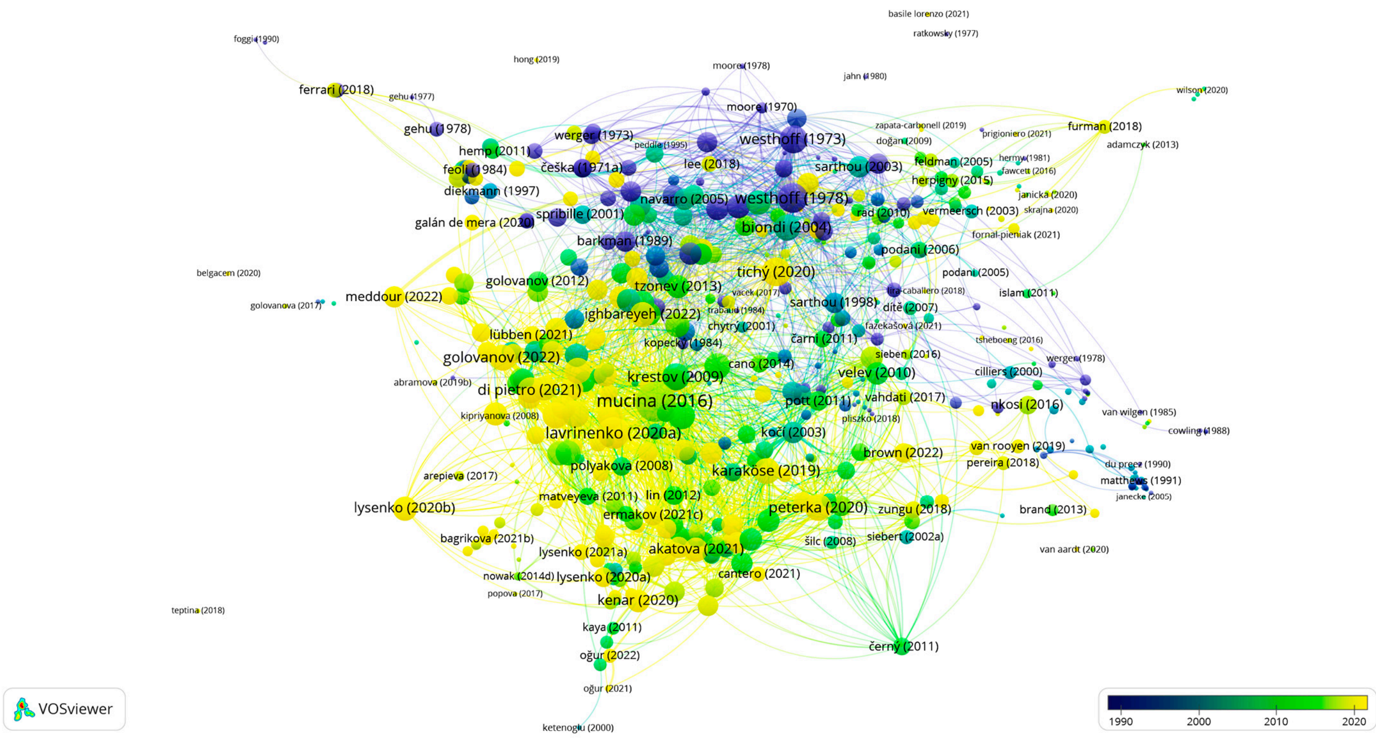


**Figure 6.** Bibliographic-based network of papers.

### 3.5. Author Publication Activity Analysis

The analysis of the research showed that out of the 960 authors identified, 634 authors had published only one paper in the scientific field under investigation. There are 164 researchers among the authors with two articles. Only 64 researchers have three publications. However, there are authors who make a significant contribution to the scientific field in terms of the number of publications. The top 10 researchers in terms of publication activity are shown in Table 16.

**Table 16.** Authors who have published the largest number of papers on the Braun-Blanquet approach are as follows.

| Rank | Author | Institute | Country | Number of Papers | Number of Citations |
|---|---|---|---|---|---|
| 1 | Bredenkamp, G.J. | University of Pretoria | South Africa | 67 | 547 |
| 2 | Brown, L.R. | University of South Africa | South Africa | 24 | 101 |
| 3 | van Rooyen, N. | University of Pretoria | South Africa | 23 | 114 |
| 4 | Bezuidenhout, H. | University of South Africa; Applied Behavioural Ecology and Ecosystem Research Unit, UNISA | USA | 22 | 113 |
| 5 | Nobis, M. | Institute of Botany, Jagiellonian University | Poland | 17 | 132 |
| 6 | Nowak, A. | Opole University | Poland | 17 | 132 |
| 7 | Nowak, S. | Opole University | Poland | 17 | 132 |
| 8 | Chytrý, M. | Masaryk University | Czech Republic | 16 | 1317 |
| 9 | du Preez, P.J. | National Museum | South Africa | 16 | 98 |
| 10 | Cilliers, S.S. | School for Environmental Sciences and Development, Potchefstroom University for C.H.E. | South Africa | 15 | 117 |

Bredenkamp is the author of the largest number of publications. In general, in terms of the number of papers published, a small group of researchers from South Africa stand out. Table 16 shows an interesting pattern. If all the most-cited authors are concentrated in

Eurasia (Table 13), then most of the most actively publishing authors are outside Eurasia. This demonstrates the widening geography of application and the strong research interest in the Braun-Blanquet approach in new regions. It also demonstrates that the Braun-Blanquet approach is effective and in demand outside Eurasia. For the further development of this approach to vegetation classification, this point is very important.

## 4. Discussion

This global review of studies based on the Braun-Blanquet approach includes 1168 papers and was conducted using the PRISMA methodological recommendations, strict criteria for the selection/quality of papers, modern methods of data analysis, and visualization using VOSviewer software, which ensures a representative sample, minimization of subjective judgements, and reliability of conclusions. It was noted that the number of publications on Braun-Blanquet is growing exponentially. This is an indication of the scientific interest in this methodology and its continuous further development. The observed dependence of the exponential growth in the number of publications is in good agreement with other studies [185]. This is due, on the one hand, to the general trend of increasing publication activity and, on the other hand, to an increase in the number of publications with a DOI identifier. At the same time, with the increasing availability of online phytosociological databases, the processes of analyzing results and publishing works have also accelerated. This is also one of the reasons for the exponential growth in the number of publications devoted to both the Braun-Blanquet approach and other scientific areas of vegetation science. It should also be borne in mind that DOI identifiers were little used before 1997. An adjustment should therefore be made for this fact, and it should be taken into account that the figure underestimates the interest in the Braun-Blanquet approach in the early period of the research analysis. This research analysis covers a long period of research, which distinguishes it from another recent systematic review of the Braun-Blanquet approach [185]. This naturally reduces the depth of analysis of individual periods: both initial and modern. However, the scientific continuity and temporal dynamics of the network of relationships can be better traced through such an analysis. For this research analysis, this was important. At the same time, the first period is well covered in numerous reviews [51–53,60,90,186]. It was therefore important for us to trace the scientific continuity over a long period of time, rather than focusing on the classic papers. The analysis of the bibliographic network of papers in dynamics has shown that the structure of relationships is not constant and has changed significantly. At present, authors actively cite modern research, and the link with earlier work is lost. In general, this analysis has proved useful for understanding the structure and dynamics of the scientific community as a whole.

As only papers with a DOI are included in the research analysis, this must also be taken into account. Non-DOI papers were not included in the analysis. As a result, the contribution of authors who have not yet published in high-impact journals may be somewhat underestimated. On the other hand, such a research analysis will provide an incentive to publish research results in rating journals. The proposed meta-analysis is no exception. The authors of most other meta-analyses carried out on a wide range of topics set even stricter quality criteria and only include papers indexed in Web of Science and Scopus in the analysis. For example, [73–76] only use the Web of Science Core Collection (WoSCC) database. Other authors only use Scopus [77]. This undoubtedly gives authors pause for thought when choosing journals to publish their research and about their contribution to the scientific field. However, taking into account that the sample of papers based only on Web of Science or Scopus will not be complete and that for a more complete study it is necessary to analyze a wider range of papers while excluding low-quality publications, all papers with a DOI identifier were included in the analysis. This made the study more complete than other studies that were based on an automated search. Nevertheless, the analysis of the authors' publication activity showed that the vast majority of researchers have a low publication activity and have published only one to three papers in the scientific field studied. In terms of the number of papers published, a small group of researchers from South Africa stand out. A peculiarity also emerges: if all the most cited authors are concentrated in Eurasia (more than 33% of all citations are by top 20 most cited authors), then most of the most actively published authors are outside Eurasia (More than 18% of all papers are by top 20 actively published authors). This demonstrates the widening geographical coverage and the strong research interest in applying the Braun-Blanquet approach in new regions. The research analysis also showed that researchers who have been involved in large international scientific projects benefit from citations. Papers published based on the results of such research projects tend to be highly cited. At the same time, the number of citations for all authors increases accordingly. This clearly demonstrates the benefits of scientific collaboration. This result will stimulate the desire to bring together researchers from different countries to solve complex modern problems in vegetation science. This will in turn help promote and develop the Braun-Blanquet approach more successfully.

In some cases, when authors use several databases (as in our study), they impose restrictions on the language of publication [187]. In this case, a large number of papers published in other languages (e.g., Chinese, Russian, and others published in national-ranking journals) are excluded from the analysis. In this case, the percentage contribution of countries to the scientific field is distorted. There are no restrictions on the language of publication in my research analysis. The analysis includes all papers that have an abstract in English. Therefore, the results are more accurate and the conclusions are more scientifically sound. At the same time, it was found that papers in English are cited more often. This may not be the case in national citation indexes, but if national journals do not have a DOI identifier (Crossref citation), they are not included in the analysis. For this reason, publications in languages other than English are rarely mentioned in this paper. They are simply inferior in citation to English-language publications. Thus, the citation analysis confirmed that the importance of an article to the scientific community depends on the language of publication. Researchers are more active in reading and citing articles in English. This means that the same article published in English, Russian, and Chinese, for example, will have a completely different importance to the scientific community, both in terms of the number of readers and the number of citations. This is also true when analyzing the author's contribution to the scientific field. This research analysis shows that the author's contribution depends on the language of the publication.

Based on a detailed analysis of the keywords, the main research directions and challenges are identified. These include:

1. Improving the conceptual and methodological foundations of the Braun-Blanquet approach. The issues of the influence of the size of the sample area on the classification result are investigated here (due to differences in the size of the sample areas, the same vegetation can be assigned to different phytosociological classes or habitat types): the reduction in classification errors associated with inaccuracy of scales and a subjective component and the evaluation of the effectiveness of the Braun-Blanquet approach in comparison with traditional methods of multiple data analysis and others.
2. Improvement in regional vegetation classifications (including verification of their nomenclatural accuracy to ensure the accuracy of plant community biodiversity estimates and to avoid confusion in the names of syntaxons), synthesizing them and producing a comprehensive classification for large areas as a basis for biodiversity conservation and sustainable land use. It also raises questions about identifying the habitats of rare or endemic species and the vulnerability of different plant communities to stresses.
3. Expansion of the geography of the Braun-Blanquet approach: to the west (USA), to the east (Russia), to the south (South Africa), and to the north (Arctic territories).
4. Compilation and updating of databases of phytosociological data necessary to establish and maintain a basis for systematization and environmental analysis.
5. Management dynamics and vegetation management. This research area is not sufficiently popular with researchers using the Braun-Blanquet approach. It can be

assumed that this is due to the insufficient development of the methodology for identifying and evaluating vegetation dynamics. Due to the importance of this problem, there is an urgent need to improve the methodology for its successful solution.

6. Discussion of the important problem of continuity and discreteness of vegetation in the context of ecological classifications and the objectivity of the existence of isolated syntaxons.
7. Vegetation mapping. The main purpose of vegetation mapping is to provide a comprehensive understanding of the structure and dynamics of vegetation at different scales: from local to regional and global. In addition, vegetation mapping is a fundamental tool for land managers, policy makers, and conservationists, helping them to develop appropriate strategies for sustainable resource management and land-use planning. The development of vegetation maps required a mandatory consideration of climatic and other environmental factors and a corresponding revision of the diagnostic signs of syntaxons. This provided a strong impetus for further development of the approach. Classifications are beginning to combine biogeography and the assessment of factors affecting the potential and actual structure of vegetation. The geographical principle is becoming one of the most important. The interdisciplinary nature of this field of research requires special training of scientific specialists.

In general, our research analysis has shown the high effectiveness of the Braun-Blanquet approach in solving a wide range of problems, extending the scope and geography of its application. The conceptual framework and practical methods have great potential for further improvement.

Research analysis of the types of plant communities to which the Braun-Blanquet approach can be applied has shown that it is highly effective for the study of a wide range of plant communities. Researchers have successfully classified forests, meadows, mountainous grassland, wetlands, floodplains, bogs, vegetation of seasonally flooded areas, riparian and aquatic vegetation, tundra and other Arctic vegetation, and others. At the same time, both nature reserves and vegetation in the gradient of urbanization and other very different human influences are studied.

The top 20 journals that published the most cited articles were identified, among which three journals stand out: *Classification of Plant Communities, Ordination and Classification of Communities, Acta Botanica Neerlandica*. In addition, the top 20 most-cited journals were identified, where high citation number is due to the large number of high-quality papers published according to the Braun-Blanquet approach. Of these, two journals deserve special mention: *Vegetatio* and *Journal of Vegetation Science*. These lists of scientific journals are useful for researchers to search for papers or to choose the best scientific journal to publish their research results.

## 5. Conclusions

In summary, the Braun-Blanquet approach is an excellent method of ecological analysis and is well suited to identifying the diversity of different types of vegetation, solving theoretical problems of modern vegetation science; it can also provide a reliable scientific basis for developing solutions to conserve the biodiversity of plant communities and help maintain the long-term ecological and socio-economic sustainability of a wide variety of plant communities. The importance of the Braun-Blanquet approach for the study and classification of forest vegetation should be emphasized. In this case, the Braun-Blanquet approach is integrated into forest typologies, increasing their ecological validity and environmental relevance.

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