Research Article

Research Trend on the Causes of Plant Dieback *Faidherbia Albida (F. Albida)* for the Sustainable Management of Agroforestry Systems: A Bibliometric Analysis

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Abstract

Parklands dominated by tree species such as *Faidherbia albida* provide multiple ecosystem services in fragile regions of sub-Saharan Africa, but the persistent decline of F. albida raises concerns about the stability of agricultural systems and food security. The aim of the study is to analyze the research trend on the causes of *Faidherbia albida* decline, to identify the main research themes, major issues and conceptual evolutions related to *F. albida* decline, and to explore the gaps in knowledge of *F. albida* decline. The bibliometric analysis shows a general upward trend in research on the subject since 2008, with a strong contribution from South Africa. Growth factors, biotic factors, experiments and specific studies on F. albida are the main clusters linked to F. albida decline factors in scientific publications. These different clusters dealing with the factors of F. albida decline, in particular seedling mortality and excessive pruning, are less explored. The results highlight the importance of in-depth research to identify the underlying causes and develop appropriate management strategies to ensure the long-term survival of these crucial species in our ecosystems.

Introduction

Parkland agroforestry systems dominated by tree species such as *Faidherbia albida, Vitellaria paradoxa* are common in the Sudano-Sahelian zone of Sub-Saharan Africa (SSA) [1]. These parks provide multiple ecosystem services in these fragile regions, which are susceptible to degradation. *F. albida* being a legume, it improves soil fertility, recycles nutrients, reduces soil erosion, and improves soil moisture availability. Parklands also reduce climate change risk for smallholders in sub-Saharan Africa [2].

Moreover, the concept of "tree dieback" remains complex, resulting from multiple factors such as climate change, excessive use of pesticides, the presence of heavy metals in soils, and habitat fragmentation [2]. These factors have direct effects on the survival of symbiotic microorganisms, such as mycorrhizae, which are crucial for the life of trees. *Faidherbia albida*, a legume species, occupies a crucial place in agroforestry ecosystems in Africa and the Middle East [3]. Although several studies have examined the sustainability and benefits of agroforestry practices based on *Faidherbia albida*, the worrying finding of its continued decline raises concerns

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[2,4,5-7]. Factors such as seedling mortality, excessive pruning and dieback threaten the stability of agricultural systems and food security.

In the context of sub-Saharan Africa, where agroforestry practices are vital to combating land degradation and ensuring food security, the decline of *Faidherbia albida* trees is of particular importance [5]. Despite previous studies, the persistent decline indicates an urgent need for in-depth research to identify underlying causes and develop suitable management strategies. So far, none of the published reviews have explored the conceptual and intellectual structures of the knowledge generated on the causes of *F. albida* dieback (e.g. research trends, research contribution by country, topic trend). Understanding this structure is fundamental to mapping the scientific knowledge generated to establish a solid foundation for advancing knowledge of *F. albida* dieback. Bibliometric analysis is a suitable research method to provide a comprehensive overview and classification of research, as well as to further develop emerging research areas [8]. Based on citation mapping, bibliometric analysis helps to quantitatively synthesize a research topic and provide an overview of the main research directions [9]. This bibliometric and systematic review aims to (1) Analyze the research trend on the causes of *F. albida* dieback in order to identify notable periods of growth or decline of research in this area; (2) Identify the main research themes, major issues and conceptual evolution related to *F. Albida* dieback; (3) Analyze the factors contributing to the decline of *F. albida* in order to understand the determining elements of this phenomenon; (4) Explore gaps in knowledge of *F. albida* dieback, identifying under-researched areas. Bibliometric analysis is a well-accepted and used scientific method that combines mathematical and statistical techniques to evaluate research [10].

Research Methodology

Search strategy and term

A search strategy was carried out including search terms from the Scopus data source (http://www.scopus.com/search/). These data sources were chosen because it features a wide range of high-impact international academic journals [11] and mainly saves scientific articles, journals, and books, but also other documents such as conference reports, etc. The first step consisted of defining a search string taking into account the keywords and terms linked to the PIOS elements (Population, Interventions, Outcome and Setting (geolocation) (Table 1) [12].

Each element was compared by the Boolean operators OR [12,13] and their combinations by the Boolean operator AND. The terms made it possible to establish the search chain (Search by titles, summary keywords).

Analysis method

A total of 78 documents were retained from the Scopus data source. These documents were exported respectively to RIS and CSV formats on June 5, 2023, then submitted to R software to perform bibliometric analyses. Bibliometric analysis is a rigorous and objective approach to literature analysis that allows the identification, evaluation and interpretation of all available studies relevant to a research question in a specific or related area of study, to a specific problem of interest [14].

Thus, the publication trend analysis, the analysis of countries or regions having a strong contribution in the field

Table 1: Elements of PICO.

Elements	Description	Syntax
Population	Species of the genus Fabacea	"*Faidherbia albida*" OR "Agroforestry tree" OR "*Acacia albida*" OR "F. albida" OR "Faidherbia"
Intervention	Mortality	mortality OR "Tree Dieback
Outcome	Impact	impact OR effect OR Cause
Setting (geolocation)	Sub-Saharan Africa	Sub-Saharan Africa" OR "Angola" OR "Benin" OR "Botswana" OR "Burkina Faso" OR "Burundi" OR "Cabo Verde" OR "Cameroon" OR "Central African Republic" OR "CAR" OR "Chad" OR "Comoros" OR "Congo" OR "DRC" OR "Cote d'Ivoire" OR "Djibouti" OR "Equatorial Guinea" OR "Eritrea" OR "Ethiopia" OR "Gabon" OR "Gambia" OR "Ghana" OR "Guinea " OR "Guinea-Bissau" OR "Kenya" OR "Lesotho" OR "Liberia" OR "Madagascar " OR "Malawi" OR "Mali" OR "Mauritania" OR "Mauritius" OR "Mozambique" OR "Namibia" OR "Niger " OR "Nigeria" OR "Rwanda" OR "Saharawi Arab Democratic Republic" OR "Sao Tome and Principe " OR "Senegal" OR "Seychelles" OR "Sierra Leone" OR "Somalia" OR "South Africa" OR "South Sudan" OR "Sudan" OR "Swaziland" OR "Eswatini" OR "Tanzania" OR "Togo" OR "Uganda" OR "Zambia" OR "Zimbabwe"

was carried out using bibliometrix R-Tool via the biblioshiny interface [15], a recent R package that facilitates more comprehensive bibliometric analysis by employing specific tools for quantitative bibliometric and scientometric research. Also, the analysis of the contents of the documents was carried out with the VOSviewer software.

Results and Discussion

Publication trend

Dynamic trends in *F. albida* dieback studies have shown a general increasing trend over the years (Figure 1). This dynamic in the field can be subdivided into two main periods. A first phase of development took place from 1985 to 2008, characterized by low production on the subject. The second phase, between 2008 and 2022, characterized by a slow development of research on the subject, shows a general upward trend in the influence of articles on the subject.

It is plausible that the growing interest in *F. albida* dieback research is closely linked to potential implications for agroforestry. Agroforestry systems, by integrating trees into agricultural practices, are often praised for their environmental and socio-economic benefits [16]. It is conceivable that researchers have become aware of the significant impacts of F. albida dieback on agroforestry systems, leading to growing interest in understanding and mitigating these effects [17]. The focus on sustainability could also be linked to the quest for solutions to preserve the long-term viability of agroforestry systems [18,19].

International agreements and conventions play a crucial role in the promotion and preservation of agroforestry systems due to their impact on environmental and social sustainability. First of all, these agreements provide a normative framework and guidelines that encourage the adoption of environmentally friendly agricultural practices, among which agroforestry takes a central place [20,21]. For example, biodiversity conventions recognize the essential role of agroforestry systems in the conservation of biological diversity. By integrating trees into crops, these systems help maintain the ecosystem biodiversity, thus promoting the resilience of agroecosystems in the face of environmental changes. In addition, climate change agreements highlight the importance of carbon sequestration, a key benefit of agroforestry systems [22]. By promoting carbon fixation in soils and plant biomass, these systems help mitigate greenhouse gas emissions, thereby aligning agricultural practices with emissions reduction objectives [23].

Country contribution

A total of 17 countries/regions in sub-Saharan Africa contributed to research on the issues of drivers of *F. albida* dieback between 1988 and 2023 (Figure 2a). The majority of work, i.e. 25% of studies, focuses particularly on South Africa, probably highlighting the crucial importance of *F. albida* trees in this region, perhaps as key elements of local agroforestry systems. Cameroon, Uganda and Ethiopia follow with 12.5%, 11.11% and 6.97% respectively, showing increasing interest in fabacea trees as an essential element. However, significant research gaps have been identified in Senegal, Niger, Kenya and Benin, where virtually a small percentage of studies have been carried out over the past 30 years (Figure 2b).
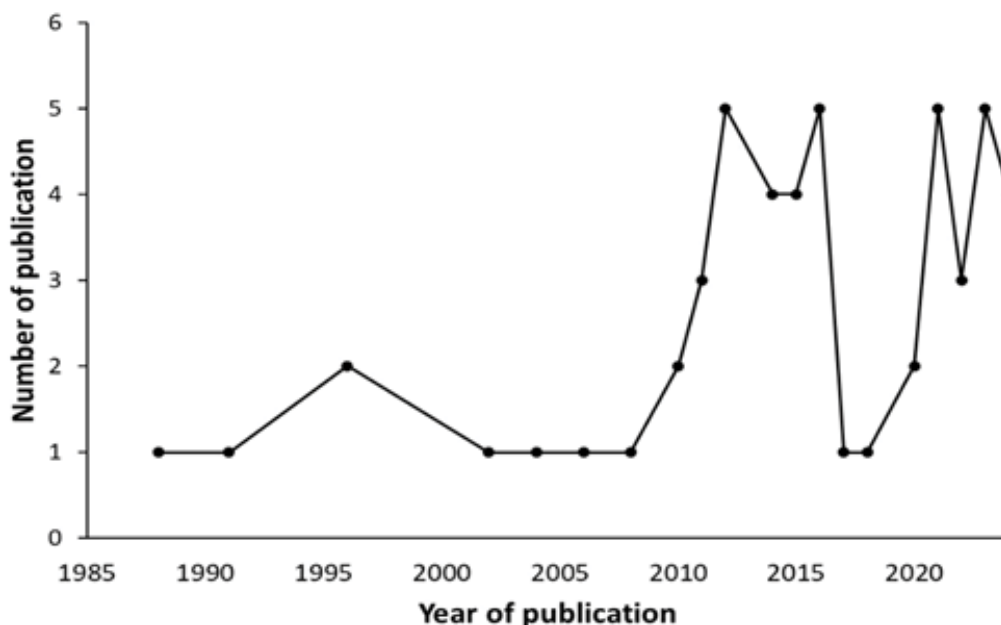

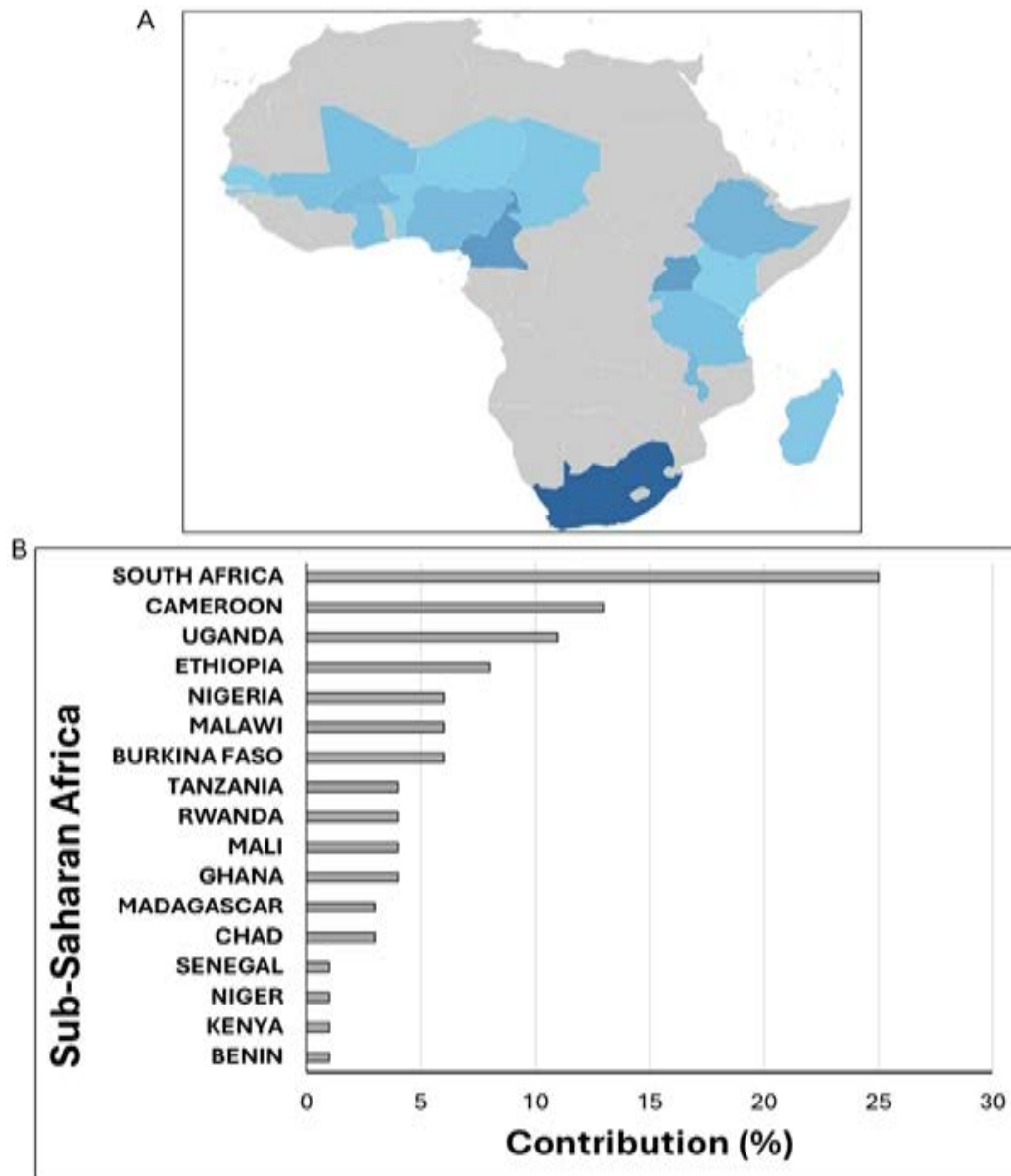**Figure 1**: Publication trend on the causes of *F. albida* dieback.

Figure 2: Distribution of studies on the causes of plant *F. albida* dieback between 1988 and 2023.

Topic trend analysis based on keywords

Figure 3 presents the evolution of the themes most used in literature on the causes of F. *albida* dieback. Based on the evolution of publications, four years were set as thresholds. These are 2008, 2012, 2018 and 2021. The size of the bars indicates how often the keywords appeared and the color helps distinguish the keywords. From 1988 to 2008, the most commonly used keywords in search engines for *F. albida* dieback factors were: "legume", "*F. albida*", "newborn". From 2009 to 2012, the words "Legume", "femal" and "newborn" were combined with the word "fabacea". During this period, we notice the appearance of the keyword "Agriculture" showing the interest of researchers in the role of F. albida in agriculture. However, the research themes

of dieback factors began to diversify from 2018 to 2023, taking into account themes related to *F. albida* in general, medicinal plants in the use of leaves, and climate change. The more specific evolution of these themes comes from generic themes such as *F. albida*, agriculture, legumes and insulation, purification.

Cluster of dieback factors studied in scientific publications

Figure 4 highlights five main clusters related to *F. albida* dieback in scientific publications. The first group, identified by the green color, is characterized by growth factors, including recruitment, tree growth, dry season. The second cluster, in red, is associated with biotic factors, characterized by the disturbances of insects and humans linked to the

extraction of alcohol which are influential on the growth and survival of *F. albida* tree species. The third group, marked in yellow, is defined by experiments and studies carried out on *F. albida*. The fourth group, in blue, is associated with ethnobotanical studies showing local perceptions of the factors causing F. albida dieback. The fifth cluster marked in sky blue is associated with natural factors such as natural deaths (Chablis) and natural pruning, causing the dieback of *F. albida* tree species.

How do traditional agricultural practices affect the vulnerability of *Faidherbia albida* to climate change?

Traditional agricultural practices such as intensive grazing, excessive pruning and changes in land use can significantly reduce the resilience of *Faidherbia albida* to climatic stresses. For example, in the Sahel, intensive pruning to provide fodder during the dry season weakens the tree's ability to recover, making it more vulnerable to climatic variations such as prolonged drought. This situation is exacerbated in regions such as Burkina Faso, where studies have shown that despite legal protections, illegal pruning and cutting leads to rapid aging of tree populations and instability in their demographic structure [24]. In addition, slash-and-burn agriculture in northern Burkina Faso destroys surrounding vegetation, exacerbating the effects of drought and further weakening these trees [15]. These

practices disturb the soil around trees, limiting their access to water and nutrients and increasing their vulnerability to rising temperatures and changes in rainfall patterns. Growth factors such as recruitment and dry season, identified in the literature as critical to tree health, are directly affected by these agricultural practices [25]. Indeed, tree density and morphological traits such as diameter and height vary significantly across climatic zones, with lower density and less developed morphological traits in the arid Sahelian zones where these practices are most common [24].

What are the main biotic factors contributing to the decline of *Fabaceae species* in sub-Saharan Africa?

The decline of Fabaceae species, including *Faidherbia albida*, in sub-Saharan Africa is often associated with a combination of biotic factors such as insect infestation, pathogens, and competition with invasive species. For example, in the Sahel region, particularly in Niger, infestations of wood-boring insects such as wood borers cause significant damage to trees, particularly when they are already weakened by other factors such as drought or poor soil conditions [26]. These insects often take advantage of periods of water stress that weaken the natural resistance of trees to establish and multiply, accelerating the mortality of *Faidherbia albida* populations.
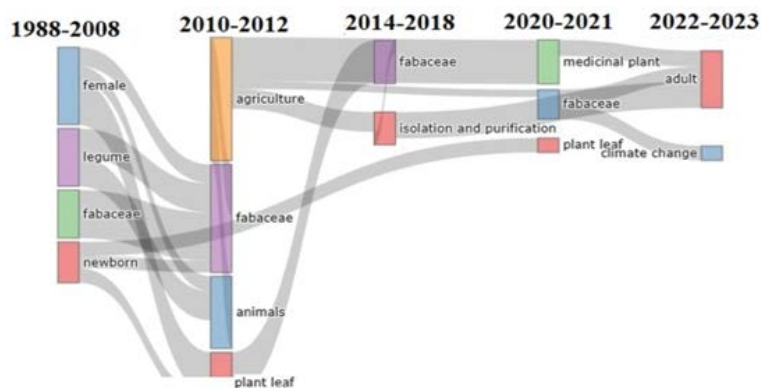

Figure 3: Evolution of the thematic map of keywords plus from 1988 to 2023.
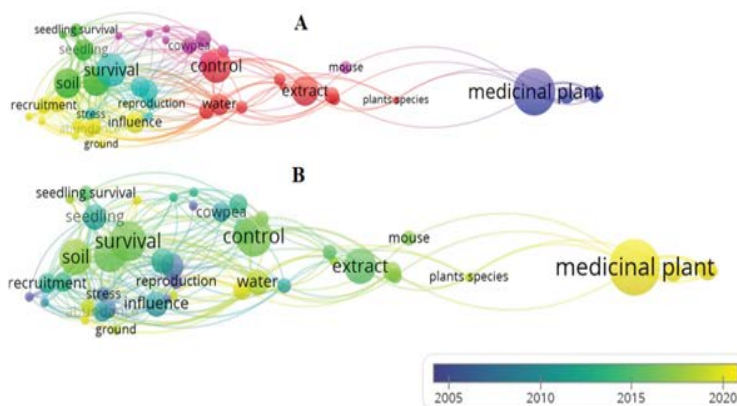

Figure 4: Cluster of factors studied in scientific publications (A) over time (B).

In Senegal, fungal infections spread more easily in weakened trees and have been identified as a major cause of increased tree mortality, contributing to the widespread decline of these species [27]. Disturbance by insects and human activities, such as resin or sap extraction for alcohol production, are also important factors exacerbating the decline of *Faidherbia albida* populations. These uncontrolled human activities damage the structure of the trees, making them more susceptible to parasitic attack, which is particularly critical for large-diameter trees, which are often most affected by defoliating caterpillars that feed on their leaves [26].

Thus, it is clear that the combination of biotic pressures and anthropogenic impacts play a critical role in the population dynamics of *Faidherbia albida* in sub-Saharan Africa, and that urgent action is needed to mitigate these factors and protect these species that are vital to local ecosystems.

How can integrative studies improve the understanding of *Faidherbia albida* dieback in different climatic zones?

Integrative studies that combine field research, modeling, and local knowledge are critical to understanding the complex interplay of factors that contribute to *Faidherbia albida* dieback. In Niger, for example, research integrating climatic data, field observations and local ecological knowledge has led to a better understanding of how variations in soil quality, rainfall patterns and human practices affect tree health in different climatic zones. These approaches enable the development of more effective conservation strategies that are adapted to local conditions. In addition, the integration of traditional ecological knowledge with scientific research provides insights into how these trees adapted to environmental change in the past, providing valuable guidance for their conservation in the face of modern challenges [7]. Ethnobotanical studies that highlight local perceptions of the factors that cause mortality enrich this understanding, while analyses of natural factors such as spontaneous mortality and natural pruning complete the picture by examining the intrinsic forces of the environment.

Knowledge gaps in *F. albida* dieback in sub-Saharan Africa

The *F. albida* dieback in sub-Saharan Africa is surrounded by a multitude of gray areas, highlighting significant gaps in our understanding of this complex phenomenon [1,6,23,28,29]. Seedling mortality is one such enigma, with causes such as diseases, pests and adverse environmental conditions still largely beyond our understanding. The potential consequences of this mortality on the sustainability of *F. albida* populations require in-depth exploration to better understand these underlying factors.

Excessive pruning is emerging as a key player in decline, threatening the stability of agricultural systems and food security. This practice raises concerns about its repercussions on the population dynamics of *F. albida*, thus justifying the need for in-depth studies to assess its real impact. Biotic factors, such as insect disturbance and human activities related to alcohol extraction, add additional complexity to understanding this decline, requiring in-depth analysis of the ecological dynamics at play.

Notable limitations in experiments and studies devoted to *F. albida* hinder the formulation of comprehensive solutions to understand and mitigate the factors contributing to their dieback. These research gaps highlight the pressing need for in-depth investigations to fill these knowledge gaps and develop more effective preservation strategies.

Ethnobotanical studies, so far neglected, could play a crucial role in providing local perspectives on the causes of *F. albida* decline. Further exploration of these perceptions can inform tailored management strategies, thereby promoting a holistic approach to the problem and better integration of local knowledge.

Finally, natural factors, such as spontaneous mortalities and natural pruning, add additional complexity to the understanding of *F. albida* dieback. The specific causes of these phenomena and the solutions to control them remain insufficiently studied, highlighting the crucial need for in-depth research to elucidate these natural mechanisms and develop more comprehensive conservation approaches.

Conclusion

The bibliometric analysis and systematic review highlight the urgency of an in-depth understanding of the causes of *F. albida* dieback to ensure the sustainability of agroforestry systems in sub-Saharan Africa. Identified research gaps on the causes of *F. albida* dieback, such as seedling mortality and biotic factors, call for increased attention and efforts to fill these knowledge gaps. It is imperative to develop management strategies based on solid evidence to preserve this crucial species and ensure food security in the region.

Declaration of competing interest

The authors declare no conflict of interest.

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