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Revamping the Natural Habitat through Understanding and Managing the Invasive Species

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Abstract

Invasive species represent one of the most significant drivers of global environmental change, posing substantial threats to native ecosystems and biodiversity across the world. Their spread contributes extensively to species decline, habitat degradation and the disruption of essential ecosystem services. Despite their destructive impacts, invasive species also provide valuable scientific opportunities to better understand ecological theory. This study sought to sensitize on how invasive species dynamics can inform strategies for revamping and restoring degraded natural habitats. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines and a formal meta-analysis were applied among 250+ publications (2019–2026) on invasive species linkages. The study identified seven core domains: climate change, loss of biodiversity, environmental effects, eradicating invasive species at Nairobi National Park, prescribed burning, renewable efforts and conservation methods. Recognizing the widespread and increasingly acknowledged consequences of biological invasions, numerous multiscale management programs have been established globally to mitigate present and future impacts. There has also been a marked increase in scientific research aimed at guiding effective intervention strategies, with particular emphasis on risk assessment, pathway and vector management, early detection and rapid response mechanisms, as well as innovative mitigation and

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restoration approaches. The findings highlight that ecological challenges are occurring at present, rather than being prospective concerns that may arise in the next 5 to 20 years, and they are already the subject of extensive discussion and widespread recognition. Early identification, continuous monitoring, and coordinated management efforts are critical components in successful habitat restoration and biodiversity conservation initiatives. Consequently, the prescribed burning remains the most feasible initiative for Nairobi National Park. Revamping natural habitats by addressing invasive species is essential for restoring ecological balance. It involves understanding how these species establish and spread, allowing for targeted strategies to prevent ecosystem degradation. The focus is on reestablishing native vegetation and wildlife to enhance ecosystem integrity and resilience. The study concludes that a comprehensive understanding of invasive species ecology, coupled with strategic prevention and control measures, is essential for achieving sustainable environmental management and promoting long-term ecosystem resilience and recovery.

Keywords: Invasive species; alien species; prescribed burning; conservation efforts; biological invasions; biodiversity decline; nature-based adaptation.

1. Introduction

Approximately 15% of the Earth's terrestrial surface is currently designated for conservation, with international targets previously aiming for at least 17% terrestrial and 10% marine protection under effective management(Álvarez-Martínez et al., 2026). Biological invasions have intensified significantly over the past five decades and are now recognized as a central driver of global environmental change and biodiversity decline (Wambua et al., 2025). The acceleration of global trade, transport, and human mobility has facilitated the widespread introduction of alien species into ecosystems that were previously geographically isolated. As a result, very few ecosystems remain unaffected by introduced species, with many regions experiencing continuous increases in both the number and distribution of invasive organisms (Sutherland et al., 2026).These invasions are widely acknowledged to contribute significantly to altered ecosystem structure and functioning across terrestrial, freshwater, and marine systems.

Recent research (Gefaell & Uller, 2026), indicate that scientific projections further underscore the magnitude of the crisis. Continued habitat conversion in tropical forests may result in approximately 49,000 extinctions per million species by 2060 if current trends persist. Around 86% of globally threatened mammals are affected by habitat change, while roughly 62% of species face extinction risks primarily due to habitat loss. The magnitude and seriousness of impacts arising from natural risks are largely determined by the degree of vulnerability and the level of exposure to a given hazard (Guzmán et al., 2026).Within the context of this study, exposure is assessed by examining the current and projected potential distribution of invasive species, under the assumption that these species are capable of occupying the most accessible and ecologically suitable portions of their niche. Vulnerability, on the other hand, is defined according to the extent to which ecosystem services known to be sensitive to specific invaders are provided within a given area, with both areas of very high and very low ecosystem service provision being regarded as vulnerable to biological invasions (Gallardo et al., 2024).

Research (Newete et al., 2025),has consistently shown that primary forests, which harbor over half of terrestrial biodiversity and exhibit high levels of endemism, are being degraded at alarming rates, contributing nearly 12% of annual global anthropogenic greenhouse gas emissions(Skinner et al., 2026). These findings reinforce the urgency of implementing restoration within protected landscapes. To effectively reverse biodiversity decline, restoration initiatives must go beyond establishing protected areas and actively address degradation drivers, particularly invasive plant species(Mugane et al., 2024). The Anthropocene has seen a rapid increase in invasions by alien species as well as by range-expanding native species. Such invasions may pose a major threat to biodiversity, the economy, and human well-being. Many factors affect the likelihood of species invasions, including background climatic conditions, the magnitude and type of anthropogenic environmental change, and biotic features of the community (e.g. the types and diversity of native species), all of which can interact(Cheng et al., 2024, Chen et al., 2021).

A study by Jomo Kenyatta University of Agriculture and Technology (JKUAT) and the University of Florida developed an innovation where they processed an invasive prickly pear cactus (*Opuntia stricta*) into nutritious pellets for cattle(Mugane et al., 2024). Trials in Laikipia indicate the pellets are safe, palatable and improve livestock weight(Sipango et al., 2022). Widespread plastic use such as carrier bags and packaging has drastically polluted both terrestrial and aquatic environments, and this issue will persist even despite current mitigation efforts. It is imperative to prevent unnecessary plastic use through avoidance, reduction, reuse, and recycling to significantly curb environmental leakage(Matagi, 2026). However, the limitations in safe disposal and recycling infrastructure must be addressed. A promising solution is converting plastic waste into edible microbial single-cell protein, offering a transformative approach to waste management(Sutherland et al., 2026).

Evidence indicates that nature-based approaches and broader nature-based solutions frameworks are increasingly recognized as viable strategies for integrating ecological restoration with climate adaptation and sustainable development goals(Waruingi et al., 2021) . However, practical and scalable implementation of these approaches in fully protected areas remains limited, necessitating stronger integration of scientific evidence, stakeholder engagement, and adaptive governance mechanisms (Gross & Lamb, 2025). Strengthening frameworks during the UN Decade on Ecosystem Restoration is essential for resilient ecosystems and sustainable biodiversity conservation.

Multiple studies (Paris-Mensah et al., 2025) stipulate that invasive species exert substantial environmental effects by modifying soil composition, nutrient cycling processes, hydrological systems, and microclimatic conditions within invaded habitats (Sutherland et al., 2026). Alterations in nitrogen retention, soil stabilization capacity, and organic matter decomposition disrupt ecological balance and reduce ecosystem resilience to additional stressors (Guzmán et al., 2026). Changes in vegetation structure caused by invasive plants often affect light penetration and surface temperatures, thereby influencing regeneration dynamics and species interactions. Such environmental transformations frequently generate positive feedback mechanisms that increase ecosystem susceptibility to further invasions and accelerate degradation processes. These impacts are particularly concerning in protected areas where ecosystems are expected to function as biodiversity refuges but are increasingly threatened by invasive species establishment(Álvarez-Martínez et al., 2026).

Globally, approximately 27% of threatened terrestrial vertebrates are affected by invasive species, and the proportion rises substantially among critically endangered species. Island ecosystems are especially vulnerable, with more than 80% of negatively impacted species being island endemics due to their evolutionary isolation and limited adaptive defenses(Paudel et al., 2025). Invasive mammalian predators, including rodents and feral cats, have been identified as primary drivers of extinction risk for critically endangered birds and reptiles on islands. Additionally, invasive pathogens such as the chytrid fungus have caused widespread amphibian population crashes, further demonstrating the multifaceted nature of invasion impacts(Gallardo et al., 2024). The consequences of biological invasions for biodiversity are profound and widely documented across taxonomic groups. Invasive species frequently outcompete native organisms for limited resources such as food, water, space, and nutrients, resulting in population declines and local extinctions. The homogenization of biological communities caused by invasions reduces species richness and alters ecological networks that sustain ecosystem functioning(Guo et al., 2024).

Scientific projections (Matagi, 2026) indicate that without strengthened conservation measures, continued habitat conversion and biological invasions could result in tens of thousands of extinctions per million species by 2060. Approximately 86% of threatened mammals and 62% of species listed on the IUCN Red List face extinction risks linked primarily to habitat change and associated pressures, including invasions These findings reinforce the urgent need for integrated, science-based approaches that address invasive species alongside climate change and habitat degradation. Strengthening research, improving threat documentation, and enhancing policy implementation will be essential to mitigate the accelerating impacts of biological invasions on global biodiversity and ecosystem services(Skinner et al., 2026).

Payment for ecosystem services that successfully engage communities can create economic motivation for managing invasive species that threaten ecosystem health. Without community buy-in, invasive species management efforts often fail regardless of technical feasibility, as ongoing monitoring and control require local cooperation and sustained effort beyond short-term interventions (Rönnfeldt et al., 2026). Community participation in forest conservation activities varied, with over 70% involvement in tree planting and forest management meetings, but only 35.6% participated in firefighting and 28.1% in forest patrols. Local communities showed lower participation in activities perceived to have fewer individual benefits, such as patrols and firefighting (Waruingi et al., 2021).

A comprehensive understanding of invasive plant species biology and ecology significantly enhances the likelihood of successful management interventions including improving the effectiveness of implementing Nature-based Adaptation (NbA) strategies (Gross & Lamb, 2025). Such knowledge facilitates the development of species-specific action plans that incorporate distinct biological traits and life-history characteristics into targeted management responses. The biological attributes of invasive plant species encompass morphological features, mechanisms of seed dormancy and germination, growth physiology, competitive capacity, soil seed bank dynamics, and the dormancy and longevity of vegetative propagules, all of which directly influence invasion success and persistence (Bacher et al., 2025). In contrast, the ecological dimensions of invasive species include factors such as population equilibrium, density-dependent mortality, interspecific interactions, and critical life stages that regulate population size and spread thereby shaping invasion trajectories across landscapes (Li et al., 2025).

Restoring invaded ecosystems requires adaptive, informed decision-making, with control and management approaches, including NbA, increasingly based on scientific research and technological innovation. Many of these approaches rely heavily on a clear and systematic understanding of the biological traits and ecological interactions of the plant species involved, which is essential for designing context-specific interventions(Gross & Lamb, 2025). Predictive modeling tools for estimating invasive plant species emergence are recommended for better management, but their accuracy relies on in-depth knowledge of both native and invasive species biology and ecology (Skinner et al., 2026). Understanding reproductive capacity, such as the number of seeds produced per invasive plant and patterns of seed dormancy, provides critical guidance for determining appropriate timelines and intensity of management actions, particularly in the implementation of NbA strategies (Rönnfeldt et al., 2026).

Such biological data are crucial for estimating invasion scale, as total seed production indicates soil seed bank density in invaded areas and informs long-term control planning. Soil seed bank magnitude and persistence are key factors in invasion resilience and restoration success, highlighting the need for thorough ecological assessments before intervention(Guo et al., 2024). Effective management of biological invasions demands a systematic understanding of the biological, ecological, and functional traits driving these processes, along with stakeholder awareness and tailored strategies. Such integrated, science-based approaches are increasingly emphasized in global biodiversity frameworks between 2016 and 2026 as essential pathways toward sustainable ecosystem management and resilience building.

A study (Bacher et al., 2025) indicated that the spread of Alien Plant Species (APS) across both natural and human-modified ecosystems is widely recognized as one of the leading global threats to biodiversity conservation. *Lantana camara* is one of the world's 100 most damaging invasive species, causing significant ecological and economic harm. It disrupts native biodiversity, especially in semi-arid ecosystems across Africa, Australia, India, and the Pacific Islands (Li et al., 2025).The species is believed to have been introduced into East Africa in the early 20th century and has since become firmly established across large areas, especially within semi-arid landscapes and protected conservation zones. In Kenya, its proliferation has been extensive, where it aggressively colonizes rangelands, competes with indigenous plant species, and substantially reduces pasture productivity(Mugane et al., 2024). Lantana camara creates dense thickets that block herbivores from accessing forage, reducing grazing efficiency and altering wildlife feeding patterns. It also suppresses native vegetation by outcompeting indigenous species, which decreases biomass and negatively impacts wildlife forage and biodiversity (Paudel et al., 2025).

This regional focus improves the relevance of the findings for policy formulation, especially regarding the European Regulation on Invasive Alien Species (EU Regulation No. 1143/2014), aimed at mitigating the harmful effects of biological invasions on biodiversity and ecosystem services. Prescribed burning (PB) is a management practice that can mitigate long-term structural degradation associated with secondary succession and promote the establishment of specialized grassland species in grassland ecosystems. Research findings indicate that less frequent burning, particularly on a triennial basis, may decrease the homogenizing effects of fire on biodiversity(Franke et al., 2025).

2. Methodology

This study was conducted through a systematic review of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method (Figure 1). Article searches were carried out using a comprehensive strategy on Scopus research journal databases. The keyword used was “invasive species” AND “conservation”. 1.129 articles from Web of Science, Scopus, and Google Scholar were mined on February 28th, 2026. The inclusion criteria were documents and articles written in English and published within the last 10 years. Meanwhile, the exclusion criteria in this study were documents that were not written in English and those published more than 10 years ago. There were 31 articles selected as the most cited and relevant articles which were selected for this systematic review. The researcher used the screening feature on the Web of Science, Scopus, and Google Scholar websites to determine the articles with the most citations and relevance. The annotation method was also carried out to ensure that the selected articles followed the research topic. The researcher used the annotation method also because some of the identification results showed research that was not relevant to invasive species, for example, only in the field of environment without any relation to invasive species.

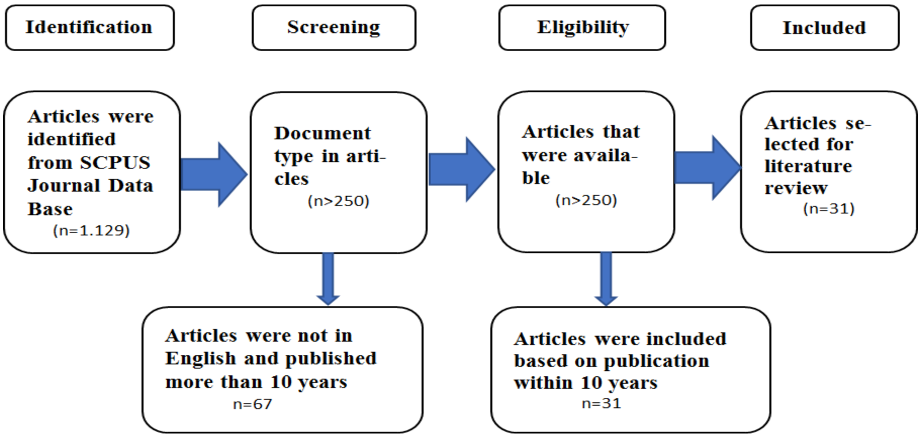

Fig. 1. PRISMA flowchart of the article selection process

3. Discussion

Awareness of invasive species biology and ecology not only strengthens the capacity to predict patterns of infestation and spread but also supports the integration of ecological knowledge into management frameworks such as NbA to enhance long-term control strategies (Gross & Lamb, 2025). Integrating biological and ecological insights into NbA approaches allows managers to design interventions that align with ecosystem processes, thereby improving restoration outcomes and reducing reinvasion risks. For instance, understanding the biological and ecological characteristics of the native grass species *C. dactylon* and the fodder crop *Desmodium intortum* has facilitated the formulation of NbA interventions that have effectively suppressed numerous invasive plant species within the family Asteraceae Such examples demonstrate that science-based ecological knowledge can inform sustainable management solutions that simultaneously promote biodiversity conservation and agricultural productivity (Qian & Grau, 2025).

Invasive species are non-native organisms that disrupt the composition, structure, and function of native ecosystems, leading to decreased ecosystem values and services (Paris-Mensah et al., 2025).They lead to biotic homogenization and can alter essential processes like nutrient cycling, negatively affecting native species and the food chain (*Strategy for Managing Invasive Species in Africa*, 2020) populations can trigger environmental changes that facilitate the establishment of invasive species by altering soil conditions and nutrient uptake, which impacts plant interactions and growth (van Wilgen et al., 2024). Climate change further exacerbates biological invasions as rising temperatures and altered rainfall patterns allow invasive species to thrive in new regions, compromising native species' resilience. Invasive species can also influence fire regimes and carbon dynamics, complicating conservation efforts (Sipango et al., 2022).

Socio-economic factors, like trade and urban expansion, increase the risk of invasions in human-modified landscapes. Even well-preserved ecosystems can be highly vulnerable to invasions, which can degrade vital ecosystem services such as habitat maintenance and flood regulation.

Soil moisture plays a critical role in water, energy, and biochemical cycles; climate regulation; and vegetation dynamics. New analyses and models highlighted a previously undetected decline in global soil moisture content of 1614 Gt from 2000 to 2002 and a further decline of 1009 Gt to 2016.The proposed, Brazil-led Tropical Forests Forever Facility (TFFF) is planned for launch at COP30. TFFF would establish a US$125 billion investment fund with returns financing annual, performance-based payments to tropical countries that maintain low deforestation (Sutherland et al., 2026).

Invasions of non-native species have significantly increased in recent decades, posing serious environmental challenges globally and putting pressure on both natural and managed ecosystems. Invasive species contribute to the homogenization of urban plant communities, especially in areas with high human disturbance. They have extensive socioeconomic and ecological impacts and threaten public health and urban ecosystem stability(Álvarez-Martínez et al., 2026).

Urban regions, with ongoing development and fragmented landscapes, create ideal conditions for invasives to thrive. Species like *Ambrosia artemisiifolia* can disrupt neighboring vegetation and harm native biodiversity, agriculture, and livestock(*Strategy for Managing Invasive Species in Africa*, 2020). Factors influencing the spread of invasive species include their proximity to source populations and environmental disturbances. Increased propagule pressure defined by the number of introduced individuals enhances invasion success(Paris-Mensah et al., 2025).

Despite progress in invasion ecology, the mechanisms behind the establishment of invasive plants remain unclear, highlighting the need for further research. A comprehensive global synthesis of the impacts of invasive species on biodiversity is still lacking. The loss of keystone species and ecological interactions destabilizes ecosystem resilience(Cheuk & Fischer, 2021). Invasion ecology now draws from multiple disciplines to address these challenges. Increased globalization has led to the majority of ecosystems being affected by invasive species, which can dominate biomes and harm essential ecosystem services. While some alien species can benefit agriculture, their unchecked spread threatens long-term sustainability, particularly in vulnerable areas(Bacher et al., 2025).

3.1 Climate Change

Earth's ecosystems are exposed to numerous environmental change factors, such as climate change, eutrophication, overgrazing and pesticide use, all of which can have profound consequences for resident biota and invaders (M. Li et al., 2021). Global warming is the gradual increase in the temperature of Earth's atmosphere, creating the greenhouse effect, driven by increased levels of carbon dioxide and CFCs. Anthropogenic factors have contributed to the invasiveness of habitat generalists, which eventually leads to climate change (Gallardo et al., 2024). Climate change is one of the most severe threats that often cause species extinction(Chowdhury et al., 2021).

Warmer temperatures generally favor invasive plant species over native species. Invasive plants benefit more from elevated temperatures, making it easier for them to establish in warmer conditions. This means climate warming reduces ecosystem resistance to invasion, particularly in low-diversity communities (M. Li et al., 2021). As global warming increases, invasive species gain advantages that accelerate biodiversity loss. Low-diversity ecosystems face a higher invasion risk due to warming (Cheng et al., 2024). Climate change also influences the spread of invasive species. If the competitive abilities of invaders weaken due to climate change, the ecological impact will be reduced to non-invasive (Feng et al., 2021). Climate change could also influence the abundance of secondary invaders. This weakens the primary invader's ability to compete for nutrients. Environmental changes make this defense mechanism even more important. Climate factors like warming, drought, and increased carbon dioxide levels are altering ecosystems worldwide (Cheng et al., 2024).

Organisms respond to climate change by moving to new areas where conditions remain suitable for their survival, causing shifts in the ecosystems (Kwon et al., 2021). Therefore, changes in habitat may explain how climate warming affects ecosystems, as demonstrated by the study of Kwon et al. (2021) showing specialist species populations shifting their core habitats.

However, plant diversity disrupts warming effects. Diverse plant communities' moderate local temperatures through shading and canopy cover. This temperature buffering reduces the competitive advantage that invasive species gain from warming, creating a biodiverse ecosystem maintaining stronger invasion resistance even as global temperatures rise. Maintaining high plant diversity provides dual benefits. It directly resists invasion while also resists temperature extremes that favor invaders (Cheng et al., 2024).

Drought creates opposite dynamics. Native plants tolerate drought better than many invasive species in simple communities. However, diverse plant communities with dense canopies reduce soil evaporation and help retain moisture (Sutherland et al., 2026). This drought resistance helps invasive plants survive dry conditions they would struggle with.

Carbon stored in the ecosystem is not in the atmosphere. During the invasion of habitat generalists, carbon stored in the soil or plants is reduced. This tends to warm the planet by releasing carbon dioxide into the atmosphere. However, invasive species that strengthen carbon storage reduce atmospheric CO2 (Skinner et al., 2026). Carbon cycling is contributed to by changes in native species composition and the resulting alterations of productivity, litter quality, and soil organic matter production and turnover. Long-term effects on carbon cycling are influenced by changes in tree species composition and the resulting alterations of productivity, soil organic matter production and turnover (Gallardo et al., 2024). Nitrogen cycle rates increase due to the invasive non-native species. Increased cycling rates reduce sustainability, leading to longer-term shifts in the composition of species, indirect effects on the micro-organisms and harm to the environment. Invasive species also affect the hydrological balance by using more water than the native species reducing soil moisture (van Wilgen et al., 2024).

Invasive species that cause an increase in fire severity will contribute to weakened plant-soil feedback. Prescribed fire is the intentional and purposeful use of fire in specific areas under managed conditions to meet land objectives. Depending on the degree and intensity, Prescribed Burning (PB) affects the biogeochemical cycles in the soil, such as carbon and nutrient cycles (Franke et al., 2025). These studies report an increase in pH and other mineral content of grassland due to short-term PB. Long-term land degradation, due to invasive species, can be prevented by PB, creating suitable conditions for specialist species to thrive, improving environment (Skinner et al., 2026).

Frequent annual burning degrades semi-natural grasslands rather than maintaining them. Annual fires prevent vegetation recovery and compromise the conservation value of these ecosystems. Fire regime effects on plant communities are observed through periodic burning. Frequent burning can eliminate native species that require time to reproduce and establish, reducing plant diversity. Degraded grasslands with reduced native diversity become vulnerable to invasive species colonization. Some invasive plants may tolerate or even benefit from frequent fire, gaining competitive advantage over fire-sensitive natives(Franke et al., 2025).

Lower-frequency burning offers a sustainable management approach. Less frequent fires allow vegetation to recover between burning events, maintaining ecosystem health while achieving management goals. Lower-frequency burning maintains native plant diversity and ecosystem structure, preserving the natural resistance to invasion that diverse communities provide. Appropriate fire management is essential for preventing both direct biodiversity loss from excessive burning and secondary losses from increased invasion vulnerability(Guo et al., 2024).

Climate change and biological invasions interact as double threats, making biodiversity conservation increasingly urgent for maintaining ecosystem resistance to invasion in a warming world(Bacher et al., 2025).

3.2 Loss of Biodiversity

Biological invasions have significant ecological consequences, leading to biodiversity decline and altering established biogeographical patterns. Invasive species also pose economic burdens on agriculture, health, and ecosystem services (M. Li et al., 2021).As globalization and anthropogenic pressures increase, the introduction and establishment rates of alien species are projected to rise. Understanding the factors influencing invasion success is vital for ecological theory and conservation efforts. Global datasets reveal that economically valuable plant species are significantly more likely to become naturalized due to enhanced propagule pressure(Kwon et al., 2021).

Invasive species impact native systems in a manner that decreases the ecosystem values and services (Novikau, 2021). Invasion causes biotic homogenization, a common recurring issue in ecosystems worldwide, driven by species invading normal flora and fauna. Invasive species have high dispersal abilities, rapid growth with short generations, and high tolerance of environmental conditions. Invasive species alter key processes such as nutrient cycling, which impact native plants and animals at higher trophic levels through the food chain (Mugane et al., 2024).This causes loss of important native species, which ensured the sustainability of the ecosystem and environment.

Biodiversity helps resist invasive species, as outlined by the biotic resistance hypothesis, which suggests that the diversity of native species enhances their ability to fend off invaders (Diamant et al., 2025). Ecosystems with many native species create competition for resources, making it challenging for invaders to establish themselves. Study results (van Wilgen et al., 2024) identified two key mechanisms behind this: first, different species utilize resources at varying levels, limiting space and availability for invaders; second, the presence of multiple native species strengthens competition, allowing natives to outperform and suppress invaders. This relationship is crucial for conservation, as protecting biodiversity helps maintain resilience against future invasions and prevents biodiversity loss (Cheng et al., 2024). Additionally, the impact of invasive species can vary across different geographical areas due to competition for resources.

Biodiversity increases resistance of grasslands against plant invasions under multiple environmental changes (Štípková et al., 2021). This suggests that biodiversity has a buffering effect. Maintaining and enhancing native plant diversity should be a priority to prevent invasion by alien species in an increasingly warmer world (Diamant et al., 2025). Although drought had positive effects on invasion resistance of monocultures, this was not the case for mixtures. Nevertheless, the relationship between biodiversity and invasion resistance was still positive under drought, indicating that biodiversity is also important under drought. Furthermore, plant diversity strengthened the positive effect of three co-acting factors on invasion resistance, suggesting that enhancing plant diversity should be prioritized to increase resistance of grasslands against invasion in a changing world in which plant communities may be exposed to multiple factors simultaneously(Cheng et al., 2024).

Biodiversity often helps communities resist invasion (Gallardo et al., 2024). Normally, some invaders are able to impact every ecosystem. Weak native species are susceptible to invasion because they cannot compete for nutrients. Vulnerable areas susceptible to invasion include areas with low soil retention capacity. Invasive species contribute to soil erosion in these areas, leading to the loss of native species. In a similar study (Štípková et al., 2021), indicated that ecosystems with few native species are vulnerable to invasion, and as invasion begins chances of colonization increase. Environmental conditions support invasion. The intensity of solar radiation, the soil type and the characteristics of the forest contribute to chances of invasion(Renčo et al., 2021) .

Research done by Bacher S et al. (2024) concluded that invasive species altered habitat structure, rapidly dominating the landscape and affecting existing ecosystems. Invasive aquatic species lower oxygen levels, increasing decomposition rates, disrupt nutrient cycling, and contribute to eutrophication, especially during massive die-offs (Jiao et al., 2021). This lowers the ecosystem's ability to retain and process nutrients. Moreover, certain invasive plants increase the chances and probabilities of fires, changing soil formation (Gallardo et al., 2024). Invasive animals also cause loss in biodiversity as they uproot plants, also causing soil erosion. Invasive species displace native species, changing ecosystem functions and disrupting the food web. Some invader species produce toxins that can harm wildlife or livestock, altering the ecosystem (Rönnfeldt et al., 2026).

Aquatic ecosystems are vulnerable to invasive plant species. These invasions create multiple environmental and economic problems. Invasive aquatic plants change native community composition, displacing native species and changing habitat structure (Li et al., 2025).

Forests provide critical economic, social, and cultural functions. However, forest degradation occurs faster than the degradation of other natural ecosystems globally(Zhao et al., 2025). Forest degradation, invasive species, and biodiversity are related in different ways. Degraded forests lose native tree diversity and structural complexity, creating favorable conditions for invasion. Invasive species outcompete native vegetation and alter ecosystem processes. The economic pressure driving forest degradation also facilitates invasive species spread through logging roads, agricultural expansion, and disrupted ecosystems. Conservation approaches like payment for ecosystem services may help maintain forest biodiversity and resistance to invasion by reducing degradation pressures(Waruingi et al., 2021).

Grassland ecosystems need periodic fire to maintain native plant communities(Gross & Lamb, 2025). Fire suppression contributes to woody plants and invasive species, displacing native grassland specialists. This invasion reduces biodiversity, alters ecosystem structure, creating hazardous fuel loads that increase wildfire endangerment. A study done (Paudel et al., 2025) in the Eastern United States revealed that some invader species make fires worse, and these fires increased the spread of invasive grass. This cycle benefits the invader's continuity in the ecosystem.

Dryland ecosystems are water-scarce, where the availability of water and nutrients controls the biome. This type of system uses the bottom-up model. This can shortly shift to consumer control (top-down) after periodic rain events (Guo et al., 2024). However, consistently wet, warm ecosystems have constant resources, so predators and herbivores control the system instead (top-down). For instance, a dryland species has adapted to sparse vegetation, low rainfall, heat, and extreme temperatures and may outcompete temperate species because it has adapted to tolerating heat and water scarcity (Gallardo et al., 2024). These dynamics affect biodiversity in drylands more than in the temperate biomes. Multiple studies (Chen et al., 2021)revealed that habitat loss and pollution were the primary threats to native species from invasive species. Their study findings stated that prevention and eradication programmes proved successful in preventing biodiversity loss.

Determining whether we view invasive species as threats to be eliminated or as inevitable components of evolving, human-influenced ecosystems remains an unsolved question. Eliminating all risks of invasive species to a region is close to impossible without affecting local economies(Cheuk & Fischer, 2021). The biggest risk is the possibility of extinction of native species by invaders. Evidence from decades of research reveals why regulatory policies have been developed, and why more need to be formed. This choice has irreversible consequences on the environment. Invasive species can trigger devastating effects, including extinction of native species, altered fire patterns, habitat degradation, and shifts in ecosystem structure and function(van Wilgen et al., 2024).

3.3 Environmental Effects

Protected areas (PAs) have been established globally as a primary strategy to combat biodiversity loss driven by human activities. The International Union for Conservation of Nature (IUCN) classifies PAs into six categories, with Categories I–III designated as fully protected areas (FPAs) where human interference is minimized (Novikau, 2021). However, even FPAs are facing ecological degradation due to invasive species, land-use change, and anthropogenic pressures (Chowdhury et al., 2021). In developing countries, economic development often relies on resource exploitation, leading to habitat fragmentation and increased extinction risks, particularly for large herbivores.

Invasive species can disrupt soil conditions and hinder native plant reproduction, creating a feedback loop that favors their growth (Sutherland et al., 2026). High plant density may lead to negative soil changes, such as increased salinity and reduced moisture, ultimately creating unsuitable conditions for all species, native and invasive alike (Asaduzzaman et al., 2022). This dynamic complicates ecosystem recovery even after the decline of invaders.

Invasive species also impact biogeochemical cycles and carbon storage in ecosystems, releasing carbon dioxide and affecting nitrogen cycling, which disrupts sustainability (Gefaell & Uller, 2026). Furthermore, they alter the hydrological balance by consuming more water than native species. Climate change exacerbates the spread of invasives, as rising temperatures may enhance their competitive advantages, although weakened invader abilities due to climate shifts could mitigate their impacts (Skinner et al., 2026).

Aquatic ecosystems are at risk from invasive plant species, which disrupt native communities and habitat structures(Feng et al., 2021). Forest degradation occurs rapidly, leading to a loss of native tree diversity and creating conditions that facilitate invasions (Waruingi et al., 2021). Economic pressures, such as logging and agricultural expansion, further promote the spread of invasive species.

Grassland ecosystems require periodic fires to maintain native plant communities. Fire suppression allows invasive plants to thrive, increasing wildfire risks. Study findings by (Gross & Lamb, 2025) indicated that some invasives can worsen fire severity, further promoting their spread. Prescribed burning (PB) can mitigate long-term land degradation by improving soil conditions for native species (Gefaell & Uller, 2026).

Despite efforts to manage invasive species, gaps in environmental impact assessment remain (Gross & Lamb, 2025). Effective assessments should consider the full range of biodiversity and regional differences in ecosystem response to invasives (Mugane et al., 2024). Invasive species can have severe consequences, including altered fire patterns and habitat degradation. Effective natural resource governance requires transformative frameworks that promote ecosystem-based adaptation while addressing challenges like social equity (Álvarez-Martínez et al., 2026). Coordinated spatial planning among stakeholders enhances conservation efforts and aligns with Sustainable Development Goals (SDGs). Embracing innovative governance systems is crucial for improved management of invasive species

In response to the growing threat of biodiversity loss, global conservation efforts increasingly focus on prevention, early detection, rapid response, and long-term ecological restoration. The UN Decade on Ecosystem Restoration (2021–2030) emphasizes invasive species management as key to reversing ecosystem degradation and enhancing climate resilience (*Strategy for Managing Invasive Species in Africa*, 2020). Evidence-based management approaches advocate for adaptive governance and ecological monitoring to improve outcomes in protected areas. Despite these efforts, many protected areas remain vulnerable to invasive species, highlighting that legal protections alone are insufficient without active management (Sutherland et al., 2026). Effective landscape governance requires coordination across institutional levels and synergies between regulatory and traditional governance, addressing potential conflicts and promoting stakeholder participation for sustainable outcomes.

While participatory methodologies and accountability mechanisms have improved in the past decade, many protected areas still face rigidity in policy frameworks that limit responsiveness to environmental challenges (Matagi, 2026). With ecosystems being dynamic, developing governance models that can adapt to uncertain future scenarios is crucial, making adaptive governance a promising approach to managing biological invasions amid ecological transformations (Gross & Lamb, 2025).

3.4 Eradicating Invasive Species at Nairobi National Park

Nairobi National Park (NNP), established in 1947 as Kenya's first conservation area, is a vital urban wildlife trove. It features natural savanna landscapes and diverse wildlife but faces a serious threat from invasive species, including *Prosopis juliflora, Parthenium hysterophorus, Lantana camara, Opuntia spp., Dovyalis caffra, Datura,* and water hyacinth which have overtaken over 27% of critical habitats. These invasive plants displace native species and disrupt ecosystems, impacting wildlife like lions, leopards, and black rhinos(KWS-NNP Blog, 2025). Study findings by (Matagi, 2026) on how invasives affect soil characteristics such as nutrient availability and microbial activity remains limited, highlighting a significant knowledge gap. Understanding these impacts is crucial for developing effective management strategies to restore affected habitats. Despite NNP's protected status, ecological pressures from these invasive species jeopardize conservation goals. Nature lovers envisage a Nairobi National Park where native acacias flourish, gazelles, buffalo roam freely, and the circle of life thrives unchecked. The conservationists' vision is being built today through bold action against invasive species like *Prosopis juliflora* and water hyacinth choking the ecosystems(Sutherland et al., 2026).

Study findings by (Mugane et al., 2024)indicated that abandonment creates conditions conducive to invaders, enhancing short-term diversity while degrading ecosystems over time. Removing these species is essential for restoring balance, boosting biodiversity, and protecting Kenya's wildlife. Healthy soils lead to stronger grazers, flourishing predators, and clearer waterways, contributing to global resilience and supporting the UN Sustainable Development Goals for planetary health. Invasive species thrive in disturbed environments, gentle slopes, and soft soils, aiding their spread in these habitats(Waruingi et al., 2021).

The Kenya Wildlife Service, in collaboration with Karuri Kenya Medical Training College, is tackling invasive species in Nairobi National Park through community-led removal and restoration efforts. These initiatives have led to healthier ecosystems, increasing grazers by 17% and enhancing water quality for migratory species. Such actions support wildlife conservation, aligning with UN SDGs 15 (Life on Land) and 13 (Climate Action), and serve as scalable models for Kenya's national parks(Kenya Wildlife Services, 2025).

Successful eradication efforts in Nairobi National Park face socio-economic and logistical challenges, including limited funding, inaccessibilty to remote areas, and the need for ongoing training of field personnel (Wambua et al., 2025). The park's size and the persistent seed banks of invasive species necessitate sustained investment over many years, straining conservation resources amid competing priorities. Additionally, urban development around the park increases invasion pressure, providing new pathways for invasive species (Waruingi et al., 2021).

Eradicating invasive species is vital for restoring the natural habitat, as they degrade native vegetation and reduce wildlife forage. Proximity to urban areas has facilitated the spread of aggressive invasives like *Parthenium hysterophorus* and *Lantana camara*, which displace indigenous plants. Eradication initiatives focus on manual removal methods, especially hand-pulling *Parthenium*, due to chemical controls being prohibited. Community involvement, including local universities and groups like Friends of Nairobi National Park, has been key in supporting these efforts(KWS-NNP Blog, 2025).

Despite these efforts, complete eradication remains elusive because invasive species possess traits such as high reproductive output, allelopathic growth, and prolific seed dispersal that enable rapid colonization of open or disturbed habitats. For example, *Parthenium hysterophorus* produces hundreds of thousands of seeds that remain viable in the soil and can be spread by wind, vehicles, or animal movement, necessitating persistent removal over multiple seasons to deplete the seed bank(Wambua et al., 2025). Similarly, *Lantana camara* not only occupies wide areas of forest edge and shrubland but also alters soil nutrient conditions to favor its own persistence, thereby inhibiting the return of indigenous species and complicating restoration efforts (Kenya Wildlife Services, 2025). These biological and ecological characteristics highlight the need for strategic, sustained eradication programs that integrate both short-term removal and long-term monitoring to prevent reinvasion.

Importantly, eradication efforts at Nairobi National Park have adopted adaptive management principles that emphasize learning from ongoing control activities and adjusting tactics based on outcomes and ecological feedback. For instance, manual removal operations are periodically reviewed to assess their impact on invasive density and native species recruitment, with data informing the prioritization of high-risk areas and the allocation of resources where reinvasion pressure is greatest(Matagi, 2026). Increased surveillance of disturbed corridors such as roadsides and fire breaks common invasion routes enable early detection and rapid response, which are critical to preventing large-scale reestablishment of invasive species (*Strategy for Managing Invasive Species in Africa*, 2020). This iterative process enhances the efficiency of eradication programs and underscores the importance of evidence-based decision-making in ecological restoration.

Collaborative partnerships between KWS, non-governmental organizations, local communities, and academic institutions have strengthened eradication initiatives by combining technical expertise, manpower, and local ecological knowledge (KWS-NNP Blog, 2025). Community engagement not only mobilizes additional volunteers for weeding exercises but also builds local stewardship and awareness about the impacts of invasive species and the value of preserving native habitat integrity. Educational activities aimed at schools and community groups further promote long-term behavioral change, discouraging the unregulated introduction of exotic plants that could become future invasives(Álvarez-Martínez et al., 2026) . Such community-driven conservation enhances social buy-in and helps sustain eradication momentum beyond formal park management interventions(*Strategy for Managing Invasive Species in Africa*, 2020).

Technological advancements hold promise for improving invasive control in Nairobi National Park by enhancing monitoring and intervention precision. Tools like remote sensing and GIS mapping can help detect invasion hotspots and plan targeted removal efforts more effectively. While their use is still developing in the park, integrating these technologies with traditional surveys could optimize eradication results and minimize labor in less critical areas. Additionally, research into the ecology of specific invasive species can inform tailored control strategies (Álvarez-Martínez et al., 2026).

Evaluating the effectiveness of eradication efforts is crucial for understanding progress with invasive species, especially as their distribution changes due to environmental factors(Skinner et al., 2026). Regular assessments of vegetation, invasive density, and native recovery help identify effective methods and management needs. These evaluations can also uncover unintended consequences, such as impacts on native species or new invaders, allowing for improved eradication techniques. Systematic monitoring enables park management to balance immediate control with long-term ecological sustainability.

Ultimately, revamping the natural habitat of Nairobi National Park through invasive species eradication exemplifies a holistic conservation approach that integrates scientific knowledge, community action, ecological restoration, and adaptive governance. Though complete elimination of invasive species remains a formidable challenge, incremental progress through coordinated efforts enhances the park's ecological integrity and supports the recovery of native biodiversity that wildlife populations depend upon(Kenya Wildlife Services, 2025). Continued commitment to eradication, combined with proactive restoration and monitoring, will improve habitat quality, strengthen ecosystem function, and safeguard the park's unique position as a protected wildlife refuge within a rapidly changing urban landscape.

Scholars emphasize core principles for adaptive governance, such as flexibility, collaboration, and learning, however, environmental legislation often fails to align with these principles, especially regarding polycentric governance and cross-sectoral collaboration (Matagi, 2026). Polycentric systems decentralize decision-making to local bodies with indigenous knowledge, which is vital for effective biodiversity management. Yet, these systems often overlook traditional institutions that are respected within local communities, hindering their potential in invasive species management and conservation.

The devastating "Black Summer" wildfires in Australia (2019-2020), along with the Canadian Prairies' success (2021-2024) and the 2025 Athi basin wildfire in NNP, highlight the importance of Prescribed Burning as a conservation strategy. These events demonstrate how controlled burning can enhance biodiversity and restore habitats, emphasizing its significance for park preservation (McCaffrey, 2025). At this point, prescribed burning is no longer merely an idealistic slogan but the most feasible strategy to eradicate invasive species at NNP.

3.5 Prescribed Burning

Non-chemical control accounted for 57.7% of the total number of interventions described in the research (Gross & Lamb, 2025) . The most common non-chemical methods are prescribed fire and mowing, followed by hand-pulling, cutting, and harrowing. The choice of method logically relates to the growth form of invasive plants.

Prescribed fire is mostly used in deserts, temperate forests, and grasslands. These ecosystems naturally depend on fire, but past fire prevention policies have prevented biodiversity and allowed invasive species to spread (McCaffrey,2025.) Fire serves both as a restoration tool and a management strategy to maintain fire-dependent ecosystems. Mowing works best in chaparral, savanna, and tropical rainforests, especially for controlling invasive grasses. Hand-pulling suits smaller projects with manageable labor costs. Cutting is common in tropical areas invaded by shrubs and trees (Franke et al., 2025).

Other non-chemical methods include grazing in temperate grasslands and, though used rarely, biological control using insects and fungi. Additional methods include soil preparation, mulching, covering, and mechanical interventions. Effectiveness of biological control depends on careful evaluation of benefits, costs, and ecological impacts. Wealthier countries mainly use prescribed burns, while lower-income countries rely more on mowing (McCaffrey, 2025).

The effects of these altered fire patterns remain unclear, requiring adaptive management to address unexpected outcomes. Fire is commonly used to control invasive plants in deserts, temperate forests, and grasslands. Fire serves both as a restoration tool and a strategy to maintain ecosystems that naturally depend on it (Franke et al., 2025) .

Regular fire schedules proved more reliable than random fire occurrence. Random fire patterns allowed long periods without fire, sometimes exceeding a century, leading to very high invasion densities and species loss. This shows that relying on unpredictable fires cannot achieve management goals. Fire probability naturally depends on climate, available fuel, and ignition sources. However, in agricultural areas where humans suppress fires, unpredictable fire patterns become unreliable and may produce the problematic long fire-free periods that allow invasions to worsen (Gross & Lamb, 2025).

Several factors complicate management decisions. Fire type is necessary for achieving hot, uniform fires (McCaffrey, 2025) . High invasion densities may also alter fire intensity and behavior. The model simplifies reality and excludes simultaneous environmental changes like fire suppression, climate shifts toward drier conditions, and land use changes. Since the invader tolerates drought and germinates under varied conditions, these factors may work together to worsen the invasion (Gross & Lamb, 2025). Models that include environmental factors and fire details like intensity and timing provide better management guidance for controlling invaders in other systems (Franke et al., 2025).

Disturbance-based management works well with other methods. In an Australian study, combining invasive grass removal with grazing and nutrient addition successfully controlled invasive herbs. Simulation modeling tests management scenarios over longer periods that other methods can, providing managers with hypotheses to test in the field. Combining modeling with field work improves invasive species management (Gross & Lamb, 2025).

Climate change has played a crucial role in increasing the frequency and intensity of wildfires globally. These wildfires often result in more extensive damage compared to controlled prescribed burning. However, ecological research indicates that both wildfires and prescribed burns can offer valuable benefits to biodiversity, such as promoting regeneration and maintaining the health of certain ecosystems(Franke et al., 2025).

The catastrophic "Black Summer" wildfires in Australia from 2019 to 2020 serve as a stark example of how climate change has fundamentally altered fire behavior, leading to longer fire seasons and more severe fire outbreaks(Gross & Lamb, 2025)ns and more severe fire o. This situation highlights the urgent need for a paradigm shift in disaster management. Rather than responding reactively to wildfires as they occur, it is increasingly necessary to adopt a proactive, community-driven approach. This would involve not only preparedness and mitigation strategies but also fostering community resilience and enhancing local awareness of fire risks (Rönnfeldt et al., 2026). By focusing on prevention and collaboration, communities can better adapt to the changing climate and its associated fire risks, ultimately protecting both lives and ecosystems.

According to (Gross & Lamb, 2025)prescribed fire is an essential land management practice employed in fire-adapted ecosystems, where the controlled use of fire helps achieve multiple ecological and cultural objectives. This technique is designed to mitigate the risks associated with uncontrolled wildfires by reducing excessive vegetation and creating a healthier landscape(McCaffrey, 2025). Additionally, prescribed burns play a crucial role in managing invasive and exotic plant species, as well as woody species that can outcompete native flora.

The benefits of these controlled burns extend beyond mere fire risk reduction; they also enhance ecosystem productivity and biodiversity(Cheng et al., 2024). By mimicking natural fire cycles, prescribed fire can rejuvenate habitats, promote the growth of native plants, and create a mosaic of diverse plant communities that support a wide range of wildlife. Furthermore, prescribed fire serves as an important educational tool, fostering the exchange of knowledge related to land stewardship and cultural practices among communities(Gross & Lamb, 2025). In western Canada, fire exclusion has predominantly guided land management strategies since the time of colonization. This approach has led to the accumulation of fuel loads, altered natural fire regimes, and increased vulnerability to catastrophic wildfires. Recognizing the benefits of prescribed fire is vital for restoring ecological balance and promoting sustainable land use practices that honor both the environment and cultural heritage.

Efforts to reintroduce prescribed fire often encounter a range of intricate obstacles that can impede progress. In response to the challenges identified during a series of workshops focused on fire management practices, the Canadian Prairies Prescribed Fire Exchange was established in 2021. This organization was created to facilitate interagency collaboration and foster partnerships among various stakeholders, including government agencies, environmental organizations, and local communities(Gross & Lamb, 2025).

Between 2021 and 2024, the success of the Canadian Prairies Prescribed Fire Exchange underscored the critical importance of cooperative efforts in addressing the barriers to effective fire management. Through collaborative initiatives and knowledge sharing, the organization has not only built robust programs but has also strengthened the relationships between different agencies. This teamwork has been pivotal in achieving shared conservation goals, such as improving ecosystem health, reducing wildfire risks, and restoring native landscapes(Franke et al., 2025). Overall, the impactful work of the exchange illustrates how collaborative approaches can pave the way for more effective and sustainable fire management practices in the Canadian Prairies.

Prescribed fire, often met with skepticism, is increasingly recognized as a viable and beneficial practice in land management. While initial objections may center around issues such as smoke exposure and the potential for losing control during burns, these concerns can often be alleviated through open dialogue. By fostering discussions that highlight the objectives and advantages of prescribed fire, agencies can gradually shift public perception and enhance community tolerance of this strategy(Rönnfeldt et al., 2026).

Leaders and managers who introduce prescribed fire as a tool may encounter resistance at first. However, as community members gain a better understanding of the ecological benefits such as reducing hazardous fuel loads, promoting biodiversity, and improving habitat quality, the likelihood of acceptance and support tends to grow(Gross & Lamb, 2025). This shift does not happen spontaneously; it requires a deliberate effort to engage with the community and address their concerns comprehensively(Matagi, 2026). Building trust is a crucial component of this process. Even the most well-informed and knowledgeable initiatives may falter without a foundation of trust between agencies and the public. If people lack faith in the implementation of prescribed burns, they may react with apprehension or hostility, regardless of the education provided. The dialogue that agencies initiate not only helps disseminate knowledge about prescribed fire but also plays a critical role in establishing relationships and cultivating trust within the community(McCaffrey, 2025).

In essence, fostering a culture of understanding and trust through consistent communication and outreach can pave the way for greater acceptance of prescribed fire as a proactive tool in land management. As stakeholders become more engaged and informed, the acceptance of this practice is likely to increase, leading to more effective stewardship of natural resources (Kenya Wildlife Services, 2025). PB has low effects on soil parameters but alters the vegetation structure of Nardus grasslands by reducing moss cover, vegetation cover, and vegetation height and by slowing the process of litter accumulation that less frequent burning can prevent the negative effects of more frequent fires on diversity.

Research findings (Franke et al., 2025) emphasize the promising role of PB as a powerful management tool for vegetation. By effectively controlling secondary succession, PB has the capacity to avert long-term structural degradation of ecosystems. Additionally, it fosters the creation of favorable conditions and potential microsites that are ideal for the establishment of specialized grassland species within savanna grasslands. This approach not only promotes biodiversity but also enhances the overall health and resilience of these vital ecosystems.

In 2025, a devastating wildfire ignited in the Athi basin area of the Nairobi National Park, rapidly engulfing approximately 5 kilometers of lush grassland and vibrant vegetation (Kenya Wildlife Services, 2025).The flames spread with ferocity, leaving charred remnants in their wake. However, after a few weeks of careful observation, a surprising transformation began to unfold. The once ravaged area saw a remarkable resurgence of flora and fauna, drawing in diverse wildlife that thrived amidst the recovering ecosystem. By the end of the year, many herbivores were frequently spotted congregating in this rejuvenated landscape, attracted by the new growth that emerged in the wake of the fire. This influx of herbivores, in turn, attracted predators such as big cats, showcasing the intricate balance of nature and its resilience (Wambua et al., 2025). This experience should profoundly influence the Kenya Wildlife Services and conservationists into reinforcing their belief in Prescribed Burning as a vital conservation strategy. The event underscored the potential benefits of controlled burning in promoting biodiversity and restoring habitats. This should be given the gravitas it deserves, leaving a lasting impression on those dedicated to the park's preservation.

As stated by (Franke et al., 2025), prescribed burning offers a cost-effective alternative to traditional animal grazing for maintaining grassland ecosystems. This management approach prevents grassland abandonment and maintains open habitat conditions. The goal is to identify optimal burning schedules that maintain ecosystem health and biodiversity in montane grasslands. Proper grassland management maintains native plant communities that resist invasion. Abandoned grasslands undergo succession, often becoming vulnerable to invasion by invasive species as woody plants encroach and native grassland species decline. Prescribed burning at appropriate frequencies keeps grasslands open and maintains diverse native plant assemblages. Managed, biodiverse grasslands are more resistant to invasive species than degraded or abandoned sites. Cost-effective management tools such as prescribed burning enable broader conservation efforts, protecting more grassland area from both abandonment-driven degradation and subsequent invasion by non-native species.

3.6 Renewable Efforts

Ecosystem monitoring has transformed from labour-intensive field surveys to advanced workflows integrating remote sensing, artificial intelligence(*Strategy for Managing Invasive Species in Africa*, 2020). This enables the detection of ecosystem changes across larger areas and longer time periods than traditional methods allowed. Effective ecosystem monitoring requires co-design with regulatory authorities to ensure thresholds and reporting meet policy needs.

Research has consistently shown (Sutherland et al., 2026) that satellite remote sensing enables observing ecological patterns at scales impossible through traditional field methods, providing global coverage at resolutions unattainable by ground surveys. For invasive species management, satellite monitoring detects invasions across vast areas at once, allowing managers to identify hotspots, track spread rates, and prioritize control efforts based on spatial patterns. This global-scale surveillance makes early detection feasible in remote areas where ground monitoring is impractical, preventing invasions before they become unmanageable.

Remote sensing enables early detection of invasive species across large areas before ground surveys identify them(Guzmán et al., 2026). AI identifies invasive species in satellite imagery for rapid response. Time-series monitoring tracks invasion progress and management effectiveness over time. Assessment tools detect ecosystem degradation, increasing invasion vulnerability, and enabling targeted restoration efforts. These technologies make invasive species surveillance scalable and cost-effective, enabling proactive management rather than reactive control after invasions become established. Advanced monitoring efficiently allocates limited conservation resources to areas where invasive species threaten biodiversity most severely(Rönnfeldt et al., 2026).

The evidence indicates that prevention requires understanding invasion pathways(Gefaell & Uller, 2026). Managing forests near urban areas, maintaining diverse native plant communities, and monitoring forest edges are essential strategies. Early detection and removal before invasive species naturalize can prevent the widespread biodiversity losses that occur once invasions become established. Stopping invasion early at forest edges proves far more effective than controlling it after invasive species penetrate entire ecosystems.
While models predict where invasive species will spread, management efforts determine whether invasive species can be successfully controlled or removed. There are two types of methods used to control invasive species: chemical and non-chemical methods (Skinner et al., 2026). Research (Paris-Mensah et al., 2025) reported that non-chemical methods were the most common approaches to invasive plant species control in restoration, in Africa and overall 62.8 ± 12.9% in the other continents, followed by chemical methods with 37.2 ± 12.9%.

3.7 Conservative Methods

Addressing invasive species threats requires global coordination in prevention, control, and eradication efforts. Human activities disrupt ecosystems, increasing invasion risks (Gallardo et al., 2024).Climate change diminishes plant protection effectiveness, worsening impacts on native species. Conservation should focus on maintaining diverse native plant communities to enhance invasion resistance, especially as temperatures rise.

Restoring and protecting plant diversity is crucial for preventing invasions and preserving biodiversity. Investments in native biodiversity protection are vital as climate change continues. Biodiversity remains important for invasion resistance even under drought conditions, and reducing fertilizer use is recommended to limit negative impacts on grasslands(Blom et al., 2025).

Choosing the right Invasive Species Management Models (ISMMs) is crucial for effective eradication. These systematic models analyze invasive species management strategies, helping to understand human actions during invasion processes.

Reaction-Advection-Diffusion Models (RADMs) and Integrodifference Equations (IDEs) are mathematical methods used to predict the growth and spread of invasive species.RADMs provide continuous tracking of movement, indicating areas of abundance or scarcity, while IDEs focus on specific intervals, such as annually, useful for monitoring seasonal breeding (Skinner et al., 2026).

Gravity Models (GMs) analyze invasive species migration through local movements and long-distance jumps, emphasizing spread patterns by considering human transport methods and traffic data (Álvarez-Martínez et al., 2026). This helps identify points for intervention and prevention. Particle Tracking Models (PTMs) predict how species disperse while passively drifting in air or water, accounting for three-dimensional movement and using environmental data like wind and water currents for accuracy (Qian & Grau, 2025).

Nonspatial discrete-time Population Growth Models (NSPGMs) predict changes in invasive species populations over regular intervals based solely on current population size, using birth and survival rates, making them suitable for species with short breeding periods. In contrast, Spatial Population Growth Models (SPGMs) track the locations of different life stages across landscape patches and species movement (Bacher et al., 2025).

Cellular Automata Models (CAMs) represent landscapes as grids of cells that can be either occupied or unoccupied by invasive species. These models assess each cell and its neighbors, allowing invasive species to spread based on local interactions, differing from the top-down approach of other models (F. F. Li et al., 2025). Individual-Based Models (IBMs) track each organism with specific traits as they navigate their environment, making decisions based on probabilities related to reproduction and movement. The key distinction between CAMs and IBMs lies in CAMs' fixed grids versus IBMs' real-time tracking of individual movements (Diamant et al., 2025).

Model selection for invasive species management depends on management goals, technical capacity, and data availability. Detailed behaviors require CAMs and IBMs, while spread patterns are suited to Gravity Models or Particle Tracking Models. For both spread and growth, Reaction-Diffusion or Integrodifference Equations are effective(Blom et al., 2025). Accessibility varies based on programming needs and data availability, emphasizing the need for intersectoral collaboration. Combining model results with cost estimates helps evaluate trade-offs(Diamant et al., 2025).

In situ conservation protects species in their natural habitats, preserving ecosystem integrity and resistance to invasions. Ex situ conservation, including botanical gardens and seed banks, acts as a backup when invasive species threaten natural habitats. The growing impact of invasives makes ex situ strategies vital while highlighting the need for in situ approaches (Diamant et al., 2025).

Protected areas, often prioritized for socio-economic factors rather than biodiversity, fail to effectively conserve high biodiversity regions (Novikau, 2021). Effectiveness assessments focus mainly on vertebrates, leaving many areas poorly evaluated. Insufficient protection may lead to habitat degradation and facilitate invasions, jeopardizing the ecosystems that should be prioritized for conservation (Chowdhury et al., 2021).

Payment for ecosystem services has emerged as a conservation strategy addressing forest degradation. Payment for ecosystem service programs are increasingly being promoted as suitable mechanism for addressing the degradation of forest resources in developing countries. These programs compensate local communities for protecting forests instead of exploiting them. The approach aims to achieve dual goals, promoting sustainable forest management while providing economic benefits to communities depending on forest resources (Waruingi et al., 2021).

Prescribed burning helps manage secondary succession by reducing moss cover and litter buildup. However, the frequency of burning influences biodiversity outcomes. Frequent annual burning can lower species richness and favor a few dominant species, harming grassland specialists and homogenizing species composition(Franke et al., 2025). Conversely, burning every three years can enhance species evenness and control succession without negative impacts. Effective fire management preserves plant diversity and invasion resistance by preventing habitat changes that favor invasive species ((Franke et al., 2025). Balancing succession control with biodiversity is key to resisting invasion.

Climate change intensifying droughts and other stresses may accelerate invasive species establishment, reducing native plant populations while facilitating invasive species establishment through maintained reproductive success (Kwon et al., 2021).

4. Conclusion

Given the current global political climate, it is noteworthy that despite documentation and scientific evidence, the issues addressed and the recent initiatives suggested may be shelved or pinned to the bureaucratic inertia which has become mainstream. These challenges are occurring at present, rather than being prospective concerns that may arise in the next 5 to 20 years, and they are already the subject of extensive discussion and widespread recognition. Consequently, the prescribed burning remains the most feasible strategy for NNP. Revamping natural habitats by addressing invasive species is essential for restoring ecological balance. It involves understanding how these species establish and spread, allowing for targeted strategies to prevent ecosystem degradation. The focus is on reestablishing native vegetation and wildlife to enhance ecosystem integrity and resilience. A key goal is to restore disrupted ecosystem functions, such as nutrient cycling and water regulation, which support biodiversity and ecosystem services. Effective restoration requires proactive monitoring, adaptive management, and community engagement to ensure sustainability and support for the efforts. A comprehensive understanding of invasive species ecology, coupled with strategic prevention and control measures, is essential for achieving sustainable environmental management and promoting long-term ecosystem resilience and recovery. Ultimately, the aim is to create ecosystems that are ecologically resilient and self-sustaining by controlling invasive species, restoring native biodiversity, and promoting balance between human activities and nature. This approach addresses both ecological and social dimensions, leading to healthier habitats ready to face future challenges.

Disclaimer (Artificial Intelligence)

During the preparation of this work, the author used Grammarly in order to spell check words and sentences. After using this tool/service, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

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Competing Interests

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