Wildfire Management Strategies and Ecosystem Resilience in Ghana's Savannah Ecological Zone Amidst Climate Change: A Systematic Review of Literature

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Abstract:- Understanding the interplay between wildfire management strategies and ecosystem resilience is crucial in the context of climate change, especially in vulnerable regions like Ghana's savannah ecological zone. This systematic literature review aims to synthesize the existing body of work on wildfire management strategies, assess the state of ecosystem resilience, and explore the impact of climate change on these dynamics within the savannah ecological zones of Ghana. A comprehensive search yielded 371 studies from Google Scholar, Scopus, and other indexed journals, of which 54 were selected for in-depth analysis. The review identifies three main categories of wildfire management strategies: community-based efforts, policy and regulatory frameworks, and technology interventions. A significant observation is the distinction often made between natural and human-induced fires, which oversimplifies the complex nature of wildfires and underscores the need for a more integrated approach to wildfire management and ecosystem resilience. This study highlights critical gaps and challenges in current strategies, offering a foundation for further research aimed at enhancing wildfire management and ecosystem resilience in the savannah ecological zone of Ghana.

Keywords:- Wildfire Management, Ecosystem Resilience, Savannah, Climate Change, Ghana.

I. INTRODUCTION

Wildfires pose a multifaceted threat to ecosystems and human communities. In the savannah ecological zones, this threat indicates the delicate balance between human activities and environmental dynamics, a balance increasingly disrupted by climate change (Dahan, Kasei, Husseini, et al., 2023). With its various ecological zones (forest, transition areas, and savannahs), Ghana faces significant challenges in managing the impacts of fires (Sackey & Hale, 2008). The FAO's 2010 assessment indicates Ghana has one of the highest rates of vegetation loss due to wildfires. Additionally, a previous FAO report in 2001 pointed out that the savannahs of the West African sub-region are mainly susceptible to wildfires, exacerbated by dramatic climatic shifts.

The World Health Organization in 2021 characterized wildfires as unintentional burns that destroy natural areas like meadows and forests. These fires have historically sustained savannah vegetation, influencing ecosystem structure and composition over millions of years. Despite their natural role, the scientific community predominantly perceives fires as detrimental to ecology integrity, sparking considerable interest in their study (Valea Francoise &Ballouche Aziz, 2012). Several factors, including land-use changes, human activity, and climate change, have intensified wildfire frequency and severity (Dahan & Kasei, 2022). Most fires in the savannah ecological zones are anthropogenic, ignited by pastoralists to promote regrowth or near settlements in natural parks to mitigate large-scale fires and reduce total burned areas (Dwomoh et al., 2019).

Fire management strategies have evolved over the years, with significant shifts observed in protected areas (Pereira et al., 2012; Government Republic of Namibia, 2016). Yet, a comprehensive understanding of the efficacy, challenges, and prospects of wildfire prevention, mitigation, and management strategies in Ghana's savannah remains elusive. These strategies include community-based fire management, public awareness campaigns, research and monitoring, and early warning systems (Anane A P & Antwi-Agyei P, 2021). A critical examination of wildlife strategies and ecosystem resilience in this context is imperative for sustainable environmental management.

Ghana's 2020 Nationally Determined Contributions (NDC) report identifies the country —and particularly its savannah ecological zone—as highly vulnerable. Despite growing research interest, the nexus of climate change, wildfire management strategies and ecosystem resilience in

Ghana's savannah ecological zones presents a mosaic of insight into empirical studies and policy considerations. This gap underscores the need for a detailed literature review. The current systematic literature review seeks to synthesize and critically analyze the existing body of knowledge, providing a comprehensive insight into wildfire strategies and their implication on ecosystem resilience in Ghana's savannah. By assessing the historical context of wildfires, identifying management strategies, and examining ecosystem adaptive capabilities and resilience against climate change, this review elucidates the intricate relationship between wildfires, climate change, and ecosystem resilience in Ghana's Savannah ecological zone.

II.   MATERIALS AND METHODS

A. Design

The methodology for this systematic literature review on wildfire strategies and ecosystem resilience in the savannah ecological zones was structured around the Preferred Reporting Items of Systematic Reviews and Meta-analysis (P.R.I.S.M.A.). This guideline was used by several authors such as (da Veiga & Nikolakis, 2022) to help in documenting the number of studies identified, screened, and included in their reviews, as well as the reasons for exclusions at each stage. A comprehensive search strategy was employed across multiple electronic databases and specialized journals focusing on wildfires and ecosystem resilience. The search utilized Keywords relevant to the review's topic without imposing restrictions on the publication date to include historical literature. This approach was broadened to encompass studies on savannah ecosystems in Ghana and other West African sub-regions, showcasing the diversity of strategies across different savannah ecosystems. The review was limited to peer-reviewed publications. The inclusion and exclusion criteria were meticulously applied to ensure only relevant studies were considered for analysis.

B. Review Question

This systematic literature review is guided by the following questions to encapsulate the current understanding of wildfire strategies and ecosystem resilience in Ghana's savannah ecological zones in the context of climate change.

- What are the existing wildfire strategies implemented in Ghana's savannah ecological zone?
- How does climate change impact wildfires in the Savannah ecological zones?
- What is the current state of ecosystem resilience in response to wildfires in Ghana's savannah ecological zone?
- What wildfire legislations and policies exist in Ghana's savannah ecological zone?

C. Inclusions and Exclusion Criteria:

The review focused on studies specifically related to wildfire strategies, ecosystem resilience, climate change impacts, and wildfire policies and legislations within the geographical scope of Ghana's savannah ecological zone, extending to the West African savannah and broader African contexts. Consideration was also given to literature from other parts of the world to illustrate strategies used in various savannah ecosystems. The search included only peer-reviewed publications, policy documents, and legislative texts. A preference was given to open-access publications directly related to the review's thematic areas. Exclusions were made for studies outside the specified geographical scope, those not relevant to wildfire strategies and ecosystem resilience, and paid publications. Figure 1 shows articles that were reviewed over the period based on the inclusion and exclusion criteria. The application of these inclusion and exclusion criteria ensured the review's focus remained on pertinent and accessible scholarly work.
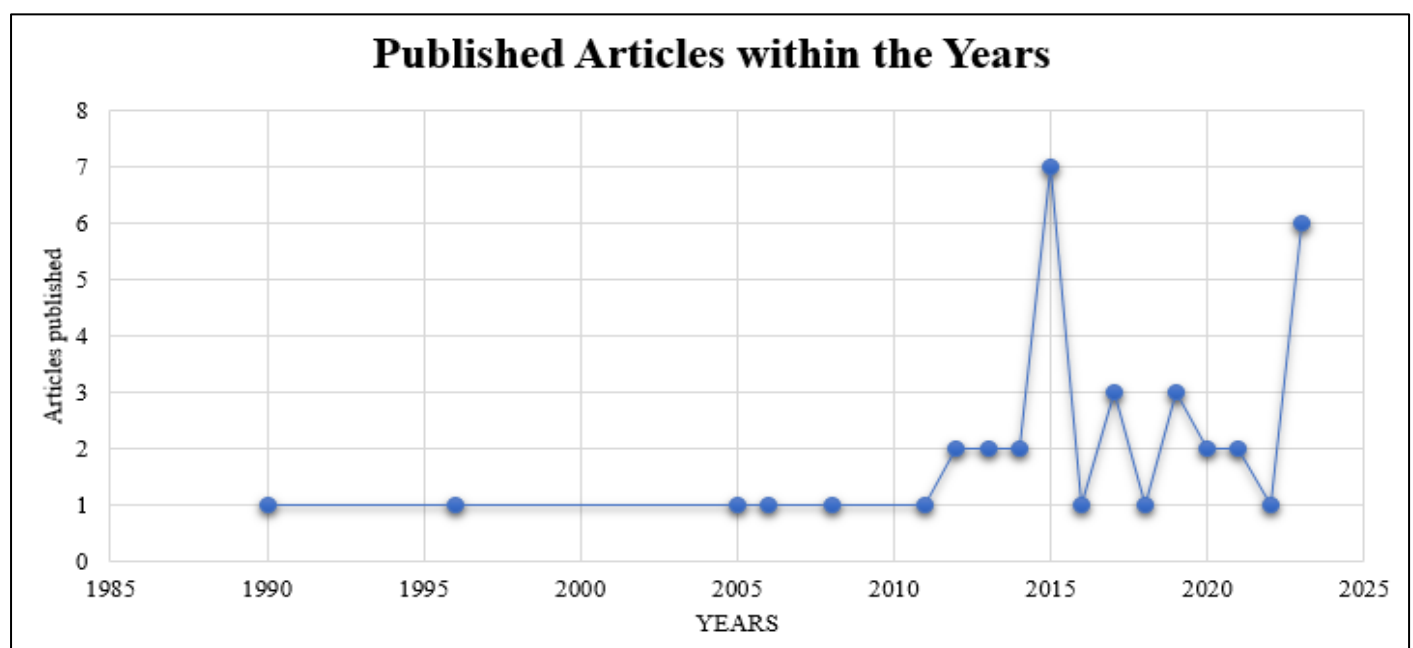

Fig 1: Peer-Reviewed Articles Over the Years that Met the Inclusion and Exclusion Criteria

D. Data Collections

Multiple databases were searched for comprehensive coverage of literature on the subject. Literature was collected from various databases and search engines as evidence included in the review. Database and search engines that were searched in the review include:

Table 1: Databases and Search Engines Searched

Database and Search Engine	Link
UDSspace University for development studies online database	http://udsspace.uds.edu.gh/bitstream
K.N.U.S.T. Space Kwame Nkrumah University of Science and Technology online database	https://ir.knust.edu.gh/home
U.G. Space, university of Ghana online database	https://ugspace.ug.edu.gh/bitstream
U.C.C. Institutional Repository, University of Cape Coast	https://ir.ucc.edu.gh/
Google Scholar	(https://scholar.google.com/
African journals online	https://www.ajol.info/index.php/ajol
Scopus	Scopus preview - Scopus - Welcome to Scopus
International Journal of Wildland Fire	https://www.iawfonline.org/international-journal-wildland-fire-ijwf/

III. RESULTS

A. Selection of Studies

A total of 371 articles, publications, policies, and regulations were initially identified. Out of these, 286 articles and publications were excluded based on several criteria: irrelevance to wildfire strategy (e.g., focusing instead on fire disaster management strategy), lack of relation to the savannah ecological zone, non-relevance to ecosystem resilience or climate change, and inability to access the full-text due to paywalls. This rigorous assessment process ensured that only the most relevant and accessible materials were included in the review. The extracted information was then carefully analyzed, and the findings were presented clearly and comprehensively to ensure transparency and adherence to recognized academic and research standards.
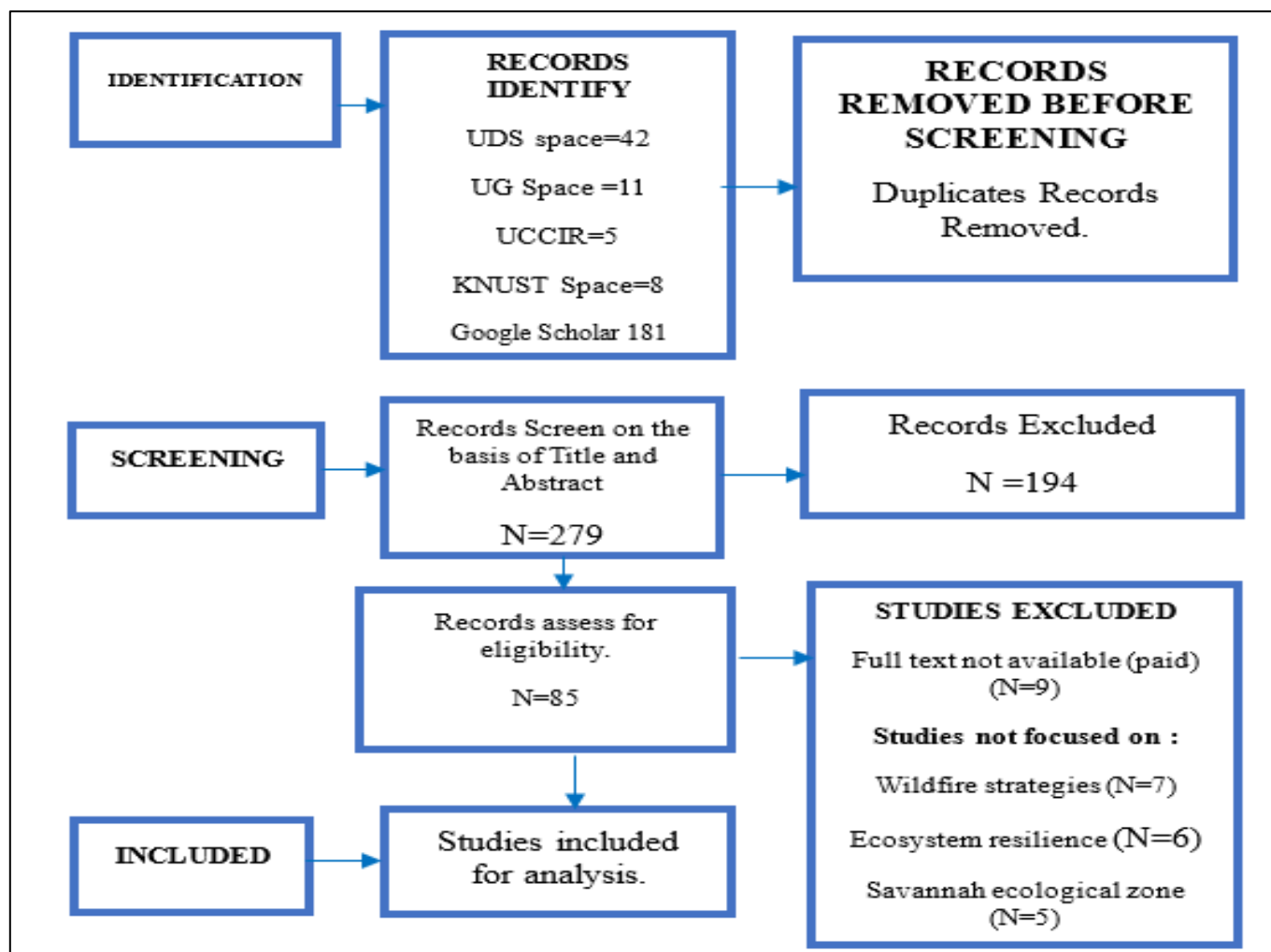

Fig 2: Literature Database Building, Articles Selection and Categorization Adopted

B. The Impact of Climate Change on Ghana's Savannah Ecological Zones: Implications for Wildfires and Ecosystem Resilience.

Globally, the impacts of climate change are particularly pronounced in vulnerable developing nations, with Ghana experiencing rising temperatures, declining rainfall, increased variability, rising sea levels, and more frequent extreme weather events and disasters (Minia Z, 2004). The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as "a change of climate attributed directly or indirectly to human activities that alter the composition of the global atmosphere, in addition to the natural climate variability observed over comparable periods" (UNFCC, 2011). In Ghana, vulnerability to climate change encompasses exposure to floods, droughts, sea erosion, and temperature increases, affecting people, environments, and sectors differently based on their vulnerability levels.

In the savannah ecological zone, extreme weather events like flooding, high temperatures, and shifts in rainfall patterns pose significant challenges. The increase in temperatures, reduced humidity, and extended dry periods increase the risk of wildfires. Dry vegetation becomes highly flammable, and fires can spread rapidly once ignited. The Savannah ecological zones, with their vast expanses of grasslands and scattered trees, are particularly prone to rapid wildfire spread. Human activities, including land clearance and slash-and-burn agriculture, significantly contribute to the risk of uncontrolled fires. Furthermore, deforestation for agricultural expansion alters the landscape, increasing fire risks (Amogu et al., 2010). The interplay of climate change and wildfires threatens biodiversity due to habitat loss and fragmentation, affecting the survival of various species (Awuni et al., 2023). Changes in climate conditions also impact vegetation composition and health, causing shifts in vegetation dynamics and affecting ecosystem resilience (Laris et al., 2015).

Climate change significantly affects human livelihoods. Changes in precipitation patterns and increased temperatures affect crop suitability, while unpredictable weather disrupts traditional farming practices, impacting food security (Adiku et al., 2015). These disruptions, along with food shortages and increased vulnerability to climate change impacts, increase community vulnerability. Previously, efforts to minimize climate change impacts were reactionary. However, the importance of proactive adaptations and mitigation strategies is now recognized. Government policies focusing on deforestation curtailment, sustainable agriculture, and climate resilience integration into development planning are crucial for enhancing ecosystem resilience.

C. Wildfire Management and Prevention Strategies in Ghana's Savannah Ecological Zone

The severe drought from 1982 to 1983 caused substantial destruction to forests and land in Ghana, leading to an annual income loss of $24 million and a cumulative GDP decrease of nearly 3%, significantly affecting local people and their ecosystems (Mensah et al., 2015). This crisis prompted the establishment of environmental and forest resource management laws aimed at wildfire management. The Savannah Woodland Policy of 1934 was established to promote fire management and discourage the burning of farmlands and grasslands. Following this, in 1983, the Ghanaian government introduced PNDCL Law 46, which prohibited the initiation of fires for specified purposes such as forestry, game management, or agriculture. Additional legislative efforts including the formation of the National Bush-fire Committee, National Environmental Action Plan, Bushfire Prevention and Control Act, Forestry and Wildlife Policy, the Ghana National Fire Service Act and the Ghana National Climate Change Adaptation Strategy were established to address environmental issues and bolster government efforts in bushfire management.
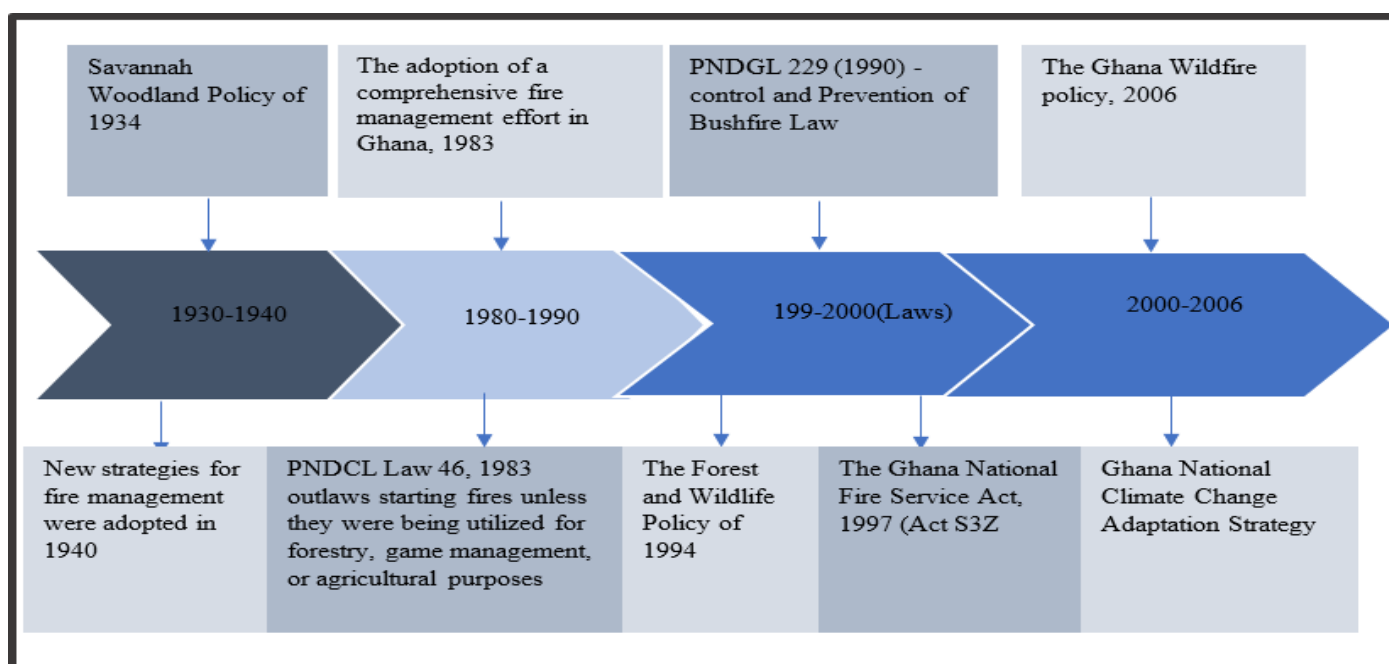

Fig 3: Key Policies and Laws that were Implemented as Efforts to Manage Wildfires in Ghana from the Years 1980s to 2000

The literature review on wildfire management strategies reveals that community-based fire management has become a prevalent approach in Ghana's savannah ecological zone. This strategy hinges on the active engagement of local communities and the application of Indigenous knowledge for wildfire prevention, control, and management. It recognizes the critical role of communities, including local people and traditional authorities, in ecosystem understanding and management. By encouraging community leadership and ownership in wildfire initiatives, this approach aims to leverage local insights for effective wildfire response (Diemont & Wanders, 2023).

Key elements of community-based fire management strategies include community education and awareness campaigns, campaigns, aimed at informing residents about wildfire risks, safety practices, management techniques, and early reporting mechanisms (Husseini et al., 2020a). The establishment of community fireguards, which involves creating and maintaining clear vegetation-free areas as firebreaks, is another significant strategy. Additionally, the training of community-based firefighting crews and monitoring groups has been emphasized, where trained volunteers are equipped to tackle emerging wildfires and conduct traditional surveillance for early detection.

Incorporating Indigenous ecological knowledge into wildfire management is also recognized as a vital component. this involves integrating local practices and wisdom into contemporary wildfire strategies, facilitating community meetings for strategic planning, and adopting cultural practices to mitigate wildfire risks (Egyir et al., 2015). Despite not being fully developed and utilized, some studies propose elements of community-based research and data collection as a strategy by engaging communities and collaborating with local members to collect information on historical wildfires, patterns, vegetation types, causes, ignition sources and other factors influencing wildfires in their communities to understand better the local dynamics of wildfires in the savannah ecological zone.

While Community-based fire management strategies are widely advocated, some highlight the effectiveness of collaborations, legislation and enforcement as essential to wildfire management in the savannah ecological zone of Ghana. This includes partnerships among government agencies, district assemblies, local communities, NGOs, and the implementation of programs for vegetation management and sustainable land use to minimize wildfire risks. Enforcing wildfire control legislation and penalizing illegal burning activities have also been identified as crucial measures (Sackey & Hale, 2008).

Emerging technological tools and research play a pivotal role in enhancing wildfire management and prevention. The adoption of Geographical Information Systems (GIS), remote sensing technologies, and Unmanned Aerial Vehicles (UAVs) for weather forecasting, wildfire prediction, and monitoring has significantly contributed to understanding and managing wildfire dynamics in the savannah ecological zones of Ghana. These technologies are also employed in monitoring systems and early detection of wildfires through satellite imagery and some ground-based surveillance and the development of rapid response systems to address and suppress emerging wildfires effectively (Dahan, Kasei, & Husseini, 2023).

D. Wildfire and Climate Change Policies and Regulations in the Savannah Ecological Zone.

Wildfires and climate change issues are given significant attention in policy and legislation. Like other countries, policies and legislations related to wildfires and climate change management adaptations in Ghana are often under the broader environmental and forestry framework. Several policies and legislative documents related to wildfire and climate change in the savannah ecological zone, although no specific policies or legislation exist for this area. The National Forestry and Wildlife Policy (2012), (Resources, 2012) aims to ensure sustainable management, conservation, and utilization of forest and wildlife resources in the savannah ecological zone. The policy also spelt out a special need for sustainable measures to prevent and manage wildfires, especially in the Mole National Park and reserves and protected areas in the savannah ecological zone.

The 2013 National Climate Change Policy, (MESTI, 2013) developed through a consultative meeting between stakeholders integrates climate change considerations into Ghana's development to enhance resilience and reduce vulnerability to climate impacts. The policy emphasizes climate change and proposes strategies to manage wildfires in Ghana's forests, savannahs, transitions, and ecological zones. The National Disaster Management Organizations Act (2016), (Government of Ghana, 2016) the act passed by the parliament of Ghana in 2016, amended and updated the responsibilities of the national disaster management organizations to coordinate and manage disasters and response efforts. The act recognizes wildfires, drought, and extreme weather conditions as disasters, and N.A.D.M.O. plays a role in coordinating response efforts, including wildfire management.

Other strategies identified are the Ghana national climate change adaptations strategy (2018), (UNEP & UNDP, 2019) the national biodiversity strategy and action plan (2016) by the (Ministry of Environment Science Technology and Innovation, 2016) and the strategy for reducing emissions from deforestation and forest degradation (REDD+).

E. Effectiveness of Wildfire Management and Prevention Strategies in Ghana's Savannah Ecological Zone.

The utilization of the wildfire management and prevention strategies identified in the systematic literature review depends on their effectiveness. While some strategies are widely known and used in the Savannah ecological zone, some require technical support and enforcement. Community-based fire management strategies recognize the active participation and valuable role communities play in preventing, controlling and managing wildfires. It also identifies how communities understand their local environment and ecosystem strategy and empowers them to take ownership of managing wildfires; the effectiveness of

Community-based fire management strategies involves building trust, fostering collaborations, and recognizing the unique skills and knowledge of communities within the savannah ecological zones. Education is a crucial step which may increase awareness and lead to responsible behaviour. However, a greater willingness to participate in wildfire management will lead to greater effectiveness. The success of the community fireguards depends on regular maintenance, a commitment by the community and coordination with more extensive wildfire management efforts. Adapting and integrating Indigenous knowledge can be effective when it aligns with scientific knowledge and contemporary conditions of communities and wildfire dynamics. The availability of resources for ongoing training, quick reporting and action, and collaboration with more extensive firefighting efforts and professionals will make the community fire monitoring and community-based firefighting crew effective. Wildfire participatory planning, decision-making, and community-based research and data collection success depends on collaborations and understanding of indigenous communities, cultural practices, and adaptations to contemporary wildfire management objectives. Community-based fire management strategies hinge on effective collaborations among government agencies and communities. Legislation and enforcement are crucial in managing wildfires; enforcing legislation on land use, wildfires, firebreaks, and illegal burning significantly reduces wildfires incidents. The application of penalties for illegal burning and adherence to wildfire laws and regulations by individuals pose a deterrent to wildfire. The effectiveness of the legislation depends on the clarity and specifications of the legislation related to wildfire prevention and management. Providing resources and personnel and empowering institutions to enforce the legislation is essential to wildfire law enforcement. Stakeholder collaboration and coordination, such as local government, local communities, and non-governmental organizations, are essential for effective wildfire management. The complexity of wildfire incidents requires a multifaceted approach where different institutions work together.

Technological tools and research as a strategy significantly enhance understanding, early detection, and efficient response in making improved wildfire decisions. Advanced technologies like Geographic Information Systems (GIS), remote sensing, satellite images, and Unmanned Aerial Vehicles (UAVs) aid in the early detection and monitoring of wildfires. Real-time imagery helps identify fire hotspots, track wildfire spread, and investigate severity. GIS allows mapping and analysis of wildfire-prone areas, while machine learning and data analytics help identify patterns and trends. Effective wildfire management strategies require integration, collaboration, and public awareness.

F. Indicators of Ecosystem Resilience and Factors Influencing Recovery.

Natural fires play a crucial role in maintaining biodiversity balance by promoting plant and animal diversity, controlling vegetation dynamics, and preventing invasive species from spreading. Wildfire-resistant mechanisms, such as fire-resistant bark and behavioural patterns, contribute to resilience. The combustion of vegetation during fires also promotes nutrient availability, promoting soil health and plant growth, ultimately benefiting overall ecosystem recovery.

The community's involvement in wildfire prevention, planning, reporting, and control, utilizing indigenous knowledge, and community ownership of strategies, is crucial for effective management. Implementing wildfire legislation and policies promotes sustainable practices, balances human activities with ecological integrity, and enhances ecosystem resilience. Lastly, the applications of scientific research and technologies for evidence-based wildfire management, such as real-time data on fire behaviour, ecosystem health, and integrated planning based on scientific knowledge, contribute to the effectiveness of wildfire management and ecosystem resilience (Mensah et al., 2015). These factors collectively contribute to understanding ecosystem resilience in the context of wildfire management in the savannah ecological zones of Ghana.

Table 2: Case Studies

N	AUTHOR(S)/ YEAR	TITLE	PURPOSE OF STUDY	RESEARCH DESIGN/ TYPE OF STUDY	ECOLOGICAL ZONE	RESULTS/OUTCOMES	IMPLICATIONS FOR RESEARCH	LIMITATIONS OR WEAKNESS
1	(Yahaya & Amoah, 2013)	Bushfire in the Nandom district of the upper west regions of Ghana: Perpetual threat to food crop productions	The study investigated the impact of bushfires on food crop production. It highlighted the causes of	The study utilizes a combination of quantitative and qualitative approaches in data collection and analysis.	Northern Savannah	Bushfires significantly impact food crop production, causing soil degradation, destruction, and reduced yield. Human activities and natural events contribute to bushfires. The study suggests	Further research is needed on socioeconomic and cultural factors contributing to bushfires, evaluating awareness creation initiatives,	The study's small sample size(40) and limited exploration of socioeconomic and cultural factors contribute

		bushfires and their adverse effect on soil fertility and crop destruction			sanctions, incentives, and increased awareness to discourage bushfires.	and assessing the effectiveness of proposed sanctions and incentive schemes.	to its limited generalizability and need for empirical testing.
2	(Lignule, 2017)	Sel-mobilizations for wildfire prevention in the Goziiri community, Upper West Region, Ghana.	The study explored the knowledge and experiences of the Goziiri community in managing bushfires for land restoration. It also assesses the community approach to wildfire prevention strategies they adopt.	The study utilizes a qualitative research design: semi-structured interviews and focus group discussions.	Northern Savannah	The community adopts a community-based approach to wildfire management and prevention, utilizing transformational leadership and involving all sectors. This approach is effective, but encroaching fires pose challenges to the strategies.	Research on leadership's role is crucial in community-based wildfire management efforts, emphasizing the significance of transformational leadership and adopting local content-focused strategies.	The small sample size focuses on experiences and knowledge, limiting the study's generalizability. The study may be subject to researcher bias and interpretation due to interviews and focus group discussions.
3	(Kosoe et al., 2015)	Wildfire management in the Tain II Forest reserves of Ghana: an evaluation of community participation	The article explores the challenges of wildfire management, emphasizing the importance of firefighting volunteers and the involvement of community stakeholders.	The article uses combinations of quantitative and qualitative approaches. Household questionnaires, focus group discussions, and interviews were used to collect data.	Transitions zone	Community stakeholders in wildfire management should be incentivized to reduce reluctance during outbreaks, due to limited participation, communication gaps, and household discrepancies in planning and implementation.	The study suggests a need to assess stakeholder participation in wildfire management, identify barriers like lack of incentives, and develop participatory strategies to enhance participation.	The study faced limitations and bias due to the use of questionnaires, focus group discussions, and interviews, as well as challenges in data integration and generalizability.
4	(Husseini et al., 2020b)	Fire control systems in forest reserves: An assessment	It assesses the impact of annual vegetation burns on the	This study employed a mixed-method research design	Northern Savannah	January is the peak season for fires, with a consistent pattern from January to March. Despite	The study underscores the need for comprehensive data on forest fire	The analysis of forest fire occurrences is hindered by

		of three forest districts in the Northern Region, Ghana	environment, the periods of occurrence, emissions, and loss of nutrients due to burns.	and integrated remote-sensing techniques.		being the main economic activities, forestry, agriculture, and hunting contribute minimally. Fire detection is crucial for control and management, but collaborations among institutions are inadequate. (e.g. Forest Commission and Fire Service Department)	occurrences and detailed patterns to improve management strategies, highlighting the importance of indigenous knowledge and community participation.	reliance on secondary data and challenges like ineffective collaborations among regulatory institutions and firefighting equipment.
5	(Sackey & Hale, 2008)	Effects Of Perennial Fires on The Woody Vegetation Of Mole National Park, Ghana	The article examines the effects of perennial fire and assesses the impacts of the fires on the density, abundance and structure of trees and shrubs in the savannah ecosystem	field surveys and observations	Northern savannah	Giant trees face higher fire scars compared to smaller ones, indicating species-specific scarring. Fire-induced mortality is notable, and larger trees lead to a decline in woody vegetation density, highlighting the significant impact of perennial fires on the savannah ecosystem.	Tree species' fire damage susceptibility necessitates species-specific studies, focusing on how vegetation changes affect faunal communities, especially herbivores relying on these plants for food and shelter.	The study's scope was restricted to specific heights of trees and shrubs, excluding data on small plants' fire responses and focusing on a small savannah zone area.
6	(Dahan, Kasei, Husseini, et al., 2023)	Towards understanding the environmental and climatic changes and its contribution to the spread of wildfires in Ghana using remote sensing tools and machine learning (Google Earth Engine)	It examines the relationship between climate change, drought monitoring, fire behaviours and their impacts on vegetation and water resources in different ecological zones in Ghana. It also explores climate variability	Applications of machine learning techniques through Google Earth engine.	Forest savannah, guinea savannah, Mosaic zones	The study reveals a decrease in rainfall and increased temperature in Guinea forest savannah zones, highlighting climate variability's impact on fire dynamics.	The study highlights the potential of remote sensing tools and machine learning in understanding climate change's impact on wildfires, thereby enhancing capacity building in climate change research.	Remote sensing data may have limitations in spatio-temporal resolutions, potentially impacting wildfire predictions due to its neglect of social interaction between humans and environmental activities.

			and fire dynamics.				
7	(Dahan, Kasei, & Husseini, 2023)	Contribution of remote sensing to wildfire trend and dynamic analysis in two of Ghana's ecological zones: Guinea-savannah and Forest-savannah mosaic	The study uses remote sensing data to assess the spatiotemporal dynamics of fires and understand the trends of burns and active fires in savannah ecological zones.	Remote sensing and G.I.S.	Northern and coastal savannahs	The study reveals fire activity variations in Guinea Savannah and forest Savannah zones, with January being the most fire-prone month, with intensity, density, and frequency influenced by land use. Implications of changing climate impacts on wildfires and fire behaviour	Remote sensing and statistical analysis offer a robust approach for monitoring and assessing fire trends in ecological zones, providing a framework for similar studies.	The study suggests potential overestimations due to image resolutions and the insufficient image for detecting small or fragmented fires, as well as the insufficient account of human activities and environmental interactions.
8	(Amoako & Gambiza, 2019)	Effects of Anthropogenic Fires on some soil properties and the Implications of fire Frequency for the Guinea Savannah Ecological Zone, Ghana	It investigated the influences of fire on soil properties in burned crop fields and woodlands and their implications and highlights the importance of fire regimes on soil.	Field survey, purposive sampling.	Northern savannah	The study reveals significant variations in soil properties and fire counts across land use types, with seasonal fire recurrence more frequent in districts with large open and wet savannahs.	Further research is needed to understand the intricate relationship between fire regimes and soil properties, including the need for more data on fire intensity and other socioeconomic factors.	More data on fire intensity on land samples is needed, as different communities have higher sampled plots than others.
9	(Kusimi & Appati, 2012)	Bushfires In the Krachi District: The Socioeconomic and Environmental Implications	It assesses the causes and effects of annual bushfires on the local populations and the vegetation cover, biodiversity loss and depletion.	Remote sensing /field survey	Northern savannah	The study highlights the devastating impact of bushfires on individuals, communities, and the environment, highlighting socio-cultural factors, political indifference, and weak legislation as contributing factors.	The lack of published data on fire frequency, intensity, and durational effects necessitates enhanced data collection and the integration of remote	The scope of the study is limited and cannot be generalized. Limited quality data availability, especially bushfire records. Challenges with

							sensing techniques and humanistic approaches in environmental research.	satellite images can affect the analysis of relevant change
10	(Nyadzi et al., 2015)	Assessment of Trace Gas Emissions from Wildfires in Different Vegetation Types in Northern Ghana: Implications for Global Warming	It assesses greenhouse gas emission discrepancies from different vegetative cover and the need for effective wildfire management policies in Ghana.	Field survey	Northern savannah	The study reveals significant differences in CH4 and CO emissions across vegetation, with savannah woodlands emitting the most and closed woodlands emitting the least, indicating rising atmospheric concentration.	Cross-disciplinary research is needed to understand emission variations, improve wildfire management policies in Ghana, and understand the impact of wildfire emissions on global warming.	The study's scope and sample size are limited, and it doesn't account for annual biomass and emission variations, potentially affecting the accuracy of the combustion furnace method.
11	(Dwomoh & Wimberly, 2017)	Fire Regimes and Their Drivers in the Upper Guinean Region of West Africa	It analyses the spatiotemporal patterns of fire activities in West Africa's savannah, understanding the interrelationship among various fire regimes and identifying fire trends and related influencing factors.	Remote sensing and quantitative.	West Africa savannah	The study reveals that fire activities are more prevalent in the northern parts of the West African Savannah, with factors like vegetation type, climate, topography, and human activity influencing bushfires, and identifying distinct fire regime patterns.	It underscores the need for a region-specific study to understand the regimes. It provides foundations for future studies on fire dynamics and related studies.	Data limitations by quality and availability of data used.
12	(Acheampong, 2013)	Bushfires In the Savannah: A Case Study of Osramani in The Krachi District Of Ghana	It investigated the scale and frequency of bushfires and understood	Case study	Northern savannah	Bushfires are a significant worrying phenomenon, providing certain benefits such as clearing farmlands.	Serves as a basis for further research.	Limited in scope

			local communities' perspectives on bushfire impacts and effects.				
1 3	(N'Datchoh et al., 2015)	Effects of climate variability on savannah fire regimes in West Africa	It investigated variability in burns areas and explored the potential relationship between local climate and large-scale climatic indexes in West African savannah.	Remote sensing field survey	West Africa savannah	Burned areas increased significantly from November to February, peaking in December. Positive correlations were found with rainfall, climate indexes, and human activities controlling fire variability.	There is a need for future research on regional-specific variability in correlations between climate indexes.	Data limitations by quality and availability of data used. The study does not include how climate change projects can affect fire regimes
1 4	(Appiah, 2021)	Enhancing Resilience to Drought and Ecosystem Change in Drylands: Assessing Principles of Building Social-Ecological Resilience in Northern Ghana	It explores the relationship between adaptive capacity and resilience in social-ecological systems, focusing on smallholder farmers and the complexities surrounding resilience in different contexts in northern Ghana.	A case study approach utilizing a mixed method (quantitative and qualitative)	Northern savannah	Social principles provide strong values in building community resilience to climate and environmental change. A robust social-ecological system contributes to solid climate change strategies and policies.	The study highlights the need for further empirical research on the relationship between adaptive capacity and resilience, using a case-study approach in Northern Ghana.	The case study approach limits the scope of the study, and generalizations of the study will be restricted
1 5	(Antwi et al., 2014)	Developing a Community-Based Resilience Assessment Model concerning Northern Ghana	It assesses the development and applications of community-based resilience models to	Community participatory approach, field observations and survey.	Northern savannah	The development of a resilience assessment model was significant since it provides a framework for assessing community resilience to	The article highlights the need for an integrated approach to enhance community resilience. There is a need for	The study's replicability may be hindered by reliance on expected knowledge and observation, and the

			climate change-related shocks. It also evaluates rural communities' ecological, engineering and socioeconomic resilience in the face of climate change.			climate change shocks. The resilience matrix developed provides a checklist for researchers to evaluate community resilience and use in other regions.	further research to refine and develop models that consider ecological, socioeconomic, and engineering factors in a holistic manner	simultaneous use of indicators may complicate assessing resilience.
1 6	(Egyir et al., 2015)	Adaptive Capacity and Coping Strategies in the Face of Climate Change: A Comparative Study of Communities around Two Protected Areas in the Coastal Savannah and Transitional Zones	The study explores the adaptation strategies adopted by households in protected areas to adapt to changing climate conditions, focusing on the factors influencing their adoption of modern productivity-enhancing strategies.	Field survey / cross-sectional design	Coastal savannah	The study highlights the need for improved households' adaptive capacity and coping strategies, including Indigenous ones, to manage climate change, influenced by factors like location, age, and income.	The study highlights the need for indigenous knowledge and modern technologies in climate change adaptation, while also highlighting disparities in social, financial, natural, physical, and human capital.	The small sample size limits the generalizability of the study. Temporal and seasonal variability of the coping strategies are not accounted for
1 7	(MLFM, 2006)	The National Wildfire Policy in Ghana	The policy aims to promote efficient wildfire prevention and control, encourage alternative resource management systems, and involve stakeholders in their	Stakeholders' engagement and consultations.	All Ecological Zones of Ghana	The initiative aims to reduce wildfires' impact and promote socio-economic transformation by promoting efficient wildfire management, user-focused research, and stakeholder participation in sustainable natural resource management and environmental quality.	It promotes effective collaboration and coordination among relevant institutions for research for knowledge and information sharing on wildfire management.	Wildfire management policies' effectiveness may be hindered by inadequate stakeholder coordination, insufficient legislative support, and the need for increased empowerment of

		manageme nt.					traditional and local authorities.
1 8	(Sub- committee et al., 1990)	Control and Prevention of Bushfires Act, 1990 P.N.D.C.L. 229	This legislation prohibits bushfires and regulates burning activities within and outside conservati on areas, defining what constitutes starting a fire.	Legal framewor k.	Ghana	The act prohibits bushfires without authorization under specific conditions and controlled fires, establishes sub-committees for local governance, specifies burning periods, conditions, and penalties, and protects ecologically sensitive areas, while ensuring community involvement and local governance.	The subcommitte e's data collection on bushfires aids in studying fire patterns, and policy analysis research can determine the legal framework's contribution to environment al contribution s and ecosystem resilience.	Enforceme nt challenges, Reporting compliance since the reporting of fires relies on individuals' initiative to report fire incidences.
1 9	(Mabe et al., 2014)	Determinan ts of Choice of Climate Change Adaptation Strategies in Northern Ghana	The paper examines the factors influencing farmers' climate change adaptation strategies in Northern Ghana.	the binary logistic regression model	Northern savannah	The study reveals that socioeconomic factors and farm characteristics significantly influence farmers' climate change adaptation strategies. Access to phones, experience, education, and credit are also identified as factors influencing livestock.	A need for further research to find effective ways to disseminate weather information. Further, Study into socioecono mic and cultural factors.	The findings' generalizab ility is limited by their small sample size and potential inaccuracie s due to memory errors or personal biases in self-reported data.

IV. DISCUSSION

A. Climate Change Impacts and Its Effects on Wildfire Management Strategies.

The review also confirmed that climate change is a direct influencing factor in wildfires, it has significantly impacted the wildfire management strategies in the savannah ecological zone. Wildfire management strategies in the ecological zones face challenges due to the evolving climatic conditions. Adapting wildfire management strategies to changing climate conditions requires dynamic and flexible approaches, crucial to ensuring ecosystem resilience and efficacy of wildfire management efforts. Climate change significantly affects community-based fire management strategies, necessitating frequent campaigns to educate communities about wildfire risks. Furthermore, Indigenous knowledge of wildfire practices may need modifications to address climate change impacts on vegetation and fire behaviours. Temperature and precipitation changes may interfere with vegetation management programs and sustainable land use practices. These will go a long way to influence wildfire legislation enforcement hence requiring some reviews and adjustments. Climate change could impact the accuracy and reliability of geographic information systems and remote sensing in predicting and managing wildfires. This necessitates continuous refinement of these tools and technology, as well as reevaluation of counterproductive approaches and collaborative efforts to adjust legal measures to reflect future climate realities.

B. Community Involvement in Wildfire Management Strategies and Ecosystem Resilience

The review has established that Wildfire incidents in the savannah ecological zone often occur in communities, which play a pivotal role in prevention and management. Their intimate knowledge about their environment is essential for effective strategies, and local communities are recognized as active stakeholders in preventing, controlling, and managing wildfires. The inclusion is based on their understanding and knowledge of their immediate environment, cultural practices and application of these knowledge and practices to contemporary wildfire management strategies. The involvement of communities in wildfire strategies involves their ability to detect signs of potential wildfires through traditional observations and promptly report to either (traditional authorities or local government authorities) for quick response and preventive measures. Although several fire management practices have become largely outdated such as fire suppression policies (Nieman et al., 2021), active participation of communities in the creation and establishment of community fireguards, participation in community firefighting volunteer groups, and engagement in education and awareness campaigns have allowed communities to participate in wildfire management. Using community practices such as taboos, customary laws, and totems in managing vegetation reduces wildfire incidents, and integrating these cultural practices into broader fire management strategies ensures community participation.

Communities play a limited role in implementing wildlife policies and enforcing legislative strategies for wildfire management strategies. However, communities actively collaborate with government agencies, district assemblies, and non-governmental organizations for coordinated planning and response actions to ensure multistakeholder approaches in wildfire management strategies. The contributions of community members to stakeholders' consultative meetings in developing wildfire management strategies, policies, and plans provide an opportunity for local communities' participation. The involvement of communities in wildfire management strategies, especially community-based strategies, enhances the effectiveness of ecosystem resilience in the savannah ecological zone. The intimate familiarity with the local environment and ability to detect wildfires early and swiftly report and respond to wildfires help contain the escalation of wildfires, minimizing the overall impact on the ecosystem. Indigenous knowledge and cultural practices enable context-specific wildfire management, aligning with Savannah ecosystem dynamics. Community fireguards and training enhance local capacity controls, contributing to effective wildfire management and preventing fire spread within communities. Community collaborations with external entities like government agencies, NGOs, and district authorities foster a multistakeholder approach, utilizing diverse resources and expertise for effective wildfire management and ecosystem resilience. Local communities in the savannah ecological zone of Ghana are not to be viewed as recipients of wildfire management strategies, but as contributors and stakeholders; therefore, their involvement in wildfire management strategies is embedded in indigenous knowledge and practices.

C. Alternatives to Fire Management

In the face of global change, novel methods such as the use of remote sensing to monitor the occurrence and spread of wildfires are proposed. Unfortunately, the direct involvement of communities in adopting and using technological tools in wildfire management strategies is limited, even though they benefit from the results of the applications of these technologies since they require specialized skills and knowledge. Geographic information systems and remote sensing technologies are beneficial for weather forecasting, wildfire predictions and monitoring. The limited access to geographic information systems (G.I.S.) and remote sensing technologies and data impede the adoption of these technologies in wildfire management strategies, hindering real-time monitoring, early detection and data-driven decision-making and planning. The literature mentions technology adoption but does not explore barriers to technological adoption and suitability in all areas. Further research to investigate the impediments, applicability to all areas, and potential solutions for the wider adoption of these technologies.

V. CONCLUSION

The systematic review of the literature on wildfire management strategies and ecosystem resilience in Ghana's savannah ecological zone emphasizes the dynamic interaction between natural and anthropogenic fires, highlighting the critical need for a comprehensive approach. The intricate balance between human needs, ecosystem preservations, and climate change influences underscores the complex challenges faced in wildfire management strategies and ecosystem resilience. Most studies recognize the role of natural fires as an integral component of the savannah ecosystem and highlight the importance of maintaining biodiversity, preventing the encroachment of woody vegetation, and regulating vegetation density. Community-based wildfire management strategies have been identified as the fundamental ones leveraging community participation, cultural practices, indigenous knowledge and community collaborations as key management strategy components. Policies and legislation serve as the legal backing and framework for sustainable practices, regulations of illegal fires, and management of protected areas. The challenge, therefore, is the effective implementation and enforcement of the regulations. The applications of technologies such as geographic information systems (G.I.S.) and remote sensing enhance early detection, monitoring and real-time data analysis, contributing to evidence-based decision-making and holistic wildfire management.

The resilience of the ecosystem relies on the recognition of natural fires, maintaining biodiversity by preventing single-plant species dominance, creating a mosaic of vegetation types, and promoting ecological diversity. The combustion of vegetation and release of nutrients into soil promote nutrient cycling and enhance soil health and fire-triggered seed germination and regeneration mechanism.

Human-induced fires have been associated with human activities that disrupt natural fire regimes, leading to shifts in fire timing, frequency, and intensity, creating some effects on biodiversity and vegetation. More attention should be given to the socioeconomic implications of wildfires, including the effect on livelihoods, infrastructure, and community wellbeing. In understanding the complexity of wildfire management strategies and ecosystem resilience in Ghana's savannah ecological zone, there is the need for a multifaceted approach including communities, researchers, government agencies, technology innovations, non-governmental organizations, and adaptive policies and regulations that will prioritise wellbeing, ecosystems, and communities.

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