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RESEARCH ARTICLE

Assessing the political vulnerability of National Parks in sub-Saharan Africa using data on digital trends and engagement

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Abstract

1. National Parks (NPs) and other protected areas in sub-Saharan Africa are crucial in attracting international tourists interested in wildlife tourism, contributing to national economies. Despite their cultural, economic, and conservation significance, these areas face diverse development threats, leading to pressures for protected area downgrading, downsizing, or degazettement (known as PADDD).
2. We comprehensively analyse the geographical, historical, and structural aspects of 322 NPs in sub-Saharan Africa and assess their political vulnerability by exploring the interplay of development pressures and public interest (as measured through Wikipedia page views).
3. Fewer than 30% of these NPs possess or report information regarding management plans, even among the five most frequently viewed areas on Wikipedia. This is particularly concerning, since among those who underwent a PADDD event (51 NPs), almost 90% of them also had no information about the existence of management plans.
4. Although we did not identify a statistically significant association between tourism and public interest online, tourism emerges as a potential mitigating factor against PADDD, along with high levels of peace.
5. NPs that garner significant public interest online do not share the same socio-geographic profile as parks that are most resilient to PADDD events. While digital metrics of public interest have potential as indicators of political resilience in NP, our research has shown that these metrics need refinement to fully understand which biophysical and cultural aspects of parks attract more public attention. Overall, effective conservation strategies in sub-Saharan Africa require a more holistic understanding of historical, socio-economic, and cultural factors.

KEYWORDS
conservation culturomics, development threats, environmental policy, protected areas, public interest

1 | INTRODUCTION

Protected areas (PAs) play a crucial role in global biodiversity conservation, preserving diverse habitats, providing sanctuary for unique species, and safeguarding against habitat degradation and fragmentation (Watson et al., 2014). These areas also facilitate the maintenance of crucial ecosystem services such as carbon sequestration, clean water provision, and pollination (Pu et al., 2023). Furthermore, they serve as repositories of genetic diversity vital for species' resilience and adaptation (Figgis et al., 2015) and can significantly contribute to climate change mitigation (Melillo et al., 2016). Often coinciding with biodiversity hotspots, PAs also support rigorous scientific research, providing insights into ecological dynamics, evolutionary processes, and species interactions (Correia et al., 2016; Mittermeier & Rylands, 2017). Among various categories of PAs, National Parks (NPs) are perhaps the most iconic, hosting some of the world's most spectacular landscapes and natural phenomena (Keiter, 2013).

In sub-Saharan Africa, numerous PAs enjoy global recognition for their abundant and diverse wildlife, unique megafauna, and stunning landscapes. Despite their significant cultural importance in driving ecotourism demand and supporting conservation efforts (Buckley & Mossaz, 2018; Hausmann et al., 2017), PAs worldwide face vulnerability to persistent development pressures and civil conflicts (Brockington, 2002; Jones, 2021). Left unchecked, these pressures can lead to significant consequences, including decreases in legal restrictions on human uses within a PA (known as Downgrading), a reduction in PA size (known as Downsizing), and even a complete loss of legal protection status (known as Degazettement). These processes are collectively known as protected area downgrading, downsizing, and degazettement or PADDD (Mascia & Pailler, 2011; Mascia et al, 2014; Pack et al., 2016). A global dataset has been created to track these events and identify the factors that catalyse them (Kroner et al., 2019; Qin et al., 2019). The occurrence of PADDD events may be favoured by contextual factors and the location of the protected area (Keles et al., 2020). Alongside top-down decision-making processes, a lack of transparency, and limited commitment to procedural obligations coupled with power dynamics prevent successful opposition to this phenomenon (Dawson et al., 2018; de Koning et al., 2017; Morea, 2019).

Addressing PADDD requires robust management facilitated by polycentric governance of protected areas (De Vos et al., 2019). Currently, governance structures of sub-Saharan African PAs encompass collaborative management involving the state with other institutions, whether private or NGOs, management by responsible federal/national agencies, or even government-delegated management. Additionally, there are PAs governed locally, privately, or collaboratively involving diverse societal actors (UNEP-WCMC, 2023). In sub-Saharan Africa, efficient collaboration among international actors, governments, the private sector, and local communities is considered imperative and should be grounded in a governance framework that emphasises justice, inclusivity, trust, and equitable power relationships (Siakwah et al., 2020). Indeed, a collective effort involving various stakeholders (e.g., managers, local communities, NGOs, academics, etc.) working alongside central governments to enhance transparency and accountability can quickly counteract these threats (Nuttall et al., 2023; Qin et al., 2019). This is particularly the case where there is a trade-off between conservation costs and development (Tesfaw et al., 2018). In such instances, demonstrating the societal value of PAs can potentially render them less susceptible to such events (Bernard et al., 2014; McDonough MacKenzie et al., 2020).

The political vulnerability of PAs can thus be framed as a balance between development threats (e.g., mining, infrastructure development, and agriculture) and the capacity of civil society to resist these threats, which in turn heavily depends on public support for the protected area (Guedes-Santos, Correia, Mendes Malhado, & Ladle, 2021; Jepson et al., 2017). However, measuring public support can be challenging and costly if using a more traditional social survey approach. This has led some scientists to suggest the use of metrics of digital engagement with PAs (e.g., page views of websites, internet searches) as proxies for potential support (Correia et al., 2018, 2021). The premise is that digital interest in a protected area often correlates with a personal desire to visit, and/or an individual valuing some aspect of the park, be it scientific or cultural (Souza et al., 2021).

Metrics of digital engagement are typically calculated through culturomics, a form of analysis that studies cultural trends through the quantitative analysis of digitised texts (Ladle et al., 2016; Michel et al., 2011). Several studies have used culturomics to quantify public interest in PAs. For instance, Correia et al. (2018) investigated the connection between indicators of public interest and the internet visibility of PAs, highlighting a robust relationship between public interest (measured through Google Trends) and their online presence. Interestingly, this study also found that areas with more online presence seemed to be more robust to PADDD events. Guedes-Santos, Correia, Jepson, and Ladle (2021) used Wikipedia pageviews (PVs) as a metric of public interest in Brazilian PAs and found that both national and international attention was greater for larger, well-established areas, particularly NPs. The advantage of these digital, data-rich approaches is their ability to operate on a wide geographic scale and their cost-effectiveness (in contrast to traditional social survey methodologies). However, drawbacks include: (i) 'interest' can also be influenced by negative sentiments (e.g., conflicts), though these will typically be less

significant drivers of engagement compared with positive motivations such as intention to visit (e.g., Souza et al., 2021, 2024); (ii) results may be biased by internet geographies, limiting their capacity to capture the perspectives of local communities without internet access (Ladle et al., 2016); (iii) digital metrics might lack precision, as they do not directly measure potential support like survey-based methods such as willingness to pay.

Culturomic approaches may be particularly relevant for assessing global interest in sub-Saharan African NP, where international tourism significantly drives socio-economic value (Rhama et al., 2020). In this context, our study has three main objectives: first, to provide a comprehensive analysis of the geographical, historical, and structural aspects of African NP to identify the socio-geographical catalysts behind PADDD events. Second, to investigate the relationship between public interest (as measured by Wikipedia page views) and pressure indicators, taking into consideration country-level socio-economic factors. Third, to explore the potential impact of pressure indicators, country-level socio-economic factors, international tourism, and online visibility on the likelihood of different types of PADDD events. Our central hypothesis is that African NP experiencing higher development pressures, coupled with lower online visibility and less international tourism, are more vulnerable to PADDD events.

2 | MATERIALS AND METHODS

2.1 | Socio-geographic attributes of NPs in sub-Saharan Africa

We compiled information on the PAs of sub-Saharan Africa from the dataset available in the World Database of Protected Planet (UNEP-WCMC, 2023 from Protected Planet; https://www.protectedplanet.net). The WDPA is a global database that compiles detailed information about PAs worldwide, including geographical location, protection category, area, and conservation status. In addition to these descriptive characteristics of the areas obtained from WDPA, we also compiled information on the existence of a management plan, the size of the area, and the year in which it was established. These models are described below. The latter was converted to a measure of the 'age of the protected area' in the model by subtracting the year of its creation from the current year (2023). To focus exclusively on protected areas in sub-Saharan Africa, we applied specific filters to the data. First, we selected areas designated as NPs (excluding other categories such as reserves, etc.) within countries from the sub-Saharan domain. NP is a particularly common and iconic category of protected area in Africa, often contributing to local economies through educational and recreational tourism, without compromising their primary goal of safeguarding biodiversity and ecological processes (Chardonnet, 2019). This designation is considered ideal for this study, as NPs tend to be more lenient with human visitation and may thus better capitalise on the presence of African iconic species and landscapes to attract public interest and visitation. Notably, the wildlife tourism promoted by sub-Saharan African parks generates around USD 142 million in entrance fees (Chardonnet, 2019; WTTC, 2022).

To identify NPs that are potentially vulnerable or resilient to development pressures, we extracted socio-geographic information from their surrounding areas, from various global datasets. First, we extract four pressure indicators at NP level, compiled by the Digital Observatory of Protected Areas, 4th version (DOPA) (Dubois et al., 2019). The DOPA database provides information about various pressures, geographic and socio-economic indicators at the country and protected area levels. Following the same methodology adopted by Guedes-Santos, Correia, Mendes Malhado, and Ladle (2021), we extracted the following indices: (i) agricultural pressure—the percentage of the NPs surface and of its 10-km unprotected buffer covered by cultivated land; (ii) population pressure—the percentage of the population density (km^2) inside and outside 10-km unprotected buffer zone; (iii) built-up area pressure—the percentage of the built-up areas inside a 10 km buffer surrounding a protected area; (iv) road pressure—the percentage of coverage by roads with a 250 m buffer inside and outside (10-km unprotected buffer zone) of the NP. The Digital Observatory of Protected Areas does not provide information on PAs smaller than 100 km^2.

Second, we generated a database of socio-geographic information from the countries which host these areas. This information is based on indicators from the Positive Peace Index 2022 Report, and the Global Peace Index value from each country, produced by the Institute for Economics and Peace (IEP, 2022). These indicators encompass information about: (i) international tourism—the number of tourists (arrivals per 100,000 population) who travel to a country (staying at least one night) other than in which they have their usual residence; (ii) gross domestic product (GDP) per capita—the gross domestic product divided by midyear population (current US$); (iii) researchers—the professionals in research and development, expressed as a per 1 million; (iv) government openness transparency—an index that captures to what extent government operations can be legally influenced by citizens and are open to scrutiny from society; (v) External Intervention—an indicator which considers the influence and impact of external actors in the functioning—particularly security and economic—of a state; and (vi) GPI—the Global Peace Index assesses the level of negative peace, or just the lack of peace in a country through three domains: continuous domestic and international conflicts, levels of internal harmony or discord, and the relationship between military strengthening, access to weapons, and national and international peace. We opted to use the Positive Peace Index instead of other indices like the Worldwide Governance Indicator (Kaufmann & Kraay, 2023) because we were specifically interested in understanding the potential impact of civil conflicts on PADDD events. Such conflicts change institutional dynamics such as deceasing enforcement and conservation activities while placing greater pressure on natural resources (Gaynor et al., 2016). Such

potential impacts make the Peace Index particularly relevant for sub-Saharan Africa due to its recent history of civil conflicts, independence, and pacification. In addition, the Positive Peace Index also covers governance-related aspects in its evaluation of positive peace. Details about the methodology used by IEP to compile these data can be accessed in the documents available on the IEP page at https://www.visionofhumanity.org/maps/#/. Finally, data related to PADDD events, such as the date, type, and cause of the event, were obtained from the World Wildlife Fund (Conservation International and World Wildlife Fund, 2021) available on the PADDDtracker.org platform.

2.2 | Digital metric of public interest in NPs

We use a simple digital metric of public interest in sub-Saharan National NPs based on Wikipedia page views (following Guedes-Santos, Correia, Jepson, & Ladle, 2021). The data collection process involved automated searches using the English names of NPs, facilitated by the 'tidywikidataR' package (Comai, 2023). Each specific Wikipedia page is linked with its corresponding entity on Wikidata (the centralised repository of structured data for Wikipedia), which enables the extraction of essential information about each NP. The search was based on the NP name (e.g. 'Kruger National Park'), from which the following information was also extracted from Wikidata: page creation date, wiki data identifier, page URL, languages in which the page was available, and general description presented on the page. Each page (entity) can have multiple language versions that share the same ID (hereafter, we will use the term 'Wikidata ID' to refer to this ID). Nevertheless, some geographical entities, including certain NPs, may lack a dedicated Wikipedia page or may not be represented in the official language of their host country. We relied solely on page views from the English version to ensure the data were comparable between NPs. Due to the predominance of the English language on Wikipedia pages for parks in sub-Saharan Africa, and the higher volume of page views in English compared with other languages when available. Furthermore, this language-based data filtering is important due to the international appeal of these NPs, making the English version ideal for our study. We used the 'pageviews' package (Keyes & Lewis, 2016) to retrieve daily page views to the English page of each NP. We then calculated the average number of daily views to each NP page based on how many days the page had been available to account for differences between pages created at different times. Furthermore, we retrieved views from the start of the available year (2015) until the pre-COVID-19 pandemic period (early 2020), because the pandemic disrupted attention and thus the patterns may be unrepresentative of border support during and after this period (Souza et al., 2021). Out of the initial sample of 322 parks, 47 were excluded from further analysis. Nineteen of these parks did not have a Wikipedia page, while the others either lacked an English page or had pages created after the study's timeframe (before the COVID-19 pandemic). As a result, these NP were not included in the subsequent analysis.

2.3 | Modelling the relative vulnerability and resilience of NPs

To explore the relationship between public interest (Wikipedia page views) and NP pressure indicators/countries' socio-geographic indicators, we initially assessed for multicollinearity among these predictors. This involved examining the correlation coefficient among variables and removing highly related variables with a Spearman correlation coefficient (r) greater than 0.6. The removal of correlated explanatory variables avoids problems with multicollinearity when fitting multiple regression models (Kim, 2019). To understand whether the public interest in NPs can be influenced by pressure indicators, such as agricultural pressure, human population, road density and urbanised area, and the other socio-geographic indicators. We applied a generalised linear mixed model (GLMM) with the country as a random variable and a gamma distribution. Additionally, we performed a multinomial logistic regression analysis to examine how pressure indicators and socio-geographic indicators of different countries are associated with the likelihood of experiencing distinct types of PADDD events (Degazettement, Downsizing, and Downgrading). We used the incidence of any downsizing and downgrading event as response variables (only for enacted events); degazettement events were not considered, as there were only three occurrences in the dataset. These include one occurrence in Etosha National Park in 1958, reversed on unknown date; two events in Addo-Elephant National Park in 1991 and 2005, both reversed in 2005. To compare the effect of different predictor variables on the response variables, we standardised the predictors (so that they were on a scale with a mean of zero and a standard deviation of one). To better comprehend the premise behind the associations among the selected variables and the parks in this study, see Supporting Information. After running the models (GLMM and Multinomial logistic regression), we inspected model residuals and checked the variance inflation factors (VIF's). All VIF values had values of less than 5, indicating no issues with multicollinearity in the models. All statistical analyses were performed using the R Software (R Core Team, 2023), see Supporting Information for details about the models.

3 | RESULTS

In total, we gathered data on 322 PAs from 44 out of the 49 countries in sub-Saharan Africa. The highest number of NPs is found in Austral Africa, with a total of 118 NPs, followed by East Africa with 75 NPs. Western Africa and Central Africa are home to 68 and 61 NPs, respectively (see Supporting Information).

3.1 | Geographical, historical, and structural aspects of the NPs

Overall, a wide variation in NP sizes was observed, ranging from small reserves covering half a square kilometre (Iles de la Madeleine NP from Senegal), to vast expanses exceeding 50,000 km^2 (Namib-Naukluft NP from Namibia). Notably, the larger NPs are predominantly located in austral and eastern Africa. Less than 30 NPs exceed 10,000 km^2, and except for Limpopo National NP (11,233 km^2) in Mozambique and Sperrgebiet National NP (21,812 km^2) in Namibia, which were established after the 2000s, all these large NPs were created between the late 1920s and 1980.

Also, over 200 NPs in our study were established from the 1970s onwards. Austral Africa experienced a peak in NP creation between the 1960s and 1980s, while Central Africa experienced a more recent boom from the 1990s onwards. Among the NPs examined, 13 lack year of establishment information in the Protected Planet database. Out of these, 10 NPs are listed as proposed (not officially NP established) and are located in countries, such as Cameroon, Ethiopia, Kenya, Nigeria, and Sierra Leone. Notably, the Kibale, Boé, and Mafou Forest NPs in Uganda, Guinea-Bissau, and Guinea, respectively, are designated NPs, but their year of creation remains unknown.

Among the NPs in our sample, over 200 are under federal or national management, whereas 75 do not have reported any type of governance to the WDPA Database (Figure 1). Our analysis also highlights the involvement of non-governmental organisations, ministries, subnational agencies, and collaborative partnerships in the management of a number of NPs (see Supporting Information). Furthermore, one limitation and concern emerging from the analysis of the WDPA Database pertains to the governance of the NPs, namely, the availability of management plans. At least 29 out of the 44 countries analysed here did not inform if their NPs had a management plan or not, representing 69% of NPs without a clear indication of the existence of a management plan. Countries such as Liberia, Uganda, Zimbabwe, Ethiopia, Tanzania, Zambia, South Africa, Madagascar, Namibia, and Kenya, which host more than 10 NPs, are among these countries. Among the 28 NPs that indicated they do not have a management plan, 57% of them are in Cameroon. Although many countries that did not provide information about management plans also did not provide information about governance types, we observed that among the NPs with management plans, they are often under collaborative or joint governance (12 NPs). They are also under government-delegated management (6 NPs), and federal command structures (52 NPs).

Among the NPs in our study, we recorded 100 PADDD events reported from PADDD Tracker database, distributed among 51 out of the 322 NPs. With some NPs, Augrabies Falls and Addo-Elephant in South Africa, and Mount Elgon in Uganda, being the most affected and experiencing multiple events. Most of the specific causes of PADDD events remain unclarified. Among those PADDD events for which the driver is known, they relate mostly to activities such as mining, conservation planning, land claims and agribusiness ventures (Figure 2).

Most PADDD events documented in the database involved the downgrading of protected status, with South Africa being heavily impacted. Notably, three countries—South Africa, Uganda, and Zambia—accounted for a significant proportion (71%) of the recorded events, mostly caused by conservation planning, land claims, and mining activities, respectively. Although, 32% of the events recorded had an unknown driver. These events typically occurred within the first two or three decades following the year of creation of the NP, as exemplified by Table Mountain NP, created in 1998 and experiencing downsizing events in their first decade. NPs with multiple events often encountered them within a short time frame. For instance, Augrabies Falls National

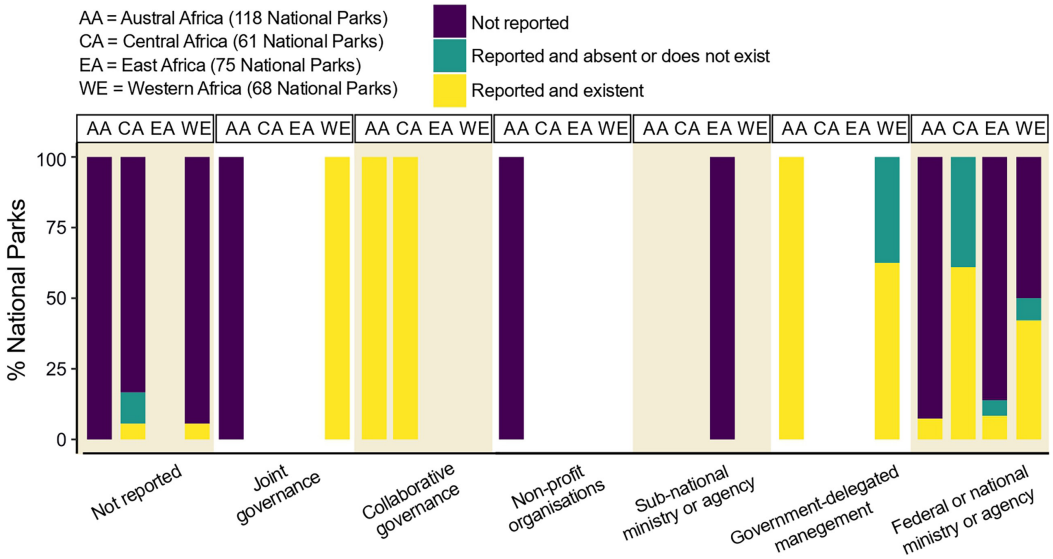

FIGURE 1 Type and distribution of National Park management and governance, and an indication of the presence of available management plans, across regions in sub-Saharan Africa.

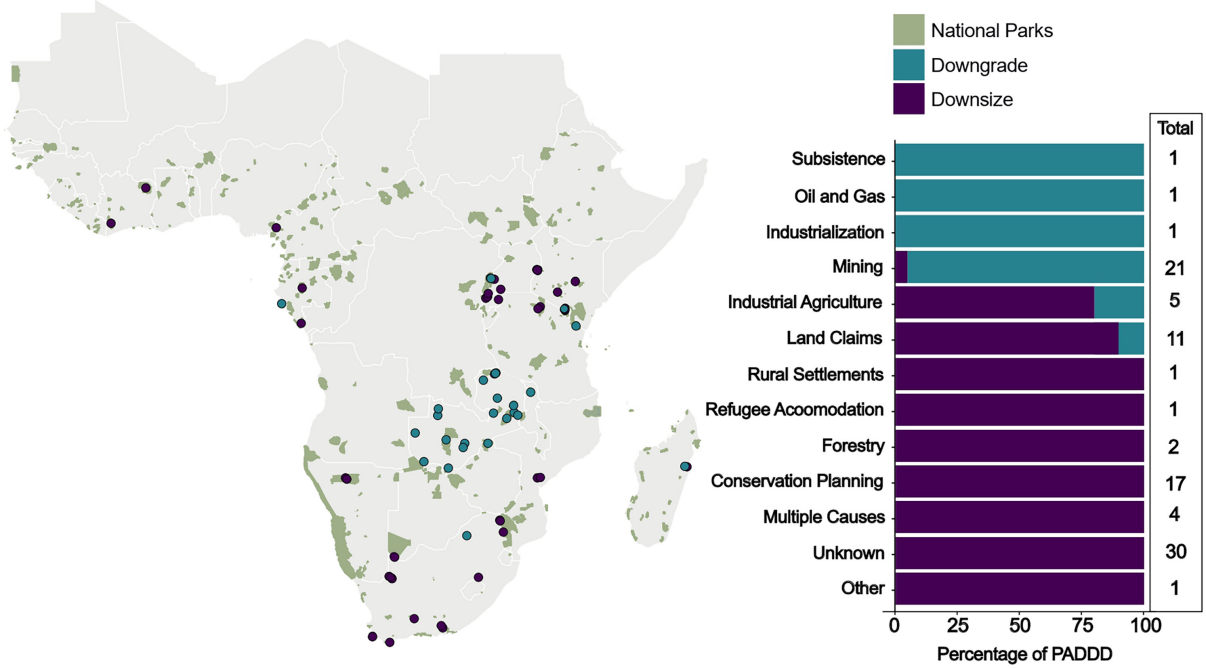

FIGURE 2 Map of the distribution of National Parks in sub-Saharan Africa, indicating the protected area downgrading, downsizing, or degazettement (PADDD) events, and the motivating causes of the respective events (downgrading and downsizing) according to the PADDD Tracker. Degazetting events are not represented due to the very low frequency of occurrence.

NP experienced seven downsizing events between the 1980s and early 2020s (Figure 3).

In our analysis, only Etosha (Namibia) and Addo-Elephant (South Africa) recorded degazettement events, both reverted. Downgrading and downsizing events are more prevalent among sub-Saharan parks. Many downgrading events were prompted by mining activities (other few stemming from oil and gas exploration, industrialization, and subsistence). The majority of which occurred across different areas of Zambia—including Blue Lagoon, Isangano, Kafue, Kasanka, North and South Luangwa, Lower Zambezi, Lavushi Manda, Lusenga Plain, Lukusuzi, Liuwa Plain, Lochinvar, Luambe, West Lunga, Mosi oa Tunya, Nsumbu, and Sioma Ngwezi. All within the same year, 1998.

As the DOPA database does not provide information on PAs smaller than 100 km^2, 55 NPs lack data on road density and urban coverage in their surroundings. However, NPs with higher road accessibility are typically traditional NPs established between the 1950s and 1980s, located in Kenya, Burundi, and Sierra Leone, such as Aberdare, Rusizi, Kibira, Ruvubu, and Loma Mountain. NPs with higher urban coverage in their surroundings were identified in South Africa, Ivory Coast, and Gambia, including prominent NPs like Table Mountain, Banco, and Tambi Complex.

3.2 | Beyond borders: Language accessibility and global engagement

Our findings highlight both opportunities and gaps in language accessibility within Wikipedia. English stands out as the most widely visited language. The availability of Wikipedia pages varies across different regions of sub-Saharan Africa, ranging from 21 for East and Western Africa to 15 for Austral and Central Africa. Notably, in West Africa, three NPs have Wikipedia pages available in over 100 languages. These NPs, namely 'W du Benin', 'W du Burkina Faso' and 'Parc National du W du Niger' comprise a large NP called W National Park, which shares borders between Benin, Burkina Faso, and Niger respectively, and ranks among the top 20 NPs with the highest Wikipedia views. Moreover, only the W NP from Burkina Faso and Niger had available management plans from the top 20 NPs with the highest Wikipedia views.

The range of the average of views was from 0.54 to 639.83 daily page views. However, only 11 NPs had more than an average of 100 daily views, the vast majority are in Southern Africa, and the most accessed was Kruger in South Africa. Followed by: Serengeti (Tanzania), Virunga (Democratic Republic of Congo), Sambisa (Nigeria), Kalahari (South Africa), Gemsbok (Botswana), Hell's Gate (Kenya), Etosha (Namibia), Nairobi (Kenya), Chobe (Botswana), and Amboseli (Kenya).

The most visited Wikipedia pages are about NPs that were established from the 1920s to the 1970s, except Bemarahan in Madagascar established in 1997, and Hell's Gate in Kenya in 1984. Among the 20 most visited NPs is Sambisa in Nigeria, for which the date of creation remains undisclosed.

3.3 | Relationship between Wikipedia page views and pressure indicators

In our analysis of country-level socio-economic factors, pressure indicators, and their potential influence on public interest in NPs,

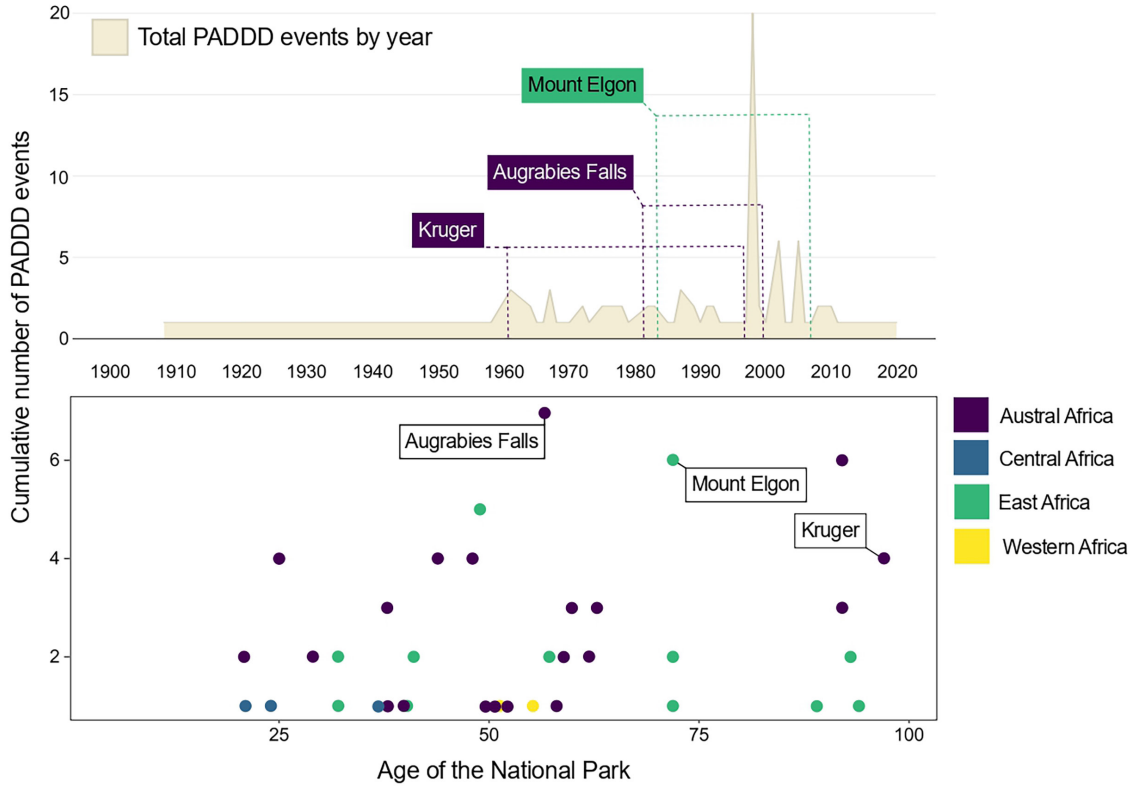

FIGURE 3 Cumulative number of protected area downgrading, downsizing, or degazettement (PADDD) events by year (above), showing the time interval from the National Parks (NPs) that most suffered PADDD events. Age of the NP associated with the cumulative number of PADDD events (below).

measured by Wikipedia page views, we found that only the size and age of the parks are significantly associated with public interest. Larger, older areas are associated with fewer Wikipedia views (Table 1).

3.4 | Socio-geographic drivers of PADDD events

The multinomial logistic regression results reveal significant associations between the predictors and the likelihood of downgrade in the NPs. A 1% increase in built-up area is linked to a 50% reduction in the odds of downgrading (odds ratio = 0.58), underscoring the role of infrastructure surrounding these parks in maintaining protected area categories. The Global Peace Index had an inverse association, with a one-unit increase yielding odds of downgrading events a thousand times lower (odds ratio = 0.001). This suggests that NPs within more peaceful countries from sub-Saharan Africa are noticeably less susceptible to PA downgrading. Additionally, we noted a strong association between a country's GDP per capita and a sixfold increase in the likelihood of downgrading (odds ratio = 6.32), indicating a meaningful adverse impact of economic advancement on the sustaining of the NP category. Furthermore, there are also effects from external interventions, increasing the probability of downgrading by 24% (odds ratio = 1.24). Lastly, international tourism seems to exert a protective influence, with an increase in this variable leading to a near 50% reduction in the odds of downgrading (odds ratio = 0.40; Table 2).

The results for downsizing exhibited similar patterns to those observed for downgrading, indicating the presence of comparable drivers for both PADDD events. However, unlike the downgrading scenario, which had no effect, greater online visibility was associated with a slight increase in the probability of downsizing events (~3%; odds ratio = 1.03). In relation to the Global Peace Index, a one-unit increase could reduce the odds of this event by more than 60% (odds ratio = 0.30), underscoring the relevance of peace levels for category maintenance. Additionally, an increase in GDP per capita was associated with a more than twofold increase in the odds of downsizing (odds ratio = 2.19), highlighting a substantial negative influence of economic development. More concerning was the negative influence of the external interventions (odds ratio = 5.19), which could be associated with more than fivefold increase in odds of downsizing events. There was a significant reduction in the odds of downsizing with a one-unit increase in the international tourism variable (odd ratio = 0.17; Table 2). Due to the absence of PADDD events in parks that reported having no management plan, this variable was removed from the model construction.

4 | DISCUSSION

The parks that attracted the most public interest online, particularly smaller and newer ones as measured by Wikipedia visibility, did not correspond with the socio-geographic profile of parks most

Response variable	Predictors	Estimate	*p*-value
Wikipedia page views	Agricultural pressure	−0.0088	0.3364
	Built-up pressure	−0.0083	0.3315
	Population pressure	−0.0054	0.5779
	Road pressure	−0.0008	0.9438
	NP's area	−0.0349	<0.001***
	NP's age	−0.0267	0.0051**
	Global Peace Index	0.0191	0.3954
	GDP per capita	−0.0021	0.9346
	International tourism	0.0074	0.7841
	Government openness transparency	0.0274	0.3151

TABLE 1 Summary results of generalised linear mixed model relating the pressure indicators (agricultural, built-up, population density, and road) and socio-geographic variables (NP's area and age, GDP per capita, Peace Index, international tourism and government openness transparency) to public interest.

Note: Values represented are estimated model coefficients (β slope) and respective significance.
*$p<0.05$. **$p<0.01$. ***$p<0.001$.

Response variable	Predictors	Coefficient	Odds ratio	*p*-value
Downgrade	Wikipedia views	−0.024	0.98	0.2
	Agricultural pressure	−0.009	0.99	0.6
	Built-up pressure	−0.545	0.58	<0.001***
	Population pressure	0.00	1.00	0.7
	NP's area	−0.00	1.00	0.8
	PA's age	0.026	1.03	0.07
	Global Peace Index	−8.544	0.00	<0.001***
	GDP per capita	1.843	6.32	<0.001***
	International tourism	−0.921	0.40	<0.001***
	External intervention	0.218	1.24	<0.001***
Downsize	Wikipedia views	0.033	1.03	<0.001***
	Agricultural pressure	0.011	1.01	0.05*
	Built-up pressure	0.049	1.05	0.4
	Population pressure	−0.000	1.00	0.2
	PA's area	−0.000	1.00	0.12
	PA's age	0.016	1.02	0.15
	Global Peace Index	−1.21	0.30	<0.001***
	GDP per capita	0.782	2.19	<0.001***
	International tourism	−1.764	0.17	<0.001***
	External intervention	1.647	5.19	<0.001***

TABLE 2 Multinomial logistic regression relating pressure indicators and socio-geographic variables with the likelihood of suffering from different types of protected area downgrading, downsizing, or degazettement events (only Downsizing and Downgrading) occurring.

Note: Odds ratio indicates the magnitude of the effect that the predictor has on the response variable, that is, it shows the change in the probability of an event occurring based on a one-unit change in the predictor.
*$p<0.05$. **$p<0.01$. ***$p<0.001$.

vulnerable to PADDD events. Our analysis revealed that the most vulnerable parks were in countries with higher economic power (as indicated by GDP per capita), greater external intervention, and a history of higher conflict levels, coupled with lower levels of international tourism. Moreover, less than 30% of the NPs in our sample reported having a management plan. Notably, among the 51 parks that experienced a PADDD event, nearly 90% lacked information about the existence of such plans. This highlights a significant knowledge gap that could lead to biased predictions about conservation capacity and the effectiveness of governance in achieving global objectives (Lopes-Lima et al., 2021).

Many of the reserves in our database are rooted in an American vision of 'uninhabited and uninhabitable protected areas', characterised by principles and objectives tailored to Western tourists' expectations, often disconnected from local communities and traditional resource management (De Vos et al., 2019; Jones, 2021; Weigel et al., 2007). This pattern aligns with other reviews and critical analyses of the history behind the creation of these areas

across the African continent (Jones, 2021; Umuziranenge & Ntiranyibagira, 2020). Furthermore, many NPs in the study region exist only on paper and are not genuinely operational, making them more vulnerable to PADDD.

These areas frequently lack defined management categories, goals, and plans. In our database, 23% of the NPs lack a management plan, and 69% do not report if they possess these governance structures. When management plans exist, they are rarely validated, implemented, evaluated, or updated (Carruthers & Foxcroft, 2019; Jones, 2021; Umuziranenge & Ntiranyibagira, 2020). Recent research suggests that fragmented legal provisions related to management plans, especially those publicly disclosed, point to incomplete or inadequately defined plans that fall short of the requirements necessary to ensure these areas fulfil their designated functions (Goosen & Blackmore, 2019). This situation has led to calls for a comprehensive review of national environmental legislation to improve our understanding of the contribution of PAs to conservation and community well-being (Goosen & Blackmore, 2019).

It is important to note that the WDPA database has complex data collection and curation processes (Thomas et al., 2014), and national reporting can be affected by a lack of specified roles and limited funding or technical capacity (Yang et al., 2020). While efforts are underway to improve internal and external validation procedures and expert reviews, challenges remain in efficiently assessing errors and omissions (Milam et al., 2016). Although information about management tools like a robust management plan may be underestimated, the database remains a rich source of information for various types of protected area assessments.

On the other hand, some NPs have been appropriately designated and adopt a collaborative management and governance approach, as seen in 80% of NPs in Mozambique. This offers an alternative to the colonial conservation policy model widely implemented elsewhere in Africa (Lindsey et al., 2021; Musavengane & Leonard, 2019). However, the majority of the top 20 most viewed African parks on Wikipedia are among those whose information about accessible management plans for conservationists, scientists, and stakeholders worldwide is absent from the WDPA database or lack collaborative governance. These traditional areas, such as Kruger (South Africa, SANParks), Serengeti (Tanzania, TANAPA), Virunga (Democratic Republic of Congo, not reported), Sambisa (Nigeria, not reported), and Kalahari Gemsbok (South Africa, SANParks), have significant reputations and investments in the tourism sector by overseeing agencies/governments and almost certainly have well-developed management plans.

Overall, there was very limited digital engagement with most NPs in our study. However, it is interesting to note that parks with high public interest are slightly more likely to experience downsizing events, according to our model. It is challenging to determine whether public interest in a NP stems from its natural beauty and biodiversity, or results from media coverage of an event affecting the park. In the United States, faced with the possibility of a significant downsizing event in a protected area, a record number of public comments opposed the decision (McDonough MacKenzie et al., 2020). Federal agencies in the US solicit public comments to gather ideas, address issues, and use the best available science for policy, legislation, and management formulation. Although most comments were submitted by bots, human public sentiment overwhelmingly opposed the review of national monuments. Consequently, the Biden administration reversed the reduction (and other PADDD events from the Trump administration) early in its term (Reese, 2021).

Examining other factors behind downsizing events in African National Parks, it is important to highlight the historical context in which conservation policies and practices pushed local populations to the peripheries, turning these areas into zones of hostility and rebellion (Jones, 2021). This exclusionary model, displacing local residents and limiting their access to natural resources for subsistence, turned many Africans PAs into 'food pantries surrounded by hunger' (Jones, 2021; Ntiranyibagira et al., 2019). These flawed policies often required long-term revisions of conservation boundaries and plans. Factors such as poverty, lack of alternative livelihoods, weak law enforcement, political instability, etc., thus become catalysts for PADDD in sub-Saharan protected areas (Matseketsa et al., 2022), and the result of our model reinforces this. External intervention in countries can have a strong negative influence on the resilience of these areas.

Not all PADDD events lead to negative outcomes. Our results showed that many PADDD events, especially downsizing, were directly motivated by conservation planning reviews (21%) and land claims (15%). Maintaining larger NPs does not necessarily guarantee corresponding ecological benefits. In some cases, reducing these PAs through conservation planning reviews can optimise allocation of conservation resources without compromising their ecological potential (Cobb et al., 2024; Justeau-Allaire et al., 2021). Furthermore, PADDD can serve as a mechanism to rectify historical injustices (Dowie, 2009), as exemplified by the land restitutions that occurred in post-democratisation South Africa, in 1994 (Cundill et al., 2013). Evaluating conservation progress should not solely hinge on rates of establishment of PAs (De Vos et al., 2019; Wilson & Primack, 2019). A deeper understanding of the context, processes, and drivers leading to these events, along with their socio-ecological consequences on various scales, is necessary.

Several factors can contribute to the resilience of these parks against development pressures. Our findings indicate that PADDD events are less likely to occur in peaceful countries with high levels of tourism. Conflict zones indeed represent significant risks to PAs and their wildlife, emphasising the urgent need for integrated conservation strategies, post-conflict rehabilitation initiatives, and collaborative efforts to mitigate threats and protect biodiversity in these vulnerable regions (Daskin & Pringle, 2018). More than 80% of armed conflicts occurred in biodiversity hotspots between 1950 and 2000, often coinciding with environmental impacts from independence struggles and agricultural expansion (Rudel, 2009). Many critical areas overlap with indigeneous lands, and research indicates that indigeneous peoples can mitigate ecosystem degradation before, during, and after armed conflicts due to their strong ties to

their lands and determination to defend their rights and territories (Beattie et al., 2023).

However, green militarization and green violence—using military and paramilitary forces in conservation—persist as remnants of Africa's late colonial era, similar to the fortress conservation model from apartheid (Mashau, 2022). This strategy, aimed at protecting areas from illegal activities, has been widely debated, especially in parks like Kruger (Lunstrum, 2014, 2015) and Virunga (Marijnen & Verweijen, 2016), the most attractive parks in this study. There are other countries with a high incidence of PADDD events, that have also seen militarization framed as an anti-poaching strategy, like Tanzania (Mabele, 2017), Kenya (Asaka, 2018), Uganda (Runhovde, 2017), and South Africa (Annecke & Masubelele, 2016). While some argue that this approach can yield short to medium-term benefits, the long-term financial and socio-economic costs to people are often underestimated (Annecke & Masubelele, 2016). Besides, communities near parks in African biodiversity hotspots already perceive the significant risks faced (Hartter et al., 2016). Since our model indicates greater resilience in peaceful and tourist-oriented parks, conflict-zone parks might benefit from integrating community conservation initiatives, prioritising local involvement, peace-building, and sustainable governance (Vimal et al., 2018), thus strengthening the relationship between parks and their dependent communities (King, 2010; Fisher et al., 2023).

Finally, both types of PADDD events are more common in nations with high levels of economic development, indicated by high GDP per capita, likely reflecting the driving role of mining activities in most cases. Although mining can contribute to per capita income through job creation and improved living conditions (when legal and properly regulated), it can also lead to community displacement due to land loss and natural resource degradation, with long-term impacts on local well-being (Bertinelli & Bourgain, 2021; Kumwenda & Chileshe, 2019; Nalule & Nalule, 2020). Mining activities in Africa have significantly increased since the early 2000s (Ahmed et al., 2021; Takam Tiamgne et al., 2022), including legal and informal operations, such as artisanal and small-scale mining (Hilson et al., 2017; Lèbre et al., 2017). The economic returns from these activities are not always clear, especially when driven by foreign actors (Gochero & Boopen, 2020; Wegenast et al., 2019). There is indeed a relationship between higher contributions of mineral revenues to GDP and higher levels of poverty in African nations (Kolala & Bwalya Umar, 2019; Takam Tiamgne et al., 2022). This trend is particularly concerning given that approximately 44% of significant mining sites in sub-Saharan Africa are located within or near PAs (Durán et al., 2013).

Reducing the pressures of PADDD is not simple. Some researchers suggest pressing for greater engagement with international tourism with a positive agenda for Nature (WTTC, 2022). Such a strategy could potentially enhance reputation and trust while appealing to socially and environmentally conscious employees, customers, and travellers (WTTC, 2022; Go et al., 2020). More generally, any strategies that increase public support for conservation in general and PAs, in particular, will make it more likely that citizens and institutions will come together in defence of PAs under threat (Bernard et al., 2014; Guedes-Santos, Correia, Jepson, & Ladle, 2021).

5 | CONCLUSIONS

National Parks that garner significant public interest online do not share the same socio-geographic profile as parks that are most resilient to PADDD events. However, digital metrics to measure public interest need to be further refined to fully understand which biophysical and cultural aspects of parks attract more public interest, and how these attributes can be enhanced to strengthen the resilience of parks in countries with higher external intervention and economic power (Jepson et al., 2017). The NPs from these countries were found to be the most vulnerable to area reduction and changes in use.

As with many regions worldwide, conservation policy in sub-Saharan Africa has been shifting towards a community-oriented approach (Cassidy & Salerno, 2020). Ecotourism, driven by Africa's unique wildlife and landscapes, is a potential ally for local development and environmental conservation (Novelli, 2015). Our investigation suggests that more peaceful regions with active tourism may be less susceptible to these events. To strengthen this sector and enhance commitment and investment in these areas while bolstering conservation efforts (Rylance et al., 2017; Jarić et al., 2023), we need to better understand the factors that attract (and deter) international tourists.

Future studies could investigate the preferences of individuals visiting these areas in relation to the conservation plans established by managers, specifically examining what makes smaller and newer parks—those with the highest public interest—so attractive. This knowledge could help more vulnerable parks improve their management and governance. However, for this to be effective, management plans must also be transparent and accessible. Additionally, a culturomics approach could be employed to understand the engagement with the debates surrounding green militarization issues in Africa. This could facilitate dialogue between conservationists, local communities, and policymakers, promoting more inclusive and holistic strategies that prioritise both environmental protection and community well-being. Finally, given the inherent limitations of culturomic metrics, analyses encompassing the full temporal scope of online visibility, combined with data from other online platforms (e.g., news media sites), could offer a more comprehensive understanding of what drives public interest in NPs and conservation issues in sub-Saharan Africa.

AUTHOR CONTRIBUTIONS

Karoline Azevedo conceived the ideas together with Richard Ladle, Ricardo Aleixo Correia, Fernanda Alves-Martins, and Javier Martinez-Arribas. Karoline Azevedo designed the methodology together with Fernanda Alves-Martins, Javier Martinez-Arribas and Ricardo Aleixo Correia; Karoline Azevedo collected and analysed the data; Karoline Azevedo led the writing of the manuscript; Richard

Ladle, Fernanda Alvez-Martinez, Ricardo Aleixo Correia, Ana Cláudia Mendes Malhado, and Javier Martinez-Arribas reviewed and improved the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

Richard Ladle and Ricardo Correia are associate editors of *People and Nature* but did not participate in the peer review or decision-making processes for this manuscript. All other authors declare that they have no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly and available in Figshare at http://doi/ 10.6084/m9.figshare.26861977. Contains information from World Database of Protected Planet (UNEP-WCMC, 2023 from Protected Planet; https://www.protectedplanet.net), Institute for Economics and Peace (IEP, 2022), Digital Observatory of Protected Areas, 4th version (DOPA) (Dubois et al., 2019), and extract from Wikipedia.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1: List of all the protected areas assessed in this work, including respective additional information compiled and/or generated about the public interest metric, governance and management structure.

Table S2: Number of protected areas, gross national income (per capita), protected area's size, and number of PADDD events, by country.

Table S3: Model selection criteria to generalised linear mixed model.

Table S4: Model selection criteria to multinomial logistic regression.

Table S5: Variance inflation factors of the selected generalised linear mixed model.

Table S6: Variance inflation factors of the selected multinomial logistic regression.

Figure S1: Sub-Saharan African National Parks (in green). Countries in dark grey were affected by PADDD events. The red dots represent parks where PADDD events of downgrading, and downsizing occurred.

Figure S2: National Parks who suffered PADDD events and respective number of events along of page views gradient (left). Sub-Saharan Africa countries and National Parks, with respective values from page views by Wikipedia (right). In red, National Parks without Wikipedia English pages or Wikipedia pageviews.

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