Article

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Exploring the Global Perspectives on Forest Wildfire Protection and Biodiversity Conservation Strategies

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Abstract: One of the primary focal points is the critical evaluation of the role that prescribed burning plays in temperate and boreal forests. The significance of understanding the intricate interplay between human intervention and natural processes in these ecosystems. While non-intervention strategies are often heralded as the optimal approach for preserving biodiversity, it is crucial to recognize the pivotal role that wildfires, both naturally occurring and prescribed, play in shaping and maintaining the robustness of forest ecosystems. This study a scoping review aims to explore in-depth the intricate and multifaceted relationship between forest wildfire protection and biodiversity conservation strategies, delving into the complexities and nuances that exist within this crucial field. This comprehensive examination draws insights of recent scholarly contributions, encompassing a diverse range of perspectives and methodologies to provide a holistic understanding. Relationship between forest wildfire management and biodiversity conservation, highlighting the necessity for adaptive strategies that incorporate both scientific insights and traditional ecological knowledge. In conclusion, the literature collectively underscores the critical need for re-evaluating current fire management practices to enhance biodiversity outcomes in the climate crisis. The integration of scientific insights with Indigenous fire stewardship presents a promising pathway for fostering resilient forest ecosystems and promoting biodiversity conservation.

Keywords: biodiversity conservation; ecological restoration; forest wildfire; global strategies; climate crisis

1. Introduction

Wildfire is an ancient and natural process that shapes the structure and function of nearly every ecosystem on Earth[1]. It plays a crucial role in maintaining ecosystem health and promoting biodiversity, in recent years, there have been significant changes in land use patterns, coupled with the effects of climate change such as increasing drought and temperatures[2]. These changes are leading to a dramatic increase in the frequency and intensity of wildfires, pushing them to unprecedented levels[3]. The impacts of these larger and more severe wildfires are being felt across the globe, all ecosystems are experiencing a rise in the occurrence of uncontrollable fires, posing challenges to indigenous communities, fire management groups, and land managers[4,5]. As a result, there is a growing need to balance the conservation of biodiversity with the protection of human assets from wildfires[6]. Understanding the intricate interactions between fire management strategies and the conservation of biodiversity is of utmost importance, the efforts are being made by national

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and global communities to develop a new approach to fire management that takes into account the preservation of native species and their habitats[7].

This includes incorporating traditional knowledge and practices from Indigenous people, who have long possessed valuable insights into sustainable fire management, and native species conservation, we can work towards ensuring the long-term health and resilience of our ecosystems[8]. This involves implementing active fire management techniques, such as controlled burns, which can help reduce the risk of uncontrolled wildfires it is crucial to protect and conserve the biota in managed flammable systems, safeguarding not only the biodiversity but also the cultural heritage tied to these ecosystems[2,4,9]. As we navigate the challenges posed by changing landscapes and a warming climate, it is critical to prioritize the preservation of our natural heritage, efforts between diverse stakeholders, including indigenous communities, fire management groups, and land managers, will be essential in finding sustainable solutions[9,10].

Through shared knowledge and innovative approaches, we can better safeguard our ecosystems, mitigating the devastating impacts of wildfires while nurturing the delicate balance between human needs and the natural world[5,10]. To mitigate the impacts on biodiversity, environmental leaders should consider implementing a variety of burning options to address the challenges posed by unplanned ignitions in a changing climate[19,20]. There is a growing concern in scientific literature and the media about the rise in forest wildfires. In the past, local communities have recognized the importance of controlling these fires and have implemented various strategies to do so[21].

With industrialization, forest management began to view fire as a hazard and restricted human intervention, the devastating effects of wildfires on society led to a reevaluation of this approach and a more flexible societal approach to fire management was adopted, allowing some fires to burn for community safety[22,23]. Most recent forest fires are believed to be a result of human activities, such as campfires, discarded cigarettes, burning of plants, and use of fire for hunting, military activities, and farming[23].

Fragmentation and simplification of wild forest ecosystems have made them more susceptible to fire, along with the reduction of biodiversity[24]. Wild land species tend to suffer reduced yield losses, highlighting the pivotal role of biodiversity in ecosystem stability, due to the increasing occurrence and intensity of forest fires globally, new strategic approaches are needed to minimize damages and conserve biodiversity[25]. Climate change, climate variability, and the increasing vulnerability of urban interfaces have made forest fires a pressing global problem, and it is essential to integrate wildfire risk reduction goals into policies, plans, and activities of various stakeholders, including agricultural and forest land management agencies, private contractors, and residents in wildland-urban interfaces[26,27].

Collaboration among these stakeholders and agencies is crucial for successful forest fire management[28]. Globalization has also increased the risk of expanding forest wildfires, as warned in scientific literature[29,30]. This study is a scoping review of the global adoption of joint fire and biodiversity strategies and collected examples from different regions. This review emphasized the urgent need for countries to allocate their fire management resources more effectively to reduce the risk of major wildfires and their consequences. The study aims to show that rapid response and suppression strategies are not suitable for managing wildfires at a landscape scale, and the increasing demands of fires are consuming significant resources, impacting both nature conservation and economic potential. The scope of this study is to improve the importance of Cost-effective approaches such as fuel reduction management prioritized over extensive resources for full preparedness programs, and traditional joint fire and biodiversity strategies should be incorporated into prevention efforts to reduce severe wildfires.

2. Materials and Methods

2.1. Methodology

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The focus of this scoping review is to synthesize current research regarding how forest wildfires are managed to protect biodiversit. In particular, the scoping review will focus on wildfires that occur in forests, scrublands, marquis, and other wild land areas, including peat lands and savannah, since these comprise the majority of wildfires. Although recognized as an important phenomenon, the review will not cover house and industrial fires. Wildfires can be started or exacerbated by both human and natural sources. The review is not limited to specific conservation strategies, and the objectives are focused on how wildfires themselves can be used as conservation tools, which also have the potential to drive negative impacts on biodiversity.

The aim of the review is to 'map' the current evidence and to present overviews of the current evidence to identify gaps in the literature and the future research's needs. This scoping review of the literature included a thorough and relevant investigation of past research available through electronic databases, including publications and studies from international scientific organizations. An assortment of databases and resources from WHO, UNDP, Copernicus, NACo/EDGE, NASA, and also collect the Global included Local Governments Gazettes, Regulations, Documents, International reports, and data, including articles, and papers from, EBSCO, EMBASE, CINAHL, Scopus, Science Direct, Web of Science, and Google Scholar. The design of the study is a scoping review of the literature using a variety of analysis techniques included in the mixed methods review.

2.2. Materials and Technique:

The following requirements must be met:

1) Every study must have been published in a peer-reviewed journal.
2) All of the included studies, and reports were written in English.
3) All of the examined studies included sample studies of the Methodology in Global Perspectives on Forest Wildfire Protection and Biodiversity Conservation Strategies

The Inclusion criteria for the scoping review study:

i) The included studies, and reports evaluated the measures reported for environmental, Forest Wildfire Protection and Biodiversity Conservation Strategies, and Ecosystems Climate Crisis aspects.
ii) The included articles, report, proceedings, and conference papers evaluated aspects of Forest Wildfire, Biodiversity Strategies, and their effects.
iii) All the keywords of the title study's, research on the literature.

The exclusion criteria for the scoping review study:

i) English is the only language used in the study.
ii) Studies using a sample of Forest Wildfire and other Kind of Fires were excluded.
ii) All authors participated equally in all stages and steps of the study.

The histogram at Figure 1 shows the frequency and the number of database studies and reports that were used. Figure 2 shows the PRISMA guidelines [31], and a flow chart diagram, which incorporates all of the proceeding papers, Local government gazettes, regulations articles, reviews, and reports included in this study's literature.

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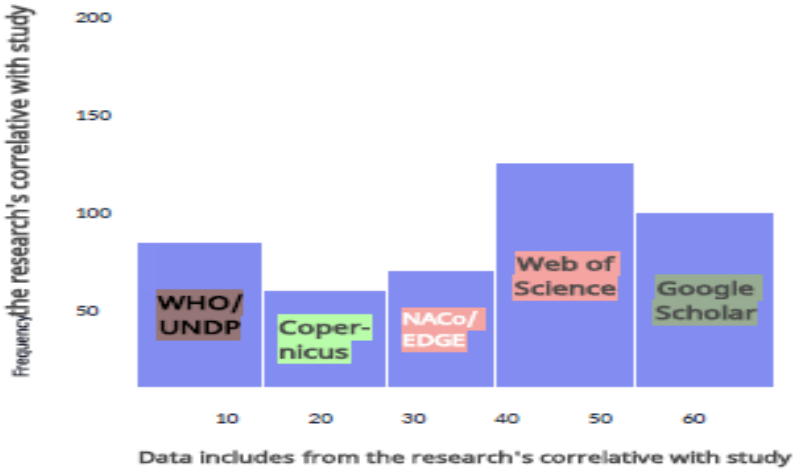

Figure 1. The histogram of the frequency and the number of database studies and reports that were used.

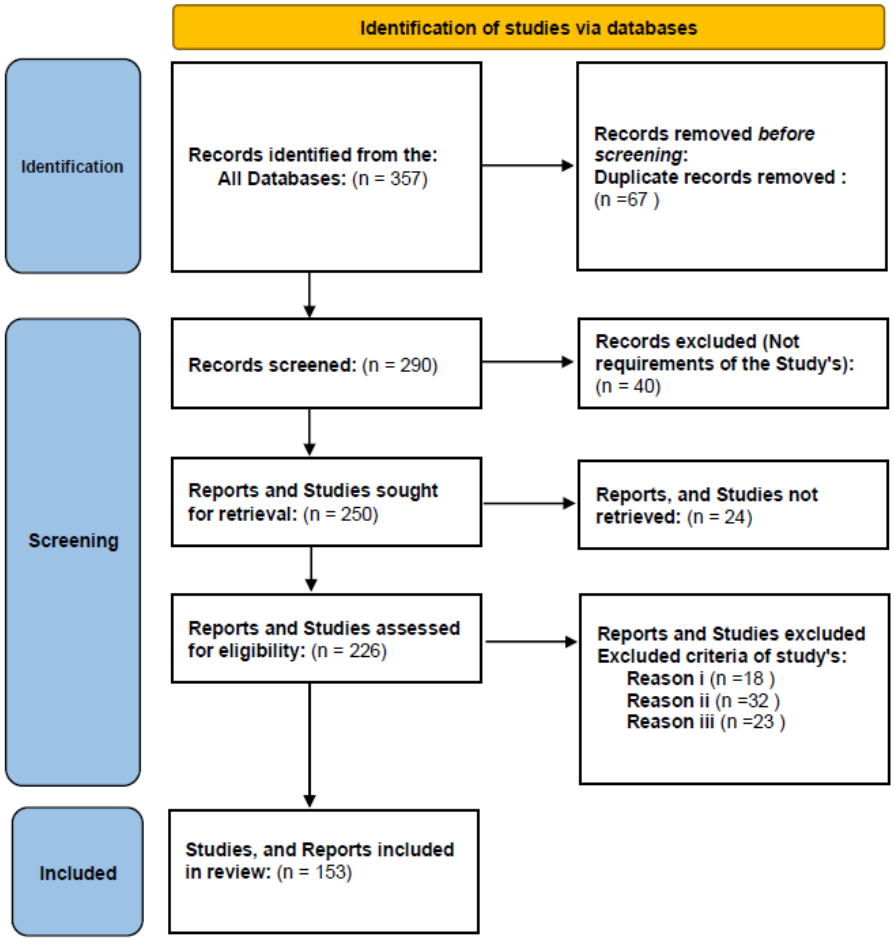

Figure 2. The flow chart of the study's PRISMA.

3. Results

3.1. Diversity Wildfire Forest Analyzing Data

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This study estimated biodiversity in forest fire-prone sites and natural forests, analyzing data for species response and calculating the Importance Value Index (IVI). Herb data was also analyzed for frequency and dominance. The Shannon-Wiener diversity index used mathematical calculations measures [32]. The following mathematical formula is used to calculate the diversity index by the following formula:

$$H = -\Sigma^{s}_{i=1} \; PilnPi$$

When **(H)** is the diversity of species, **(S)** is the number of species, and **(Pi)** is the fraction of individuals in the whole sample who belong to the **(i)** species. This index considers both the quantity and the relative abundance of species.

The Climate Crisis and extreme weather events are predicted to become more common in the future, raising the possibility of unprecedented climatic extremes or record-breaking catastrophes. Extreme heat waves and droughts have a significant impact on ecosystem stability and carbon cycling because they cause increased plant mortality and delay ecosystem recovery[33]. Figure 3 shows the exploring the impacts of unprecedented climate extremes on forest ecosystems.

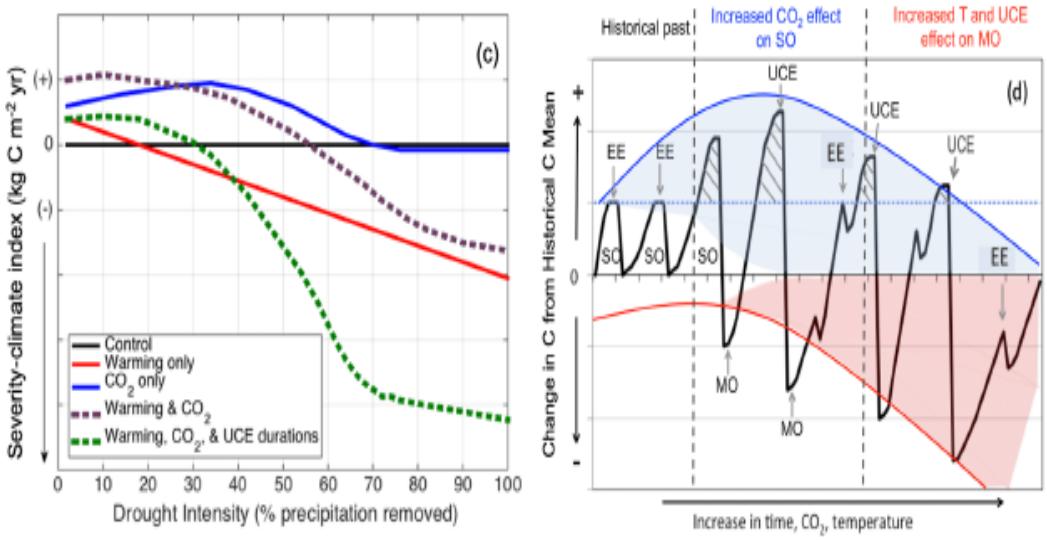

Figure 3. Exploring the impacts of unprecedented climate extremes on forest ecosystems[33].

3.2. Understanding Forest Wildfires

Wildfires are influenced by ecological, climatic, institutional, and socio-economic factors, resulting in varying perspectives on the subject[34–38]. Biodiversity encompasses the breadth of life forms on Earth, including plants, animals, microorganisms, their genetic composition, and the ecosystems they form[2,39]. The study's approach considers ecological, social, and economic perspectives to define biodiversity and evaluate the management of natural ecosystems for preserving biodiversity[40]. Throughout the review, we assess the strengths and limitations of the research[40,41]. Despite a scarcity of published material on forests, wildfires, and conservation, we aim to offer a comprehensive overview of wildfires and their management in relation to biodiversity[42].

Forest wildfires are an important ecological process that permanently shape plant communities that require fire for seed germination and sapling growth, the link between land use and climatic change is accentuating the intensity and frequency of forest fires[43,44]. Some of the main factors inducing or contributing to the ignition of forest fires include accidents resulting from lightning on rainy days, debris burning, barbecues, car crashes, power lines, arson, hyperthermias, military activities, rallies, sabotage, and fireworks[45,46]. Wildfires have immediate and long-term effects on ecosystem health, they are also relevant for the conservation of biodiversity, the primary effects of wildfire on the environment include the combustion of biomass[9]. Changes in weather, release of

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carbon and nutrient matter to the atmosphere, impacts on local climate, irreversible destruction of soil seed and spore banks, and effects on water quality and quantity[34,47]. Wildfires cause changes in the ecosystem structure and function, transformations in the landscape configuration, and fragmentation, hence altering the ecosystem dynamics and the environmental services land provides to humans[8,47]. Besides ecological effects, the health and economies of forest-dependent people are also affected[17,49]. Wild land fires, indicating that fires are actual examples of social-ecological systems and human-environmental systems, management strategy and social response, along with the efforts of public fire services and science, also involve aspects of ethics and culture, the general behavioural pattern of wildfire is inherently unpredictable, and its complexity is tightly linked to several factors and their interactions[50,51]. Figure 4 shows the study's correlations and association of the social-ecological systems risk factors.

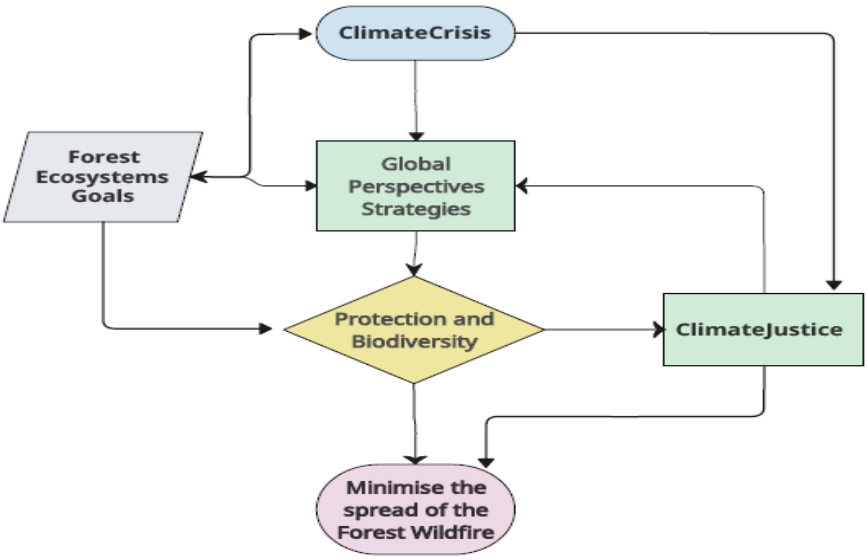

Figure 4. Study's correlations and association of the social-ecological systems risk factors.

3.3. Causes and Impacts

Nature may extend the wildfire period with relatively strong winds, one of those factors combines with severe drought conditions, the forest may burn so violently that not all seeding has a chance to replicate[52–54]. Consequently, the area could be directly colonized by pioneers, enhancing the useful diversity resulting from greater genetic drift[55,56]. Human-related activities also cause wildfires, changes in the use of natural resources or land use and neglect may promote fires in particular habitats, facilitating fire distribution and boosting fire intensity[57–59]. Wildfires have a significant impact on ecosystems, especially when it comes to altering or destroying habitats[1,60]. This poses a serious threat to biodiversity, small-scale fires can be beneficial in some healthy ecosystems, they are generally not enough to support species that depend on fire[44,61].

The increased fragmentation and loss of habitat that result from wildfires often lead to further reduction of species[2,46,62]. The changes to the landscape caused by fires can also impact the distribution of species and vegetation, leading to shifts in population sizes and displacement of certain species[5,63]. The extent and quality of areas affected by fires can also influence the composition of plant species in an area, with some plants being unable to recover from the damage caused by the fires can even lead to the complete loss of entire plant populations, resulting in the elimination of species[64].

3.4. Current Challenges

The current management of wildfires is insufficient and ill-prepared to address the challenges of the future in order to effectively preserve ecosystem services and safeguard people and human-made values[65]. Climate Change factors, such as higher average temperatures, heat waves, induced

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drought, increased frost, and thaw incidents, heightened evapotranspiration, alterations in precipitation and runoff patterns in both mountainous and flat regions[45,61]. Significantly contribute to the frequency of wildfires and the severe impacts they can have on ecosystems[66]. Forestry, integrated risk, and watershed management play a crucial role in reducing the frequency and intensity of wildfires, as well as their vulnerability and effects on ecosystems[67]. Unfortunately, current wildfire management does not receive adequate attention from decision-makers at the national policy level, in legislation, or from the scientific research community compared to other major natural disasters like flooding and earthquakes[68]. There are known effective methods for preventing wildfires, including accurate ignition predictions and lightning alert networks, reducing fine fuel near residences and settlements, and implementing controlled prescribed burning with the involvement of local communities and volunteers[54,69]. The challenge is to prevent communities from burning and to facilitate safer burning practices, considering factors such as temperature, wind direction, and smoke dispersion speed[69,70]. Restructuring and refining future fire and health strategies to adopt a multi-risk-based management approach, which integrates socio-economic and environmental trade-offs, would help enhance the resilience of human well-being, society, and ecosystems for better protection of biodiversity[20,71].

3.5. Biodiversity Conservation in Forest Ecosystems

Understanding previous research on biodiversity in natural forest ecosystems is necessary to develop appropriate and up-to-date forest management strategies, from intrinsic and moral arguments to conservation and management of lands, biodiversity actually plays a fundamental role in forest ecosystems[72]. Biodiversity is crucial for the functioning, health, and resilience of ecosystems it contributes significantly to ecosystem productivity, stability, and sustainability, its effects on ecosystem services are both direct[69]. Indirect, and it influences territorial dynamics, the potential for forest certification, and the tourism and recreation associated with the exploitation and consumption of forest products[73,74. Preserving biodiversity means firstly setting up appropriate indicators to measure its status in the ecosystem in order to propose appropriate strategies for biodiversity conservation functions and services[75]. Three metrics facilitate the quantification of different types of biological diversity in order to draw up more exhaustive biodiversity assessments, genetic diversity is vital for the ability of local populations to adapt to changes in the environment[76]. Factors, both historical and contemporary, can negatively impact the genetic resilience of tree populations, so it's important for forest management practices to prioritize the conservation of genetic diversity[77]. Crucial for effectively managing forests for genetic conservation, and the vulnerability of tree species and other life forms impact ecosystems, which in turn affects agricultural operations[78]. Cork oak forests, it's important to assess various biodiversity characteristics and indicators, such as tree age, density, and the quality of soil microorganisms[75,79]. In Mediterranean ecosystems that have been influenced by human activity, the diversity of the dominant tree species provides important ecosystem services[76,80]. A more diversified ecosystem and landscape can enhance resilience and facilitate recovery after a fire, tools that serve multiple functions, as this will contribute to the resilience of agricultural economy, investments should be supported by policy actions and should be valued by society[77,81].

3.6. Importance of Biodiversity, and Existing Wildfire Protection

Biodiversity is a key factor in the development of healthy and adaptable forest ecosystems. Ecosystem resilience can be seen in the context of maintaining biodiversity, the diverse species composition of forests can function as an ecosystem with a high adaptive capability through different environmental conditions[82,83]. The functions of diverse forest ecosystems are also visible in the various chains of living things from one place, both in the ground, in the trees, and in interaction with animals and humans[84,85]. These various unspoiled series of species can provide natural services to human life, such as soil fertility[86], good water infiltration for available clean groundwater, vegetation for stabilizing soil and reducing land and mudslides[87], water buffers, and biodiversity reservoirs, as well as being a store of biological diversity[87–91]. The Figure 5 shows holistic

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hypothesis of studies correlations and assessments of the exploring the Global perspectives on Forest wildfire protection and Biodiversity conservation strategies.

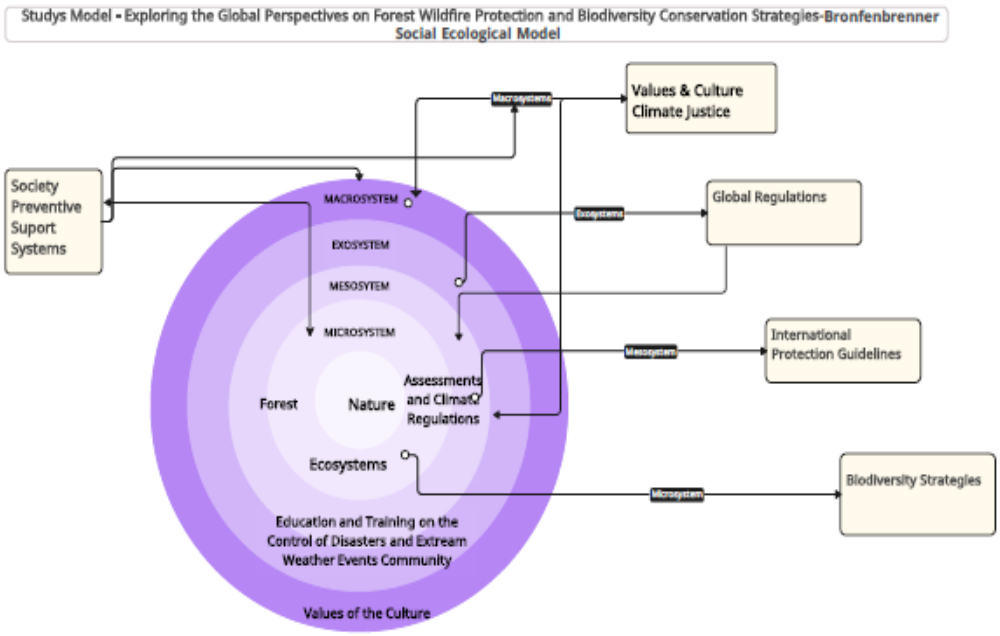

Figure 5. Hypothesis of studies correlations and assessments.

4. Discussion

From the importance of combining local and international policies for better management strategies to the challenges of doing so discuss how wildfire prevention policies can impact biodiversity based on real-life experiences in different areas and how this ties into global policy[92–106]. The local communities have limited influence on forestry practices, while others stress the importance of involving professionals like fire departments, NGOs, and private individuals[94,107,108]. Cooperation between local and professional fire departments, along with a community-wide approach, is highlighted in some studies[109], while others emphasize the need for effective communication and knowledge sharing between residents[110], politicians, and land managers for better wildfire protection[93,111]. Address public concerns about prescribed fires[95,112], emphasizing the importance of education, understanding, and engaging with the public, and the communities[113,114]. Local to global policy and legal frameworks in various parts of the world, must continue to support the full integration of wildfire protection and professional fire departments into biodiversity conservation planning, policy, and practice[96,115]. Majority of policy frameworks[10], evidence of their practical application, focus predominantly on either fire prevention, suppression[14,97], and hazard reduction by professionals or on biodiversity conservation through reducing fire frequency, inroads[6,98], or area, usually in unison with reducing other drivers of unsuitable disturbance[45,99,100]. Consequently, while these policies and legal frameworks, including their subsequent legislation[101,102,116], influence and may support the use of many different non-industrial land management practices to achieve various goals of biodiversity conservation by promoting, for example[103,117], traditional management, recycling, and grazing, wildfire protection practiced at local or land management levels is not specifically designed to support the creation of strong co-benefits, outcomes, and indicators that meet both sets of goals[104,116,118. However, such joint-focused outcomes and indicators linking wildfire protection to biodiversity conservation have been developed at different spatial levels, in other policy frameworks, and in formal conservation agreements[105,106,119]. Studies that evaluated practices reported that active fire management intervention is currently non-existent or[120], at best, poorly developed in terms of its wider use in contributing to sustained biodiversity conservation of threatened fire-dependent species[121–124]. Wild land fire science, clear results improve the way

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conservation and sustainable use are planned on the landscape[125,126]. Community led initiatives are especially important in Africa[127], as in these countries a prevalence of subsistence agriculture exists[128,129]. In Canada, a well-coordinated plan involving academic institutions, government partners[130,131], and stakeholders was put into action at three different sites to showcase a variety of forest ownership[132], wild land-urban interface status, forest management history, cultural uses, socio-economic values, and ecological features[133]. This initiative, led by natural resources communities in partnership with a small team of professionals, continues to show progress through its integrated approach[134]. In the small forested communities of Shuswap and Cranbrook, British Columbia, both a significant hazard reduction event and a field session with fire managers[135], natural resource professionals, community members, and the public have highlighted successful collaborative conservation efforts in the Columbia Basin landscape and the Kootenay Rocky Mountain Trench[136,137]. A comprehensive report assessing the results and potential of adaptive management has also been finalized, leading to a new vision, values for change, and commitments in Perspectives on Forest Wildfire Protection and Biodiversity[138–141]. Public health inspections and medical supplies play a critical role in preventing and support staffs providing healthcare services, wildfires and embracing perspectives on climate and ecosystems protection and biodiversity conservation strategies[142–148]. All facilities and educational institutes provide in-depth training on physical disasters and extreme weather events, as well as promoting and protecting public health, particularly during the Pandemic COVID-19 minimized the phenomenon, and increase on the Climate Crisis [2,87,149–153].

5. Conclusions

This study outlines the scale, approach, and details of what researchers are studying and where the knowledge and practice gaps may lie unnoticed. Emerging research in various countries held voice in this review and indicated a potential need for integrative research approaches. To enable advancement in this field, emphasis entails four major avenues. First, we need to improve understanding of the socio-cultural, economic, and ethical aspects within conservation and contiguous fields. Second, opportunities exist to address the widely unexplored entry points of tourism, sacred natural sites, pollution, and indigenous and locally adapted fire regimes. Thirdly, community-engaged and co-created research strategies may foster tolerance, wise adaptation, increase understanding, and positive management behaviors among land managers and the broader public. Finally, fourth, to enable regional scale or larger trends, need to foster research that utilizes landscape-scale and whole-of-jurisdiction approaches. While extensive and all providing relevant guidance, all literature search of this study individually highlights that this is never something that can be maintained or controlled for an extended period—fire is a formidable force with variability in a changing world, during the emergency environmental age of Climate Crisis. This study offered positive insights to some of the extraordinary nuanced field forward. The review returns a concerning yet hopeful message about the state of research today. Increasing global interdisciplinary research on biodiversity conservation in forest wildfire landscapes that are complex and multi-learning generations is essential and urgent. Until this is focused on increased, the way forward is uncertain and carries potential dangers, provided a systematic map of scientific and academic articles relevant to researchers, planners, and policymakers in the field of wildfire protection and biodiversity conservation.

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