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Original Research

Climate Change Education and Nature Conservation in South Africa: Challenges and Implications for Biodiversity Protection at Kruger National Park

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Abstract

This paper explores the role of Climate Change Education (CCE) in enhancing biodiversity conservation in South Africa, using Kruger National Park as a case study. It highlights how climate change, through rising temperatures, droughts, and increased flooding, threatens ecosystem stability and species survival, while arguing that conservation efforts are weakened when education is not fully integrated into management practices. Using a qualitative, interpretivist approach based on policy and literature analysis, the study identifies key challenges, including limited institutional capacity, fragmented educational implementation, inequitable access, and low climate literacy among stakeholders. The study positions CCE as a transformative tool that promotes climate literacy, adaptive capacity, and pro-environmental behaviour. It demonstrates how strategies such as experiential learning, ranger-led programmes, and curriculum integration can strengthen conservation outcomes. It concludes that institutionalizing CCE as a core component of adaptive management, linked to measurable ecological indicators, can significantly enhance biodiversity resilience and align conservation practice with the realities of climate change.

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Statement of Sustainability: The research links biodiversity resilience with the UN 2030 Agenda (SDG 13 and 15) (2015-2016, 2015). CCE institutionalisation elevates conservation above pure biophysical monitoring to a 'climate-protection culture'. This promotes long-term sustainability by enabling local communities to become informed stewards, thereby minimising human-wildlife conflict and ensuring ecosystem stability in a changing climate.

1. Introduction

Climate change is one of the major threats to biodiversity in the 21st century. This is particularly apparent in South Africa, which has a high diversity of flora and wildlife and rapid weather changes (IPBES, 2019; IPCC, 2022). The worsening climatic conditions, increasing temperatures, protracted droughts and changed precipitation patterns increase the risk of endangerment of ecosystems and species. Keeping children safe in secure environments has become increasingly difficult (Midgley et al., 2017). Conservation efforts should include social and educational aspects to teach people about the environment, help them adapt, and promote stewardship (UNESCO, 2017). Protected areas such as South Africa's Kruger National Park (KNP) play an important role in maintaining biodiversity and ecosystem services at national and regional levels (SANParks, 2020). But climate change is increasing the chances that such things as arid weather, changes in animal habitat and variations in fire ignitions would affect these protected regions. These characteristics may reduce the environment's ability to adapt to changes over time (Ferreira et al., 2017; Kruger & Sekele, 2013).

2. Conceptual and Theoretical Framework

2.1. Conceptualising CCE for Nature Conservation

This study uses the principles of transformational learning theory and interpretivism. Interpretivism allows for a deep examination of the perspectives of stakeholders, recognizing that context and social structures influence how climate change is understood.

Transformative learning theory stresses the power of education to question established opinions, develop critical thinking and bring about changes in attitudes and behaviour. These viewpoints underline the necessity of using structured, action-oriented and participatory instructional techniques for biodiversity protection, given the inherent unpredictability of the climate.

2.2. Comparative Analysis of Educational Frameworks

Research indicates a stark contrast between traditional and emergent educational models. A scoping review of 74 empirical studies (2015–2025) reveals that most of the biodiversity education remains tethered to the Knowledge-Attitude-Behaviour framework (Huang et al., 2024). While the KAB model assumes that increased knowledge leads to behavioural change, recent analyses suggest that this approach often overlooks empowerment and collective processes (Schrader & Lawless, 2004).

In contrast, frameworks focusing on social-ecological resilience utilize systems thinking and stewardship learning to foster adaptive capacity in the face of climate disturbances (Berkes, 2017). This resilience-based approach suggests that education can foster the ability to incorporate multiple forms of knowledge and perspectives into management decision-making (Krasny et al., 20210).

2.3. Evaluation of Measurable Biodiversity Outcomes

A repeated topic across studies is the difficulty of translating educational interventions into tangible ecological outcomes. Even when education efforts in places like Madagascar manage to increase knowledge and modify attitudes, extrinsic factors like as poverty and lack of livelihood options frequently prevent those improvements from leading to less deforestation. This makes evaluation more difficult because of "intangible value changes" which are difficult to evaluate, thus we end up using short-term self-reported measures instead of long-term measurements of environmental quality. Academics suggest that if education is to go beyond broad awareness to emotional, action-oriented outcomes, it must have a direct influence and be linked to specific local settings (Ndaguba & Van Zyl, 2025).

2.4. Regional and Institutional Implementation Gaps

There is recorded evidence of a "fractured and uneven" incorporation of climate and biodiversity subjects in formal education systems globally. An review of regional curricula in Canada found that expectations for climate change are typically superficial and restricted to voluntary senior courses rather than integrated throughout mandated disciplines (Wynes & Nicholas, 2019). Similarly, in Switzerland, the lack of comprehensive biodiversity content in teacher training inhibits teachers' ability to effectively address biological illiteracy (Lindemann-Matthies, 2009). Moreover, CCE is usually disconnected from Education for Sustainable Development. International research synthesis reveals that CCE should be situated within the broader holistic ESD framework, as climate change impacts interrelated issues such as food security and young people (Dillon, 2024).

3. Problem Statement and Research Objectives

3.1. Problem Statement

Although the theoretical link between CCE and biodiversity protection is well-established, actual evidence of observable ecological benefits is still lacking (Crossman et al., 2018) Most current evaluation frameworks highlight the KAB model, concentrating on the individual cognitive change more than tangible biodiversity (Veríssimo et al., 2024).

3.2. Research Objectives

This study examines how CCE is conceptualised, implemented, and constrained within the context of nature conservation in South Africa, using KNP as a case study. The objectives are to:

4. Research Approach and Design

This study adopts a qualitative, interpretivist research strategy using a systematic literature review methodology. To promote transparency and reproducibility, the study adheres to the PRISMA principles for identifying and screening sources.

Inclusion: Peer-reviewed papers published from 2015 to 2026; South African national policy documents (e.g., NBSAP, NCCRP); and SANParks management plans.

Exclusion: Technical climate models without social integration; general environmental education without a climate focus; and publications not in English.

Ten key papers were selected and evaluated through a thematic coding approach to detect risk perceptions and policy-practice gaps in conservation management.

5. Climate Change and Biodiversity Threats in Kruger National Park

5.1. A synopsis of the Kruger National Park

Flora and fauna can inhabit a secure environment like KNP. KNP is in the South African provinces of Mpumalanga and Limpopo, covering roughly 19,485 square kilometres. The park was established in 1898 and encompasses several river systems, including the Limpopo, Letaba, Olifants, and Sabie. The composition of rocks and precipitation volume influence the migration of savanna ecosystems from north to south (SANParks, 2020; Walker et al., 2022). KNP is one of the most visited locations in Africa to observe a diverse array of flora and fauna. Biggs et al. (2003) report the presence of around 1,900 plant species, 500 bird species, 147 mammal species, and several reptiles and invertebrates. Researchers may investigate disturbance regimes, ecosystem dynamics, and the impact of climate change on biodiversity at KNP, which serves as a living laboratory. This is due to its diverse flora and fauna, as well as a sustainable research infrastructure.

5.2. Observed and Projected Climate Change Impacts

Models and actual climate data indicate that average annual temperatures in KNP have increased significantly over the past few decades. Droughts are becoming more prevalent and severe despite lower precipitation (Kruger & Sekele, 2013). The river catchments in the park have seen progressively hotter, drier days and extended intervals without precipitation. This exacerbates losses from evapotranspiration and complicates the procurement of surface water (Engelbrecht et al., 2015). Climate models for the region indicate that if emissions remain elevated, temperatures could increase by 2 to 4 degrees Celsius by mid-century. (IPCC, 2022) This will result in increased precipitation, hence heightening the likelihood of floods and droughts as experienced in January 2026. The climate in KNP is becoming increasingly hot and arid, with floods occurring more frequently (de Beer, 2026; Weiss et al., 2024). Excessive rainfall has resulted in river overflows, flooding of lowlands, and significant habitat alterations (Figure 1).

When La Niña and cyclones occur, these disasters are exacerbated. These floods impede access to parks and cause damage to the structures within them. They alter animal habitats, compelling crocodiles, amphibians, and hippos to relocate to elevated areas (Africa News, 2026; Cavalcante et al., 2025). These incidents illustrate the significance of employing adaptive management strategies to address climate change in conservation efforts. These alterations are not typically considered by managers in terms of climate stability, nor are they the primary concerns of individuals in KNP regarding ecosystems, water-dependent fauna, and conservation infrastructure.

Figure 1. Flooding at the Kruger National Park, Letaba, in January 2026 (Source: Nordling, 2026).

Since that time, La Niña has predominated as the primary meteorological pattern in the KNP, and the annual precipitation has gradually increased (Knight & Evans, 2024). Figure 1 illustrates that Kruger's flooding is a crucial component of the ecology, as it replenishes the Park's wetlands and aquifers. Walker et al. (2022) assert that extracting water from the KNP poses a risk to wetlands and aquifers by increasing the frequency of dry spells and droughts. Increased flooding and droughts significantly impede families' access to sufficient water. Individuals and fauna residing adjacent to the national park must identify other groundwater sources due to these catastrophes (Cavalcante et al., 1993).

Research indicates that in KNP (Kruger & Sekele, 2013; Ferreira et al., 2017; de Beer, 2026), temperatures are increasing, droughts are prolonged, hydrological patterns are altering, and floods are intensifying. Recent floods have been triggered by Kenneth and Idai, two tropical storms, as well as sluggish low-pressure systems and La Niña. The floods have complicated recreational activities for tourists, displaced wildlife, and submerged low-lying regions (Weiss et al., 2024; Nordling, 2026; Dube et al., 2023). Flooding has caused several regions of Mpumalanga and Limpopo to receive double the usual annual rainfall. This illustrates the difficulty

of predicting future developments about water. Floodwaters can inundate wetlands and aquifers, but in severe instances, they can devastate habitats and impede the survival of flora and fauna.

5.3. Changes in Species and Ecosystem Vulnerability

Alterations in precipitation and increasing temperatures affect the development of woody grasses. This then alters the environments available for herbivores and predators (Midgley et al., 2017). Certain areas are experiencing a decline in bushland, whereas others are witnessing a reduction in grassland. Alterations in fire regimes are impeding nitrogen's passage through the soil, hindering plant regrowth. This is due to the increasing instability of biomass and the more frequent occurrence of severe weather events. Consequently, ecosystems exhibit diminished stability. Species with limited mobility or restricted habitats are particularly vulnerable to climate change, which may lead to a contraction of their ranges or a decline in local populations (Thuiller et al., 2015).

The alterations in the physical environment illustrate the interconnection between climate change and biodiversity loss. This may impede KNP's ability to adapt to contemporary developments. Flooding is a consequence of climate change, which alters animal habitats, ignites fires, and affects plant growth. This affects the stability and equilibrium of ecosystems (Midgley et al., 2017; de Beer, 2026). Floods displace aquatic and semi-aquatic creatures, such as crocodiles and hippopotamuses. Terrestrial animals ascend to elevated terrain. While animals may struggle to locate sustenance, predators may encounter less difficulty in this regard (Africa News, 2026; Cavalcante et al., 2025). These alterations may disrupt established food networks and complicate efforts to maintain ecosystem security.

5.4. Implications for Biodiversity Management

Impacts on Biodiversity Management Climate change is exerting an increasingly significant influence; therefore, KNP must embrace innovative strategies and adopt a proactive approach to preserving biodiversity. At SANParks, adaptive management frameworks that employ scenario planning, experiential learning, and climate science for conservation decision-making are now widely used (SANParks, 2018). Adaptation will be ineffective without technical solutions, informed stakeholders, institutional learning, and conservation specialists well-versed in climate change. Lotz-Sisitka et al. (2015) assert that climate-informed education is essential for enabling managers, rangers, communities, and visitors to comprehend climate-related concerns, as well as for promoting adaptive management and participation in conservation initiatives. Floods, for instance, compel individuals to relocate (Figure 2), and extreme weather conditions hinder animals' access to sustenance (Nordling, 2026; Nhamo et al., 2025).

Figure 2. Flooding in the Kruger National Park in January 2026 (Source: Nordling, 2026).

Ecological alterations can occur rapidly in response to severe weather conditions. Real-time environmental monitoring and proactive training are two essential components of effective adaptive management. Climate Change Education can facilitate adaptation for both humans and wildlife to shifting climatic conditions by instructing park personnel and community members on the hazards of flooding, safety measures, and the resilience of ecosystems. As an ecosystem becomes increasingly unstable, this may help safeguard its biodiversity. If Climate Change Education is excluded from biodiversity management initiatives, adaptive solutions may not integrate effectively, respond too swiftly, or encompass all the impacts of climate change on ecosystems. Walker et al. (2022) and Nhamo et al. (2025) assert that ecological planning for adaptive management must consider both extreme arid and extreme humid circumstances. Climate Change Education elucidates animal behaviour, the occurrence of floods, and the self-repair mechanisms

of ecosystems (Monroe et al., 2019; de Beer, 2026). Place-based education, such as ranger-led flood interpretation programmes, can engage individuals, support conservation initiatives, and promote fact-based decision-making to safeguard biodiversity.

6. Policy and Institutional Frameworks Supporting Climate Change Education

6.1. Global Frameworks: SDG 13 (Climate Action) and SDG 15 (Life on Land)

International Frameworks: SDG 15 (Life on Land) and SDG 13 (Climate Action) The United Nations' (2015) Sustainable Development Goals (SDGs) assert that education is a vital and effective means to safeguard biodiversity and combat climate change. Per SDG 13 (United Nations, 2015, Target 13.3), nations are required to "augment education, awareness-raising, and human and institutional capacity concerning climate change mitigation, adaptation, impact reduction, and early warning systems." This perspective asserts that societies possessing substantial knowledge of climate change and the ability to facilitate adaptation and transformation are equally vital to sustainable climate governance as technological and policy interventions. SDG 15 pertains to the preservation of terrestrial ecosystems in an environmentally beneficial manner. Education indirectly sustains biodiversity, fortifies ecosystems, and instructs individuals in the prudent utilisation of resources. UNESCO (2020) has reinforced this connection by emphasising that education is essential to ensure the fulfilment of global commitments to safeguard biodiversity and the climate in every community. This constitutes a crucial aspect of educating individuals about environmental conservation. The Sustainable Development Goals (SDGs) suggest that safeguarding conservation areas such as KNP requires educating the public about climate change.

6.2. National Climate Change and Biodiversity Policies in South Africa

The South African government asserts that education, awareness-raising, and capacity-building are essential for addressing climate change and safeguarding biodiversity. The National Climate Change Response Policy (NCCRP) asserts that to ensure individuals can adapt to and manage climate change sustainably, they must enhance their awareness, acquire knowledge, and get training (Department of Environmental Affairs (DEA, 2011). The plan stipulates that schools must be prepared for climatic variations. Individuals of all ages will have the opportunity to learn about climate change, its potential impacts, safety measures, and coping strategies. The National Biodiversity Strategy and Action Plan (NBSAP) underscore the significance of educating individuals about biodiversity and enhancing their awareness to bolster institutional capacity, foster public concern for biodiversity, and promote support for conservation initiatives (DEA, 2015). The NBSAP advocates for enhanced educational programmes for individuals residing near protected areas and for the areas themselves, aiming to provide them with the knowledge to address issues such as climate change, habitat degradation, and species extinction. South Africa must educate the populace about climate change as an integral component of its biodiversity management strategy. These policy mechanisms demonstrate this. This illustrates the significance of education in South Africa's conservation landscape, both in mitigating change and in addressing it.

6.3. SANParks Strategies on Climate Change, Conservation, and Education

The South African National Parks (SANParks) has formally recognized that climate change significantly complicates the preservation of protected areas and wildlife. The SANParks Climate Change Response Strategy emphasizes that engaging individuals, educating them, and enhancing awareness are crucial methods for fortifying communities and ecosystems. It states that every community must be prepared for climate change (SANParks, 2018). The strategy stipulates that park personnel, residents, and visitors must enhance their understanding of climate change to facilitate adaptive management, evidence-based decision-making, and garnering support for conservation initiatives. This method is superior in premier parks such as KNP as it incorporates climate change into initiatives for environmental education, fire management, biodiversity monitoring, and water resource management (SANParks, 2020). The Environmental Education and Awareness Strategy of SANParks emphasizes the need for protected areas for experiential learning on climate change and biodiversity conservation (SANParks, 2025).

Through children's activities, community outreach, and ranger-led tours, individuals can engage in discussions regarding climate change, environmental alterations, and the advantages and disadvantages of conservation. These programs demonstrate that SANParks is committed to integrating education as a fundamental component of environmental conservation, rather than treating it as a peripheral activity. The UNFCCC (2016) regulations regarding Climate Change Education and Action for Climate Empowerment globally indicate that this is permissible. SANParks' policy instruments provide protected places with a robust institutional foundation for educating individuals about climate change. This is particularly applicable in places such as KNP, where climate change may exert a significant impact.

6.4. Policy–Practice Gaps in Implementing Climate Change Education

Despite the existence of progressive policy frameworks at international, national, and institutional levels, not all SANParks implement Climate Change Education uniformly (Table 1). This arises from problems with the configuration and functionality. Lotz-Sisitka et al. (2015) and Snyman (2014) contend that studies on environmental education within South African protected areas reveal ongoing challenges attributed to inadequate money, staffing, and time resources. They believe that safeguarding biodiversity supersedes the importance of education. Certain environmental education programs address climate change indirectly. Structured

Climate Change Education programs focus on adaptation, mitigation, and socio-ecological resilience. KNP faces a conundrum at the park level: it must identify a method to finance both short-term conservation initiatives, such as fire management, anti-poaching efforts, and infrastructure upkeep, alongside long-term educational programs (Ferreira et al., 2017; SANParks, 2020).

Table 1. Critical synthesis: from conceptual frameworks to operational metrics.

Indicator Category	Operational Metric	Source
Institutional	Proportion of conservation budget allocated to CCE-linked adaptation versus reactive disaster response	(Adom & Nadunga, 2026)
Ecological Proxy	Reduction in "response lag" between a TPC breach (e.g., flood level) and management action due to improved staff literacy	(Biggs et al., 2003)
Cognitive	Stakeholder literacy scores regarding species-specific "flood hotspots" and displacement risks	(Monroe et al., 2019; Nordling, 2026)

Ranger-led interpretive and educational programs raise awareness considerably but may not use the most effective methods to educate people about climate change or assess their learning and behaviour change (Monroe et al., 2019). In the past, it has not been fair that some people living near protected areas have not been able to learn about climate change. In these areas, persons are denied access to conservation education programs due to socio-economic challenges, mobility issues, and unequal access to technology (Ardoin et al., 2020). Schools must do a better job of educating on climate change, fund it better and use innovative ideas as its basis. This will contribute to the conservation of biodiversity and increase the resilience of the SANParks protected areas to climate change. South Africa's NBSAP and SANParks strategies are robust, but a major implementation obstacle is the lack of capacity to translate awareness into co-ordinated investments (Adom & Nadunga, 2026). There is chronic under-funding for long-term education in favour of short-term anti-poaching and infrastructure repair (Adom & Nadunga, 2026).

The Shift from KAB to Social-Ecological Resilience: Current Climate Change Education is dominated by the Knowledge-Attitude-Behavior model. A scoping review of empirical studies found that most initiatives assume that cognitive shifts automatically lead to behavioural change (Marcinkowski & Reid, 2019). But this linear approach often bypasses collective empowerment. On the other hand, resilience-based framework, applying systems thinking and stewardship learning, are emerging as a more effective alternative to foster the adaptive capacity in the face of climate disturbance (Nursimulu, 2015). These models conceptualize education not as an isolated intervention, but as part of larger social-ecological feedback loop (Schlüter et al., 2019).

Barriers to Tangible Biodiversity Outcomes: Major attribution barriers often impede the transition from conservation theory to measurable ecological gains. Studies from places such as Madagascar have revealed that while environmental education programmes can increase local environmental knowledge and awareness, wider socio-economic issues, such as persistent poverty, often prevent these behaviour changes from resulting in reduced deforestation and long-term conservation benefits (Guinart et al., 2020). Furthermore, many evaluations of environmental education programmes depend on changes in attitudes, values and perceptions which are difficult to measure, resulting in an overemphasis on short-term self-reported outcomes, rather than long-term ecological indicators (Ardoin et al., 2020). Therefore, to ensure that environmental education contributes to physical conservation outcomes in a meaningful way, programmes should emphasise action-oriented and context-specific approaches that consider local socio-economic realities and community needs (McEwen et al., 2022).

Institutional Gaps and Curricular Fragmentation: There is a documented "fractured and uneven" implementation of CCE within formal systems.

A lack of integration into the curriculum: Climate change issues are often superficial and confined to senior elective courses rather than being integrated across the mandated curriculum in Canada (Wynes & Nicholas, 2019).

Teacher Preparedness: In Switzerland, the lack of systematic inclusion of biodiversity information in teachers' education restricts their ability to handle "biodiversity illiteracy" effectively (Lindemann-Matthies et al, 2009)

Disciplinary isolation: CCE is often separated from Education for Sustainable Development. The synthesis suggests CCE needs to be embedded into the holistic ESD framework to solve interrelated concerns including food security and human relocation (Odoom, 2025). Proposed Operational Indicators for Monitoring Progress

To bridge these gaps, CCE programs must move beyond internal cognitive change and adopt the following explicit metrics:

7. Formal and Informal Education Programmes

7.1. Formal and Informal Education Programmes at Kruger National Park

Kruger National Park (KNP) offers both academic and informal educational opportunities. There exist both formal and informal programmes that educate individuals on ecology, conservation, and environmental issues. The Environmental Education and Awareness projects conducted by SANParks serve as the primary method for organizing these events. Their primary emphasis is on students, educators, the community, and youth organizations, particularly those located near the park (SANParks, 2021).

Individuals can acquire knowledge about ecosystems and the preservation of flora and fauna in the park through educational excursions aligned with their curriculum, participation in conservation camps, and engagement in outreach programs. Discourse regarding climate change is infrequent. Discussions are emerging on drought, fire dynamics, and the evolving ecology of KNP (Ferreira et al., 2017; SANParks, 2020).

Protected places function as ”living laboratories” that demonstrate the environmental alterations induced by climate change. KNP’s Climate Change Education (Ballantyne & Packer, 2016) is particularly significant for out-of-school learning. KNP employs place-based and experiential methodologies (Ardoin et al., 2020), which are the most effective means of educating individuals about global conservation. They underscore the importance of learning through partnership with ecosystems and conservation specialists. Research on environmental education in South African protected areas reveals that these programs predominantly convey basic conservation principles rather than deepening students’ understanding of climate change. This complicates children’s ability to discuss the causes of climate change, strategies for addressing it, and methods for maintaining resilience throughout its occurrence (Lotz-Sisitka et al., 2015). Climate change education ought to be a significant component of both official and informal programs, regardless of the deteriorating environmental conditions. This is an excellent method to assist the environment.

7.2. Initiatives Led by Rangers and Visitor Education

Tourists may enrol in ranger-led programs in KNP, a prominent protected area in South Africa. A primary objective of these programs is to educate individuals about climate change. Individuals from countries such as the United States, United Kingdom, France, Canada, Ghana, Zambia, China, Brazil, and other nations can acquire knowledge about environmental protection in many locations. Examples include museums, information centres, educational displays, guided wildlife excursions, and ranger-led hikes (SANParks, 2020). Field guides and rangers excel at translating scientific discoveries into comprehensible narratives for all audiences. Visitors to the park can readily observe the detrimental effects of climate change. They frequently analyse contemporary data to assess the impact of aridity on factors such as animal behaviour, fire patterns, and additional elements (Ferreira et al., 2017). Flooding has been integral to ranger-led initiatives and visitor programmes that emphasize the impact of climate change on park management, animal habitat utilization, and species migration (de Beer, 2026).

Children can engage in these practical activities to explore the interconnections between extreme weather, ecological alterations, and environmental conservation initiatives. This is an excellent method to retain knowledge acquired in Climate Change Education. While these programmes may prove beneficial, the education they provide to tourists about climate change may not be. Studies on the interpretation of protected areas reveal that climate change discussions often transpire in a disorganised or fragmented fashion, rather than through systematic educational initiatives, depending on the guides’ knowledge, confidence, and training (Ballantyne et al., 2018; Monroe et al., 2019). KNP possesses extensive knowledge regarding climate change; yet it frequently neglects discussions on adaptation strategies, the impact of climate change on individuals and the economy, as well as long-term climate forecasts. This complicates tourists’ understanding of the impact of climate change on biodiversity and their potential contributions to ecosystem health amidst climate change (Moser, 2016). To assist SANParks in achieving its conservation objectives and addressing climate change, they could train more rangers, identify more effective methods of communicating climate change, and enhance the accuracy of climate change assessments for tourists.

8. Challenges in Implementing Climate Change Education

8.1. Institutional and Resource Constraints

Instead of being a fundamental part of biodiversity management, Climate Change Education is usually positioned as an auxiliary or supporting role within conservation organisations like SANParks. In South Africa, empirical research has demonstrated that enforcement, species protection, and ecological monitoring are often prioritized by institutions, especially when extreme pressures like poaching, habitat degradation, and stress brought on by climate change are present (Lotz-Sisitka et al., 2015; Ferreira et al., 2017). This makes it harder for education programmes to plan and carry out long-term, climate-focused educational initiatives because they frequently have little funding, few employees, and few opportunities for professional growth. The conflict between urgent conservation measures and educational requirements is exemplified by flood incidents. Extreme flooding frequently reduces the amount of time and attention available for scheduled educational programmes because park resources are redirected toward infrastructure restoration, visitor safety, and wildlife rescue (de Beer, 2026).

To establish a feedback loop between conservation practices and stakeholder engagement, it is imperative that Climate Change Education be incorporated into core management plans. This will allow for learning to continue even in times of emergency. Education’s marginalization reflects larger structural issues in conservation governance, where urgent ecological threats necessitate quick fixes, leaving less institutional room for long-term learning-oriented strategies that promote resilience and climate adaptation (Biggs et al., 2012; Walker et al., 2022). Priorities for park management during flood events tend to shift toward wildlife rescue, visitor safety, and infrastructure repair, which frequently leaves less staff and funding available for educational programmes (de Beer, 2026; Lotz-Sisitka et al., 2015). This emphasises how crucial it is to include Climate Change Education into core conservation management to sustain education even in times of emergency.

8.2. Access, Equity, and Inclusion

There is still unequal access to Climate Change Education in protected regions, especially for communities who are close to conservation areas like KNP. Participation in environmental education programs is nevertheless hampered by socioeconomic factors, such as chronic exclusion from protected areas, poverty, and inadequate transportation infrastructure (Ramutsindela, 2007). Research on conservation education in South Africa shows that although outreach programs are available, they frequently only reach a small percentage of the local community and might not sufficiently address the climatic vulnerabilities and lived realities of nearby people (Schudel, 2026). By perpetuating current power disparities and restricting opportunities for inclusive knowledge co-production, which is crucial for successful, locally grounded climate adaptation and biodiversity stewardship, this unequal access undercuts the transformative potential of Climate Change Education (Ardoin et al., 2020). According to Nhamo et al. (2025), rural populations that border KNP are disproportionately affected by flooding, and many of them have poor access to early-warning systems and climate education. Ensuring inclusive Climate Change Education can improve community readiness, lessen conflict between people and wildlife, and encourage adaptable behaviours.

Concrete strategies for inclusive participation include expanding community-based outreach programmes that prioritise schools and marginalised communities living adjacent to protected areas, supported by mobile education units and transport access to reduce participation barriers. Additionally, co-creation of Climate Change Education initiatives with local and Indigenous knowledge holders can ensure culturally relevant content and strengthen community ownership of conservation practices. Leveraging multilingual digital platforms, participatory workshops, and ranger–community partnerships can further broaden access, enabling diverse stakeholders to engage meaningfully in climate adaptation and biodiversity conservation.

8.3. Limited Climate Literacy among Staff and Visitors

The disparities in climate literacy between park visitors and conservation personnel present another difficulty. The effects of climate change on KNP are well understood scientifically in research and management, but this understanding is not always successfully applied in the classroom (Kruger & Sekele, 2013; Midgley et al., 2017). According to studies, field workers and environmental educators may not have received specialized training in climate science, pedagogy, or communication, which limits their capacity to hold audiences' attention while facilitating complex conversations about climate uncertainty, complexity, and long-term risk (Monroe et al., 2019; Moser, 2016). Visitors' comprehension of climate change is frequently influenced by incomplete knowledge and preconceived notions, which can reduce their openness to conservation-focused climate messages conveyed through casual interpretative interactions (Ballantyne et al., 2018). To improve the efficacy of Climate Change Education in protected areas, it is imperative that all stakeholder groups develop their climate literacy. The efficacy of adaptive management and engagement initiatives may be diminished by park employees' and visitors' inadequate training in interpreting complicated climate and flood data (Monroe et al., 2019). One way to reduce this literacy gap is to incorporate flooding scenarios into tourist education and training.

8.4. Conflicts between Conservation and Education Mandates

Conflicts between conservation objectives and educational aims are one of the most challenging aspects of managing protected lands. The discord between immediate conservation requirements and long-term educational objectives is a major issue. In contexts such as KNP (SANParks, 2020; Ferreira et al., 2017), biodiversity preservation often takes precedence over long-term educational initiatives. Monitoring animal populations amid droughts, adverse climatic conditions, and illicit wildlife trafficking is crucial. This hierarchy of significance indicates that the institution perceives education as a long-term investment with indirect consequences, in contrast to the immediate and quantifiable outcomes of enforcement and ecological initiatives. Studies on adaptive and transformative governance indicate that neglecting education undermines conservation effectiveness by limiting adaptive capacity, public support, and behavioural changes essential for long-term biodiversity resilience against climate change (Folke et al., 2005; Sterling, 2011). Climate change education ought to be redefined as a fundamental component of adaptive conservation, rather than as a competing institutional responsibility. Severe weather disasters, especially flooding (de Beer, 2026), exemplify the tension between immediate conservation efforts and long-term educational goals. The park's main goal is to be ready for disasters, but Climate Change Education should be a part of everyday life so that it can help when things go wrong.

9. Implications for Biodiversity Protection at Kruger National Park

9.1. Educational Gaps and Conservation Effectiveness

Effective and ineffective approaches in education and conservation as climate change exacerbates environmental stress, the protection of biodiversity is undermined by KNP's inadequate educational efforts about climate change within its conservation policies. Ferreira et al. (2017) and SANParks (2020) assert that while scientists possess substantial knowledge regarding the impact of climate change on the park's ecosystems, this information is frequently not integrated into structured educational programmes that aid management decision-making, enhance visitor comprehension, or engage the community. Research on conservation education indicates that stakeholders lack a comprehensive understanding of how climate change influences biodiversity, primarily because

climate communication is often unclear and poorly interconnected. This ambiguity hinders individuals' participation in environmentally beneficial activities (Monroe et al., 2019). The sole means by which protected areas can alter the environment are through management and technology. They may not recognize the significance of educating individuals about the ongoing changes in the world. This issue arises because social learning is crucial for maintaining biodiversity in a rapidly changing world (Ardoin et al., 2020). KNP's environmental protection initiatives are inadequate, as they fail to address actual weather-related catastrophes such as flooding.

9.2. Lessons for SANParks: Institutionalising Climate Change Education

Insights for SANParks: Strategies for educating the public on climate change within the framework. It is imperative to recognize that educating individuals about climate change must be integral to SANParks' conservation objectives, rather than merely an ancillary task. The research on adaptive governance emphasizes the significance of learning and education for managing complex social-ecological systems amid unpredictability. This enables firms to adjust to environmental changes and climate-related risks (Folke et al., 2005). Integrating Climate Change Education into its long-term planning, employee training, monitoring systems, and performance indicators could help SANParks reconcile its conservation management objectives with long-term climate adaptation (SANParks, 2018). Institutionalisation would make rules, processes, and stakeholder involvement more consistent. It would make sure that education directly helps KNP, and the greater network of protected areas develop stronger, which would help protect biodiversity. The flood case study shows that Climate Change Education should be a basic way to protect the environment and get people interested. Proper use of flood monitoring data in training programs helps preserve biodiversity and prepares employees and visitors for the challenges posed by climate change.

9.3. Climate Change Education and Biodiversity Resilience

Educating individuals of climate change and methods to safeguard biodiversity. It is essential for individuals to be informed about climate change to enable ecosystems and communities to adapt to alterations in weather patterns. This will result in a greater diversity of living organisms. Education enhances ecological adaptive management by informing individuals about climatic risks, feedback mechanisms, and constraints. This enhances the efficacy of conservation initiatives (Midgley et al., 2017). Climate Change Education enhances the understanding of climate change among park employees, visitors, and residents. It motivates individuals to safeguard the environment and facilitates collaborative efforts towards this goal (Lotz-Sisitka et al., 2015). Folke et al. (2005) asserts that educational institutions prioritising learning are more adept at navigating uncertainty, generating innovative ideas, and preserving biodiversity amidst climate change. In the short term, increasing Climate Change Education within KNP raises awareness and, over time, strengthens systems for biodiversity protection and conservation.

Despite the negative effects caused by flooding in KNP, conversely, flooding facilitates the regrowth of plants vital to wildlife food webs, replenishes wetlands and aquifers, disperses nutrient-rich sediments, and serves as both a stressor and a means of rejuvenating plant life (Nordling, 2026; Knight et al., 2024). Climate Change Education programmes ought to educate park managers on enhancing their strategies for species impacted by both drought and flood cycles. This is because these cycles may connect biological processes to distinct indicators of biodiversity. Flooding has catastrophic consequences, yet it also serves two significant purposes. It enhances wetlands and aquifers, facilitates the distribution of nutrient-rich sediments, and promotes plant growth. All these elements are crucial for natural food webs (Nordling, 2026; Knight et al., 2024). The park may facilitate adaptation for individuals and the environment by educating the public about climate change through observable phenomena in nature. This would facilitate the prolonged persistence of biodiversity.

9.4. A Short Case Vignette

A practical example is the employment of ranger-led programmes in Kruger National Park where flooding events are interpreted for visitors and communities to explain changes in animal movement; habitat shifts and ecosystem dynamics and connect real-time observations to an understanding of climate change. These education programs convert ecological monitoring data (flood patterns, displacements) into accessible information, allowing stakeholders to identify climate risks and effective solutions. The effects of these activities are tangible and include increased stakeholder awareness, adaptive behaviours (e.g. support for conservation measures) and increased biodiversity resilience through better decision-making and engagement in conservation initiatives.

10. Strengthening Climate Change Education for Nature Conservation

To save the ecosystem, it is imperative to enhance public awareness on climate change. We should not engage in arbitrary activities at KNP to promote awareness of climate change. We should employ a strategically integrated pedagogical framework that adapts to environmental changes. Floods, droughts, and rising temperatures are critical indicators that require public awareness of climate change and encourage individual responsibility for environmental protection.

10.1. Institutional Capacity Development Linked to Adaptive Management Indicators.

Facilitating the utilisation of indicators for adaptive management by enterprises. To operate at KNP, rangers, conservation managers, and environmental educators require enhanced training in Climate Change Education. These individuals are crucial for monitoring the environment and mobilising support from others. SANParks employs Thresholds of Potential Concern (TPCs) as a significant component of their change management strategy. They may facilitate the alignment of educational and environmental objectives (Biggs & Rogers, 2003; SANParks, 2020). Flooding devastates fauna, erodes soil, alters wetland conditions, and displaces river courses. Ranger training programmes addressing TPCs associated with floods may incorporate education on climate change. This would enable personnel to identify climate indicators, alert tourists and communities more effectively to potential threats, and implement measures before environmental changes occur. Research indicates that conservation professionals proficient in interpreting and discussing climate data are more effective at transforming monitoring information into actionable insights for stakeholders' decision-making (Monroe et al., 2019; Walker et al., 2022). Incorporating Climate Change Education into SANParks' performance and staff development plans will ensure that education is utilised to enhance resilience and facilitate informed decision-making during climatic crises, such as significant flooding events.

10.2. Curriculum Integration Aligned with KNP Conservation Monitoring Systems

Curriculum integration with KNP's conservation monitoring methods. Integrating climate change information into KNP's education activities is critical for improving biodiversity results. KNP's school outreach, ranger training and visitor interpretative programs should include long-term ecological monitoring systems such as rainfall data, river flow, changes in species populations and how fire and flooding interact (SANParks, 2020; Ferreira et al., 2017). Flooding is a huge part of it because it helps pupils connect climate change to practical things like altered habitats, animal migrations and reproductive patterns. Research demonstrates that contextualizing local ecological data in place-based climate education promotes student involvement, interest, and understanding (Ardoin et al., 2020).

Climate Change Education can directly support biodiversity monitoring and management objectives by correlating flood-related learning with observable indicators, such as the movement patterns of hippos, the recovery rate of wetlands, or the rate of spread of non-native plants following a flood. Then the new programme component enhances learning and conservation efforts by strengthening the link between education, ecological data, and adaptive management. It incorporates a blend of digital and experiential activities to prepare individuals for floods and safeguard flora and fauna.

10.3. Digital and Experiential Learning Supporting Flood Risk Awareness and Biodiversity Resilience

Digital and hands-on learning methodologies are crucial for Climate Change Education at KNP, as they may yield a greater impact and reach a wider audience. SANParks can leverage mobile applications, virtual tours, interpretive centres, and online educational platforms to provide real-time and historical flood information, along with satellite imagery and maps illustrating species movement (SANParks, 2020; UNESCO, 2019). Guided hikes, ranger presentations, and activities that allow people to observe the floodplain facilitate immediate understanding of the impact of floods on flora and fauna for both tourists and locals. This facilitates the understanding of ecosystems and their temporal changes among youth. Experiential climate education fosters emotional engagement, motivates pro-environmental actions, and enhances long-term knowledge retention (Monroe et al., 2019; Sterling, 2010). Digital and experiential learning can enhance understanding of management decisions, such as temporarily cordoning off regions during floods or altering firefighting methods, when utilised in conjunction with conservation indicators. If they proceed in this manner, individuals are more inclined to support and endorse conservation initiatives.

10.4. Strategic Partnerships and Indicator-Based Knowledge Co-Production

To establish strategic alliances and disseminate information based on metrics, KNP must collaborate with various entities to advance and sustain Climate Change Education. SANParks, academic institutions, research organizations, non-governmental entities, and local communities can synergise to generate knowledge that integrates scientific observation with experiential and indigenous viewpoints (Lotz-Sisitka et al., 2015; UNESCO, 2017). Numerous organisations are collaborating to address the challenges posed by flooding. They include watching people in the community, keeping an eye on parks, and doing climate studies in schools. Universities might assist SANParks by analysing flood patterns, predicting species responses, and developing educational programmes aligned with KNP's conservation objectives.

Incorporating local and indigenous knowledge of flood cycles, wildlife migrations, and landscape changes into community involvement initiatives could enhance educational outcomes and adaptive management strategies. Climate Change Education has the potential to serve as a strategic driver of biodiversity resilience rather than merely an ancillary activity. This can be achieved by uniting individuals who employ quantifiable conservation metrics, such as wetland restoration post-flooding, maintaining stable species numbers, and reducing human-wildlife conflict

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10.5. Integrated Conceptual Model of Climate Change Education at Kruger National Park

Figure 3 illustrates a conceptual model that integrates the primary methods via which Climate Change Education supports KNP's biodiversity. The methodology demonstrates that Climate Change Education initiatives, such as enhancing institutional capacity, integrating climate change into curricula, employing experiential and technological learning, and establishing strategic alliances, directly facilitate adaptive management and stakeholder engagement. Key indicators like as TPCs, monitoring species populations, fire regimes, and water availability (SANParks, 2020; Biggs & Rogers, 2003) assess these processes and their impact on quantifiable biodiversity resilience and conservation outcomes. The approach shows that climate change teaching is not just an extra thing to do in the park. One of the park's main goals is to protect it through a combination of teaching, science, and management. The park learns how the environment is changing by learning adaptive management. Individuals concerned with environmental preservation will acquire knowledge about safeguarding it and appropriate actions to undertake. It will also help socio-ecological systems better withstand climatic stress.

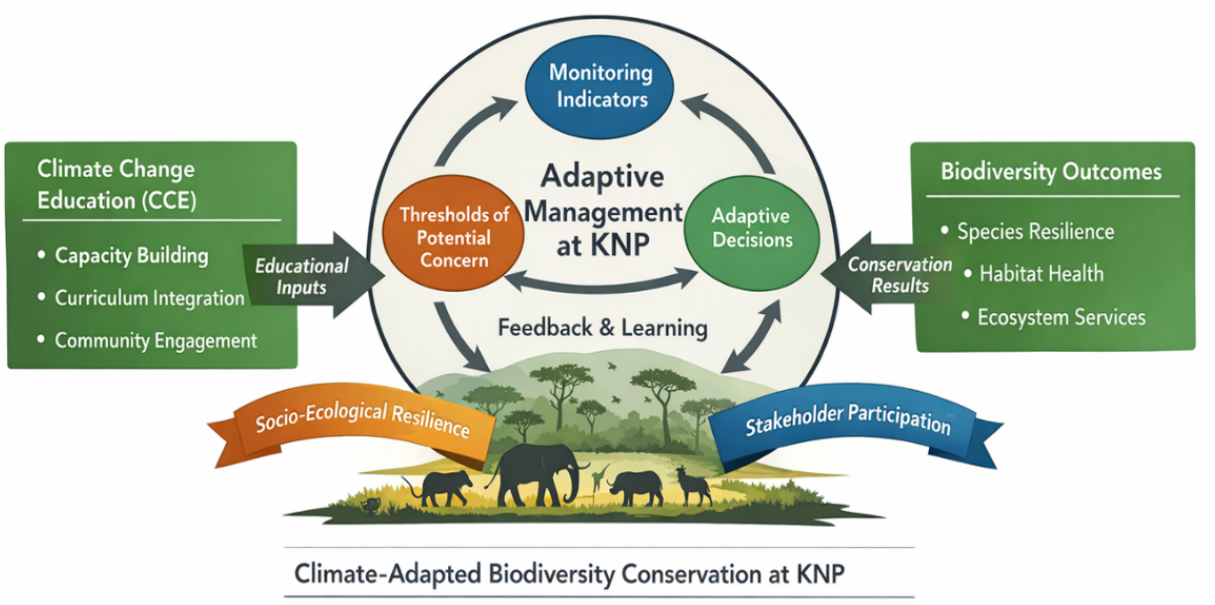

Figure 3. Integrated conceptual model linking Climate Change Education with adaptive management and biodiversity outcomes at Kruger National Park (Source: Modified by Authors, Adapted from Biggs & Rogers, 2003; Folke et al., 2005)

The conceptual approach improves adaptive governance by making Climate Change Education a key, measurable part of adaptive management systems instead of a secondary activity. It strengthens environmental education frameworks by linking learning activities to real-time ecological indicators, such as flooding and species changes. This ensures that the consequences of decision-making and conservation align with the development of new knowledge. The model also brings research, policy, and practice closer together by integrating social learning, institutional capacity, and biodiversity monitoring into a single system that strengthens ecosystems and makes stakeholders more responsive.

The Authors, by incorporating Climate Change Education into KNP's adaptive management framework, enhance both environmental and societal resilience, as illustrated in Figure 3. It integrates education, monitoring, and community engagement with quantifiable conservation outcomes (SANParks, 2020; Monroe et al., 2019).

10.6. Strengthened Theoretical Contribution

This study provides a theoretical contribution by linking Climate Change Education to quantifiable conservation metrics. This integrates teaching with adaptive conservation systems as an intrinsic component of their functionality, rather than only an ancillary task. The KNP scenario demonstrates the analytical incorporation of Climate Change Education into resilience theory and adaptive management using observable indicators, such as TPCs, ecological monitoring data, and social learning metrics. This technique advances global research and bridges the enduring divide between conservation science, policy execution, and educational practice by providing a paradigm for integrating education into protected-area performance frameworks.

The model differs from existing adaptive management frameworks by embedding Climate Change Education directly into ecological monitoring and decision-making processes, rather than treating it as a separate activity (Biggs & Rogers, 2003; SANParks, 2020). It links learning to adaptive governance through feedback loops aligned with indicators such as TPCs, enhancing responsiveness and institutional learning (Folke et al., 2005). These indicators are operationalized through education by equipping stakeholders

to interpret ecological signals and apply them in adaptive conservation actions (Monroe et al., 2019).

11. Conclusion

This study proposes that Climate Change Education has become a core strategy for promoting biodiversity conservation in response to rapid climate change, rather than operating as an ancillary activity within conservation projects. This study employs KNP to illustrate how climate change may impede protected areas' ability to adapt to environmental changes. These hazards include elevated temperatures, prolonged droughts, altered fire patterns, and shifts in the habitats of flora and fauna. The research indicates that conservation initiatives are ineffective when the individuals overseeing them lack sufficient educational materials. It remains crucial to observe phenomena scientifically and address them appropriately. Climate Change Education, when integrated with adaptive management strategies such as TPC, enhances public comprehension of climate change, encourages civic engagement, and fortifies the socio-ecological systems of KNP.

The study improves conservation practices and research in multiple dimensions. It advocates for a place-based, transformative framework of Climate Change Education grounded in interpretivist and transformative learning theories, making a clear connection between education and measurable conservation indicators. This technique augments current studies on environmental and sustainability education by illustrating that education can serve as an essential element of adaptive conservation systems, rather than simply a tool for external awareness-raising. This study contributes to the examination of protected areas by demonstrating that KNP serves as a platform for stakeholder education, biodiversity monitoring, and Climate Change Education. The study assists SANParks and similar conservation organisations in strategising, evaluating their efforts, and engaging the public through education on climate change. This makes it easier to make sure they are following the guidelines as anticipated.

The research shows that there are several ways to improve Climate Change Education. This will assist KNP and other protected areas in sustaining a diverse array of flora and fauna. All regulations and statutes must function cohesively for this to occur. National strategies about climate and biodiversity must explicitly acknowledge that educating individuals about conservation is a crucial component. This ought to be incorporated into the strategies for managing protected areas. Secondly, it is crucial to fortify institutions. Managers, educators, and park rangers will enhance their teaching efficacy if afforded consistent opportunities to research climate change. Third, training methods applicable in diverse locations should be employed to ensure participation from locals, visitors, and employees alike. These projects must combine both factual knowledge and local and indigenous epistemologies. SANParks must systematically integrate educational activities with existing conservation projects to evaluate the impact of Climate Change Education on biodiversity resilience, adaptability, and sustainable conservation outcomes.

This study's analysis is both theoretical and practical, focusing on critical areas requiring further exploration. Future research should prioritize longitudinal empirical studies that investigate the lasting effects of Climate Change Education on conservation outcomes, encompassing ecological resilience, institutional learning, and behavioural change. Mixed-methods research is crucial for clarifying the impact of learning on adaptive management decisions in protected areas by combining ecological monitoring data with social and educational factors. Comparative studies in other national parks and conservation areas would enhance our comprehension of the adaptability and applicability of localised Climate Change Education strategies in different contexts. Research on the application of digital technologies, collaborative knowledge sharing, and participatory monitoring in Climate Change Education can deepen our understanding of biodiversity conservation in the context of climate change.

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