frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 09 October 2025
DOI 10.3389/fsufs.2025.1653920

OPEN ACCESS

EDITED BY
Pradeep K. Dubey,
Banaras Hindu University, India

REVIEWED BY
Sakshi Rana,
Wildlife Institute of India, India
Mulako Kabisa,
University of the Witwatersrand, South Africa
Ghassen Halouani,
L'Ifremer en Manche Mer du Nord, France
Jacolette Adam,
Exigent, South Africa

*CORRESPONDENCE
Vincent Moseti
✉ vmosetin@uni-bonn.com

†These authors share first authorship

RECEIVED 25 June 2025
ACCEPTED 17 September 2025
PUBLISHED 09 October 2025

CITATION
Musa JK, Moseti V and Biber-Freudenberger L (2025) Role of agency in envisioning future human-nature relationships in the context of road infrastructure development in the Kavango-Zambezi region, Namibia. *Front. Sustain. Food Syst.* 9:1653920. doi: 10.3389/fsufs.2025.1653920

Role of agency in envisioning future human-nature relationships in the context of road infrastructure development in the Kavango-Zambezi region, Namibia

Judith K. Musa[1†], Vincent Moseti[2*†] and Lisa Biber-Freudenberger[2]

[1]United Nations University (EHS) and Geography Institute, University of Bonn, Bonn, Germany, [2]Center for Development Research, University of Bonn, Bonn, Germany

Amid growing concerns over climate change and biodiversity loss, there is increasing recognition of the need to reconcile local communities' economic aspirations with environmental conservation. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) introduced the Nature Futures Framework (NFF) to foster nature-positive future scenarios. This study explores the impact of road infrastructure on local communities' agency to envision and achieve desirable futures, focusing on Namibia's Kavango-Zambezi (KAZA) region. Using semi-structured questions and participatory mapping, we assessed how communities near and far from the Trans-Caprivi highway value nature in present, probable, and desirable future scenarios, as defined by the NFF. We also analyzed the impacts of socioeconomic factors such as age, education, occupation, and gender on shaping these visions. Higher education levels were associated with higher overall agency among respondents, both near and far from roads. Additionally, proximity to roads corresponded with higher agency scores for instrumental (Nature for Society) and intrinsic (Nature for Nature) values, while slightly lower scores were observed for relational (Nature as Culture) values. These patterns suggest spatial and educational factors may influence how individuals perceive their ability to shape future human–nature relationships across different value dimensions. These insights underscore the crucial need to foster nature-positive and socially inclusive futures by systematically integrating local knowledge and stakeholder perspectives into infrastructure planning and decision-making processes.

KEYWORDS

nature futures framework (NFF), nature valuation, probable future, desirable future, participatory mapping, agency

1 Introduction

The concept of human–nature relationships has undergone notable evolution over the past decades (Leinfelder, 2020; Michio, 2011), by gradually embracing more holistic ecosystem-based approaches in addition to species conservation (Mace, 2014) and increasingly integrating sustainability thinking into these dynamics (James, 2015). Scholars have sought to conceptualize these relationships through various lenses, emphasizing both anthropogenic and intrinsic values (Rea and Munns, 2017; Smythe, 2014), as well as cultural and intellectual

dimensions that highlight humanity's dependence on nature for cultural creation and its embeddedness within the environment (Kline, 2015; Potrzeba-Macrina and Zurbenko, 2020; Satz et al., 2013). Rembang (2021) further introduced a spiritual perspective that underscores the inherent limitations of human technology and knowledge, positioning humanity as fundamentally vulnerable to the power of nature. Despite this vulnerability, humans continue to harness natural resources to build advanced artificial infrastructure and improve the quality of life (Díaz et al., 2015). This interplay between human dependence and ambition highlights the multifaceted nature of human-environment interactions and their implications in sustainable development.

Road infrastructure development has been widely embraced and advanced in all parts of the world to enhance rural livelihoods and move towards visions of economic progress. Often perceived as a pathway to unlocking economic opportunities in rural areas, roads facilitate access to markets, tourism, and agricultural development, promoting social connectivity and economic growth (Anderson, 2001; Ewnetu, 2023; Kuklina et al., 2020). However, the impacts of roads encompass both positive and negative consequences (Wilkie et al., 2000). While roads enable human mobility and economic advancement, they also drive environmental degradation, habitat fragmentation, and biodiversity loss (Keller et al., 2004; Kleinschroth et al., 2019; Vilela et al., 2020). Remote communities—described by Harvey and Knox (2015) as "abandoned" within formerly "roadless" regions- often see road construction as a pathway to modernity, economic development, and better access to essential services. This perspective reflects broader development narratives that position infrastructure as a driver of growth, mobility, and connectivity (Nwagbara and Iyama, 2019). Yet such optimism can overshadow the profound socio-spiritual bonds these communities hold with their environments. As Sills (2017) notes, nature is not only a resource but also a living presence, a site of ancestral heritage, and a foundation of spiritual practice. Roads, however, risk fragmenting ecosystems and disturbing sacred landscapes, resulting in cultural displacement and the erosion of intangible heritage. Recent scholarship, such as Kim et al. (2020), emphasizes the importance of envisioning future human-nature relationships that reflect a plurality of value systems including relational, spiritual, and intrinsic values, rather than focusing solely on instrumental or utilitarian perspectives. Despite this, infrastructure planning continues to privilege economic indicators over these equally vital but less easily measurable dimensions of wellbeing.

Emerging visions for a sustainable and desirable future by the mid-21st Century emphasize the transformative role of infrastructure, especially roads, in reshaping how humans interact with nature. For instance, such futures envision multimodal transport systems (e.g., bikes, horses, shared cars, and walking paths), widespread use of electrified vehicles, and the prioritization of public transport (Constanza, 2014). Such transformations are underpinned by infrastructural developments that could facilitate (1) the reorganization of cities into smaller, self-sustaining communities with closed-loop industrial systems that emphasize recycling and reuse; (2) a global recognition and institutional protection of natural capital, accompanied by heightened awareness of the intrinsic value of regulatory ecosystem services; and (3) societies where cultural and physical conditions dictate the size and design of urban areas, with nature serving as both a foundation for learning and a source of inspiration (Constanza, 2022; Durán et al., 2023; Haga et al., 2023; Harms et al., 2024; Rana et al., 2020). These emerging visions and transformative pathways illustrate the integrative role of infrastructure alongside ecological, social, and technological innovations in shaping sustainable and synergistic human–nature relationships.

Probable future scenarios, often characterized by negative trends such as global warming and biodiversity loss, underscore the urgent need for sustainable development to remain within planetary boundaries (Becker, 2023; Díaz et al., 2015; Gupta et al., 2024; Mulgan, 2018). However, there is a need to develop alternative nature-positive scenarios and desirable future visions that inspire and guide individuals, communities, and organizations to implement strategies and policies aligned with the Convention on Biological Diversity's (CBD) vision of living in harmony with nature (IPBES, 2016a, 2016b; Tengö et al., 2017). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Scenarios and Models Expert Group developed the Nature Futures Framework (NFF) as a flexible tool to guide the creation of positive, future-oriented scenarios (IPBES, 2016a, 2016b; Kim et al., 2020). Designed as a boundary object, the NFF enables the integration of diverse perspectives on the value of nature, supporting inclusive decision-making and the development of effective management strategies (Durán et al., 2023; Palacios-Abrantes et al., 2022). Its growing adoption within the biodiversity community highlights the importance of embracing pluralistic approaches to conservation planning (Pereira et al., 2023).

The NFF has been developed by building on past perspectives that define the pillars of a sustainable human-nature relationship. Mace (2014) provides a historical overview of this evolution, tracing the shift from "nature for itself" to "nature despite people," then to "nature for people," and finally to "people and nature." While these perspectives are not mutually exclusive and continue to coexist as multiple lenses for understanding human-nature interactions, the "people and nature" perspective emphasizes relational values, particularly the cultural dimensions of these relationships. The NFF synthesizes these ideas into three key aspects: Nature for Nature (NN), which underscores the intrinsic value and autonomous existence of nature; Nature as Culture (NC), which highlights the relational values embedded in human-nature interactions (e.g., concepts such as "Mother Earth"); and Nature for Society (NS), which focuses on the utilitarian value of nature in meeting human needs (see Figure 1 below). These aspects are presented as intersecting circles, illustrating their interconnectedness and the impossibility of isolating any single dimension, as they collectively influence management strategies and decision-making. For instance, a positive and sustainable future vision might envision people living in innovative ecological commons, interconnected blue-green cities, and rural settlements that integrate nature into daily life. In such scenarios, nature is experienced as a cultural entity that responds to human and community needs, fostering a land-sharing approach where biodiversity is conserved through sustainable use (Durán et al., 2023; Palacios-Abrantes et al., 2022; Raskin, 2014). This framework highlights the interdependence of ecological, cultural, and societal values in shaping sustainable human-nature relationships.

Roads play a pivotal role in enabling access to both direct and indirect benefits that nature provides. They serve as conduits to provisioning ecosystem services such as natural resources, including minerals, fossil fuels, wind, geothermal energy, and wave power, as well as connecting people to other services such as biodiversity support, cultural, and recreational benefits, facilitating processes

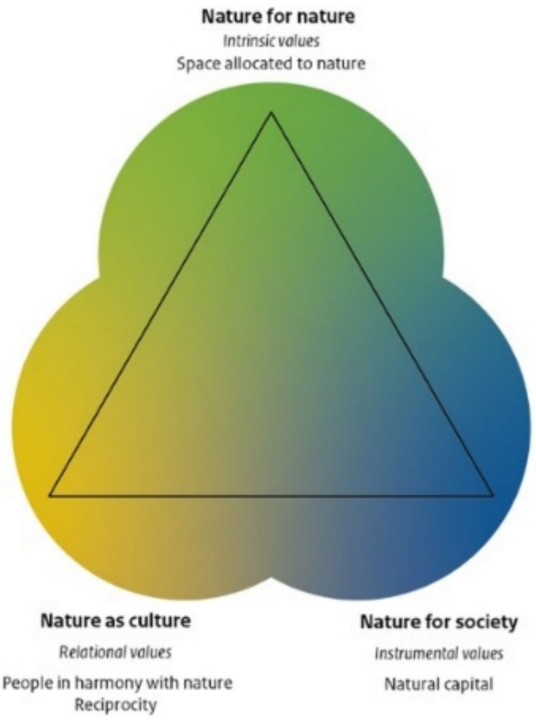

FIGURE 1
The nature futures framework and the three main value perspectives constituting the relative space between different values (from Pereira et al., 2023).

ranging from resource extraction and overexploitation to awareness-raising and conservation efforts (Díaz et al., 2015). Therefore, roads also act as direct drivers of change in human-nature relationships, influencing how development is envisioned, how impacts (both positive and negative) are perceived, and how future strategies are informed (Laurance and Arrea, 2023; Kuncoro et al., 2024). The NFF represents one approach for conceptualizing these relationships, providing a structured way to envision sustainable human-nature interactions. It emphasizes positive futures, while negative or unsustainable relationships are intentionally positioned outside its core structure.

Complementary tools and frameworks have also been developed to explore the future of nature conservation. For instance, scenario archetypes support the NFF by contributing to anticipation studies and scenario planning, enabling a deeper understanding of potential futures (Kim et al., 2020; Sharpe et al., 2016). The entangled time tree is another tool that links humanity's past, present, and future with those of other species, allowing for diverse and interconnected visions of human-nature relationships (Terry et al., 2024). Additionally, the Three Horizons Framework provides a critical lens for examining alternative future visions and transformative pathways, focusing on the current state, the desirable future, and the probable future shaped by present and planned decisions (Curry and Hodgson, 2008). The Seeds of Good Anthropocenes approach complements these tools by identifying and amplifying existing grassroots initiatives that embody hopeful, sustainable futures. By using these "seeds" to co-create bottom-up scenarios, this framework challenges dominant dystopian narratives and fosters pluralistic visions of human–nature relationships (Bennett et al., 2016; Hamann et al., 2020). Schmidt et al. (2025) emphasize that applying such frameworks, including the NFF, reveals tensions between inclusive, community-driven aspirations and dominant policy paradigms, underscoring the need for institutional shifts to support transformative change. Together, these tools and frameworks offer a multifaceted approach to understanding and shaping the complex dynamics of human-nature relationships in the context of sustainable development.

Envisioning and planning for the future, while integral to sustainability discourse, is distinct from agency, understood here as the capacity and power of individuals, communities, and institutions to act intentionally and effect change in pursuit of their desired outcomes (Emirbayer and Mische, 1998; Fischer and Newig, 2016). In the context of road infrastructure, agency plays a critical role in shaping not only the physical landscape but also the social and ecological imaginaries through which human-nature relationships are envisioned. These imaginaries—ideas about what is possible, desirable, or inevitable—are not fixed; they are constructed and reconfigured through acts of agency. As individuals and communities engage with infrastructure, they reinterpret nature's role in their lives, embedding their aspirations, values, and lived experiences into future visions that reflect both material realities and symbolic meanings. Roads, as both material and symbolic infrastructures, can, on one hand, fragment ecosystems and reinforce extractive development models.

On the other hand, they can support more equitable and ecologically integrated planning if informed by inclusive conservation-oriented human agency (Büscher and Fletcher, 2020; Laurance et al., 2014). This agency is influenced by various factors that shape people's ability to envision, value, and conserve nature. These factors include access to infrastructure such as roads, availability of technological resources, and key socioeconomic variables like age, education, gender, and occupation. Each of these elements plays a role in determining people's opportunities and constraints, which in turn affect their ability to participate in conservation efforts and pursue a good quality of life (Chan et al., 2016).

The Nature Futures Framework has been applied across diverse contexts—including the high seas (Pereira et al., 2022), urban environments (Kuiper et al., 2022), forest ecosystems (Dou et al., 2023), and youth engagement (Schmitt et al., 2025), to explore desirable human–nature futures. While these studies have primarily focused on envisioning context-specific futures scenarios, they do not examine the role of mediating factors that shape such visions. This study extends the application of the NFF by examining how environmental and infrastructural conditions, such as household proximity to roads, shape individuals' agency in nature conservation, an area that remains relatively underexplored in existing NFF literature. By focusing on road infrastructure and exploring its impact in combination with other socioeconomic variables, we aim to provide deeper insights into the mechanisms that enable or constrain communities' capacity (agency) to contribute to sustainable and nature-positive futures.

In this study, we investigate how proximity to the transnational Trans-Caprivi highway in Namibia's Kavango-Zambezi (KAZA) region influences rural communities' visions of future human-nature relationships. In addition to analyzing the spatial variable of road distance from residential areas, we incorporate socioeconomic factors such as gender, age, employment status/occupation, and education as additional relevant contextual variables. This analysis focuses on how these factors shape communities' agency for nature conservation,

particularly concerning the NFF's dimensions: NN, NC, and NS. By examining these relationships, the study sheds light on the interplay between infrastructure, socioeconomic variables, and environmental values. The paper concludes with reflections on the applicability of the NFF in understanding the role of road infrastructure in shaping human-nature interactions in the KAZA region, offering insights for sustainable development and conservation planning.

2 Materials and methods

2.1 Study area

We conducted our field research in the KAZA region of Namibia from December 24, 2023, to January 26, 2024. This region, located in the northeastern part of Namibia, within the Zambezi region (formerly known as the Caprivi strip), is part of the Kavango-Zambezi Transfrontier Conservation Area (KAZA-TFCA), one of the world's largest transnational conservation areas (Stoldt et al., 2020). KAZA spans several countries, including Angola, Botswana, Zambia, Zimbabwe, and Namibia. The Namibian part encompasses various parks, the Caprivi State Forest, conservancies, and community forests between protected zones. The capital of the Zambezi region is Katima Mulilo. In contrast to Namibia's arid regions, the Zambezi region is characterized by a network of waterways and abundant wildlife, which draws significant tourism (Dittman and Müller-Mahn, 2023). Additionally, the region is home to numerous traditional villages inhabited by several ethnic groups, such as the Subia, Herero, and Totela. As the heart of the KAZA conservation area, the Zambezi region facilitates the movement of wildlifeincluding elephants, through its wildlife corridors (Lupiya, 2019).

This biodiversity-rich stretch is fragmented by a wide, paved road that replaced the previous dirt road in 2001 (according to one elderly respondent living near the road), forming the Trans-Caprivi Highway, which connects Namibia to its neighboring countries. The Subia tribe, predominantly agropastoralists, primarily inhabits the area along this road. This study focuses on the road segment extending from Katima Mulilo to Ngoma, which borders Botswana.

2.2 Data collection

We employed systematic sampling to select four villages based on their proximity to the highway: two villages close to the highway (Ngoma and Bukalo, <1 km away) and two farther villages (Sifuha and Mutikitila, approximately 20 km away) (see Figure 2). The thresholds of <1 and 20 km were chosen to represent two distinct spatial contexts: immediate proximity and relative remoteness from infrastructure. The <1 km category captures communities directly adjacent to infrastructure, where impacts are likely to be most pronounced. The 20 km threshold

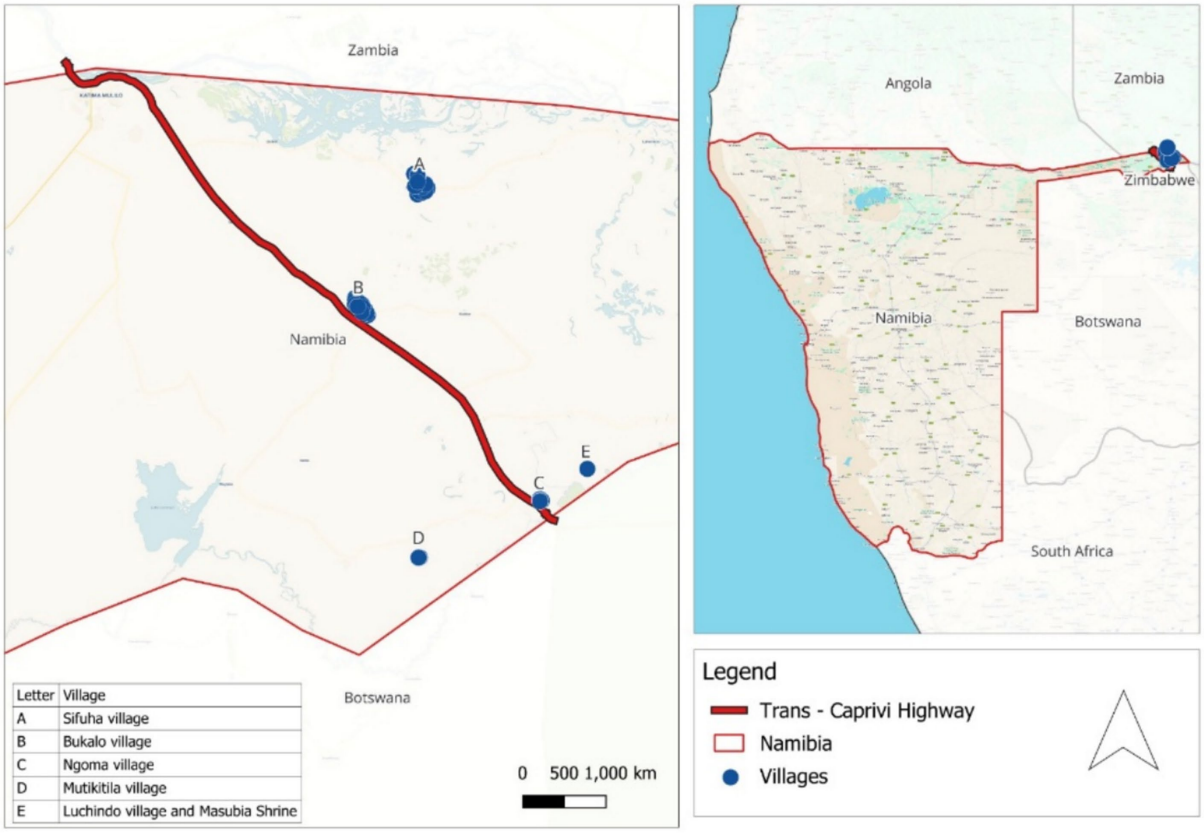

FIGURE 2
Village locations (multiple dots indicating respondents) in the study area together with Trans-Caprivi Highway (left) as well as study area location within Namibia (right).

was selected to represent communities that are significantly removed from direct infrastructure influence, serving as a comparative baseline. There are no standard thresholds on remoteness in the literature, as the distribution of households in reference to roads is context-specific.

Further, we employed a purposive sampling strategy to select individuals who represented key characteristics relevant to the research, specifically, diverse socio-ecological contexts. This approach ensured that the sample captured a broad spectrum of experiences and perspectives across the four villages. To further expand the participant pool and reach individuals who might not have been initially identified, snowball sampling was used. In this technique, initial respondents were asked to refer others within their community who met the study criteria, allowing the researchers to access more nuanced social networks and perspectives. Approximately 20 respondents were chosen from each village, with efforts made to ensure variation in key demographic characteristics such as age, gender, occupation, and number of years spent in formal education. In total, 83 respondents were selected through this combined approach. While lists from the village heads (locally referred to as Indunas) could have supported random sampling, our approach prioritized selecting participants with relevant experiential knowledge of nature-related values in varying spatial contexts. This was essential for capturing nuanced perspectives aligned with the Nature Futures Framework.

The data collection method included, first, semi-structured questions in the form of a survey and second, participatory mapping workshops, during which respondents engaged in participatory mapping exercises. Before data collection, a preliminary site visit was made to each village to inform the Indunas about the study and request permission to conduct research in the area. All four Indunas granted permission, with two actively participating as respondents. Over four weeks, the researcher and a field assistant visited the villages three days a week. Given that most respondents in the four villages were fluent in the Subia language but had limited proficiency in English, we used the assistance of a translator to facilitate effective communication during the interviews.

We designed the semi-structured questions based on the three dimensions of the NFF, which were informed by the value assessment methodology developed by IPBES (IPBES, 2022). Before administering the questions (quantitative valuing) and conducting participatory workshops (qualitative valuing), we ensured that the respondents clearly understood the NC, NN, and NS dimensions of the NFF and how we intended to use it to gain divergent valuations of nature and plural visions of human-nature relationships. Consequently, respondents completed the survey assessing their perceptions of nature [use of their natural ecosystems and biodiversity (NS), their cultural interconnectedness with them (NC), and their autonomy or right to exist, evolve, and function independently without human interference (NN)] across three temporal scenarios: the present, a probable future, and a desirable future. For each scenario, they assigned percentage values reflecting their perceived value of nature concerning the NN, NC, and NS categories. In each scenario, the sum of these values adds up to 100% (Table 1 below).

Additionally, we collected individual socioeconomic and demographic data, including age, gender, cumulative years of schooling (formal education), and employment status (whether they had a source of income or not). Furthermore, flexible follow-up questions were used to elicit unique responses from respondents. For example, during visits to traditional shrines, we aimed to gain views from respondents of different age categories on how and why the stature and protection of traditionally respected areas were changing. The geographic coordinates of respondents' houses were also recorded to estimate their approximate distance from the highway. All participants willingly consented to take part in the survey.

Following the semi-structured survey, all respondents from each of the four villages participated in a participatory mapping exercise. Before beginning, a group explanation was provided to ensure shared understanding of the task, after which the respondents worked uninterrupted and in self-coordination among themselves. Each group (the respective village respondents) independently created three sets of maps: one illustrating current land use, another depicting probable future developments, and a third reflecting their desirable vision for their village. The maps aimed to capture each group's understanding of their environment while capturing the future scenarios based on their local knowledge and lived experience. Participants used markers and manila paper, with different colours symbolizing specific land-use values based on the NFF: green for "Nature for Nature," blue for "Nature as Culture," red for "Nature for Society," and black for roads, pathways, and non-traditional residential areas.

This exercise yielded twelve maps (see Appendix)—three from each village—enabling a comparative visual analysis of both within and across villages over time. Additionally, we visited cultural sites, such as Luchindo Village and the Masubia Shrine, accompanied by one of the Indunas, who provided insights into the changing cultural roles of these historically sacred areas in nature conservation, particularly in light of generational shifts and changing land uses. These visits provided valuable contextual information, contributing to the achievement of the study's objectives.

2.3 Data analysis

The quantitative data collected during the research were systematically organized in a Microsoft Excel table format to support

TABLE 1 Example of the value assessment methodology in data collection for respondents.

Scenario	Nature for nature (NN)	Nature as culture (NC)	Nature for society (NS)	Notes from the respondent
Present	20%	30%	50%	"Right now, most people see nature as a resource – something to use. Cultural ties are fading, and intrinsic value for nature is rarely prioritized."
Probable	15%	10%	75%	"If things continue the way they are, nature will even be more commodified. Development will dominate, and cultural or intrinsic values will decline."
Desirable	40%	35%	25%	"I hope for a future where nature is protected for its own sake, and where people reconnect with it culturally, not just to use it for economic gain."

further analysis. We used R software (version 4.3.3) and relevant packages such as dplyr (Wickham, 2017) for data cleaning and lm (R Core Team, 2024) to assess the statistical relationship of the various variables. To assess the respondents' perceived agency in shaping future human-nature relationships, we operationalized agency as the alignment between their probable and desirable *futures*. Specifically, we calculated the absolute difference between each respondent's valuation of a probable future and their valuation for a desirable future (using the data collected as in Table 1) across the three dimensions of the Nature Futures Framework (NN, NC, and NS). This difference reflects the perceived gap between expectation and aspiration (see Table 2). To derive a standardized measure of agency, we subtracted the absolute difference from 100% such that higher scores indicate greater perceived agency – i.e., a stronger belief that the future one desires is attainable.

Agency Score = 100 – (Desirable -Probable).

To examine the relationship between individual perceived agency and contextual factors such as age, gender, occupation, and number of years spent in formal education. We employed beta regression analysis since our dependent variable was a percentage value, which we rescaled to a range of 0 and 1. Furthermore, we conducted a multicollinearity test to check if the independent variables were collinear. We ruled out multicollinearity in our model. Consequently, we ran beta regression models first, obtaining the logit-scale coefficient, and based on these, we estimated the marginal effect to get the effect in terms of percentage-point changes in the dependent variable (Table 3).

We classified occupation status into employed (respondents reporting a source of income regardless of which one) and unemployed (those without a source of income). Gender and occupational status were treated as binary variables, whereas age and education (measured as cumulative years of schooling) were treated as continuous variables. Although household size and wealth were not included in the present analysis, we recognize they would have a potential influence in the outcomes and recommend their inclusion on future studies. The regression analysis was conducted based on two sub-samples: villages near the road (NR), including respondents from Ngoma and Bukalo villages, and villages far from the road (FR), including respondents from Mutikitila and Sifuha villages.

Qualitative data reflecting responses to open questions and comment sections were categorized per village. However, the number of responses and comments does not necessarily correspond to the total number of respondents, as some individuals either chose not to provide additional remarks or had no further input beyond the quantified responses. We visually compared the participatory maps to identify differences between the probable and desirable future visions of villages near and distant from the main road. Additionally, observations from cultural site visits were documented in detailed descriptive notes, integrating both direct observations and the Induna's narratives of the historical significance of these sites.

3 Results

3.1 Visual interpretation of participatory maps

Respondents expressed enthusiasm in visualizing their villages' current and future states but also sought clarity on the next steps, expressing hope that their contributions would lead to tangible outcomes. The participatory maps generated by respondents provide a powerful medium to interpret how communities in the KAZA region perceive and project change across the three dimensions of NFF. A comparative visual analysis between probable and desirable futures in villages near and far from roads reveals clear spatial patterns, symbolic cues, and underlying narratives of agency.

3.1.1 Near the road

Probable future maps for Ngoma and Bukalo villages are typically dominated by green (Nature for Nature) signifying dense forests and grasslands, and blue elements (Nature as Culture) such as Khuta (traditional meeting points), traditional houses and fences. Red (Nature for Society) is limited, reflecting a vision of ecological and cultural continuity but slow development. The presence of roads is depicted passively, with existing infrastructure shown without associated community benefits such as markets or schools. This suggests that respondents perceive limited local agency to influence development despite being close to roads. However, desirable maps feature more red elements, including markets, schools, modern houses with corrugated iron roofs, and more road connections. There is a noticeable reduction in green grass, reflecting a trade-off between ecological space and the expansion of infrastructure. Blue features decrease slightly, reflecting a willingness to modernize at the cost of some cultural continuity. The visual narrative shifts from preservation to transformation, indicating that the community aspires to greater agency in shaping future socio-economic outcomes, with road infrastructure playing a more enabling role.

3.1.2 Far from the road

Probable future maps of Mutikitila and Sifuha villages show a greater variety of land uses and features compared to those near roads, with red, blue, and green appearing more frequently. These colours represent a mix of land-use priorities: red areas indicate cultural continuity, such as traditionally fenced homesteads and community gathering spaces; blue areas reflect societal improvements, including proposed markets and expanded housing; and green areas denote retained natural spaces that support ecological integrity. This suggests that, despite their remoteness, communities perceive themselves as active agents capable of shaping their environments through local cooperation and adaptive practices (Schreuder and Horlings, 2022). Desirable future maps further confirm this vision of transformation.

TABLE 2 Illustration of agency calculation.

Dimension	Probable future (%)	Desirable future (%)	Absolute difference	Agency scores (100 - absolute difference)
Nature for Nature (NN)	15%	40%	25	75
Nature as Culture (NC)	10%	35%	25	75
Nature for Society (NS)	75%	25%	50	50

TABLE 3 Beta regression results.

Agency	Near road	Far from road
NN agency	Age −0.0003 Gender M 0.0592 Occ. Unemployed 0.0619 Education 0.0057	Age 0.0072 Gender M 0.0264 Occ. Unemployed −0.0354 Education −0.0094
NC agency	Age −0.0002 Gender M 0.0447 Occ. Unemployed 0.0465 Education 0.0154**	Age −0.0047* Gender M − 0.0627* Occ. Unemployed 0.1465** Education −0.0238*
NS agency	Age −0.0012 Gender M 0.0799 Occ. Unemployed 0.0480 Education −0.0032	Age 0.0022 Gender M 0.0359 Occ. Unemployed 0.0122 Education −0.0118
Average agency	Age −0.0004 Gender M 0.0672 Occ. Unemployed 0.0515 Education 0.0062	Age 0.0010 Gender M − 0.0079 Occ. Unemployed 0.0495 Education −0.0173

Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05.

They feature even more extensive road systems, additional schools, marketplaces, and a greater number of modern housing structures represented vividly in red and black. While green spaces and cultural features remain present, they are more selectively preserved, indicating a strategic prioritization of development goals. These visualizations reflect a forward-looking orientation, where infrastructure is not seen as externally imposed but as a community-driven enabler of wellbeing and sustainable use of nature. This detailed and deliberate placement of these features suggests that distance from the road does not hinder visionary thinking, and in some cases, may even enhance localized aspirations and creativity planning.

Generally, desirable futures in far from the road areas reflect greater development ambition, challenging assumptions that remoteness equates to passivity or conservatism. These maps suggest a stronger belief in the possibility of achieving change, even in the absence of current infrastructure. Communities far off the roads often conceptualize roads primarily as gateways to future economic development but also as a means of improvement in conservation. Conversely, those in close proximity to the roads exhibit lower perceived agency, characterized by a sense of stagnation regarding the benefits of existing road access. In these contexts, roads are viewed more cautiously, often as limiting rather than enabling. While conservation was mentioned, it tended to be secondary to development priorities, especially among those already experiencing the material realities of infrastructure. This contrast highlights how proximity to roads shapes not only access but also the imagined futures tied to them.

3.2 Empirical results

3.2.1 Sample statistics

Table 4 presents the demographic breakdown of our sample (N = 83), including gender, age, occupation, and education. While the sample was purposively selected to capture variation in proximity to road infrastructure and local ecological contexts, it is not statistically representative of Namibia's population of approximately 3.02 million. However, certain demographic characteristics in our sample align with national-level patterns. For instance, the Namibia Statistics Agency reports that 51.2% of the population is female and 48.8% is male, which is consistent with the gender distribution observed in our sample. Additionally, the high proportion of youth participants reflects broader national trends, as Namibia's median age is 22 years (NSA, 2024), and youth unemployment remains a significant concern, with rates reported at 44.1% in 2023 (NSA, 2025). Educational attainment in our sample also mirrors national developments, with increasing numbers of secondary school graduates reported by the Ministry of Education—from 21,000 in 2020 to 46,000 in 2022 (Ministry of Education, Arts and Culture, 2022).

Table 5 shows a general pattern of decrease in NC and increase in NS and NN with reduced distance from the road. Specifically, the current value of NN was seen to increase near roads, while the values for NC and NS were perceived to decrease in the future. Perceptions of probable futures suggest continued increases in NN and NS values, but a further decrease in NC. Desirable futures mirrored these patterns, indicating a preference for increased NN and NS values and a continued decline in NC.

3.2.2 Beta regression results

The analysis evaluates the influence of five independent variables, age, gender, occupation status, and education, on respondents' valuation of the three dimensions of nature (NN, NS, and NC) among individuals residing near (Bukalo and Ngoma villages) and far from the highway (Mutikitila and Sifuha villages). Based on the average values, in areas with close road proximity, respondents perceived distinct effects on the three dimensions of the NFF.

Overall, no statistically significant relationship was observed between the agency for NN and NS and the four independent variables, near or far away from roads. However, a significant relationship was found between the agency for NC and these variables. Notably, the direction and statistical significance of the relationship between education and the level of agency for NC varied based on proximity to the road. Among respondents living closer to the road, higher levels of education were associated with increased agency for NC. Each additional year of formal education was associated with a 1.54 percentage point increase in their perceived agency. The influence of education is, however, different for the respondents living far from the roads, as one additional year of formal education was attributed to a reduction in perceived agency by 2.38 percentage points. This suggests that individuals with higher education levels close to roads perceive themselves as having greater control over shaping the relationship between culture and nature. Further away from roads, the opposite was true.

Although the relationship was not statistically significant, we observed a consistent trend suggesting a potential negative association between age and perceived agency across NN, NS, NC, and average agency scores among respondents living near roads. While this pattern does not support definitive conclusions, it may indicate that older individuals tend to report lower levels of perceived agency. Additionally, we noted a broader pattern in the data regarding gender and employment status, where employed respondents living near roads generally reported higher perceived agency compared to their unemployed counterparts. This observation aligns with our expectations, given that individuals residing near roads often have

TABLE 4 Sample statistics of the respondent distribution per age, gender, occupation and education.

Variable	Classes	Proportion
Gender	Males	49%
	Females	51%
Age	Old and middle-aged (>35 years old)	43%
	Youth (18–35 years old)	57%
Occupation	Employed	42%
	Unemployed	58%
Education	G0 (Grade 0 to 10)	40%
	G1 (Grade 11 and above/post-secondary school level)	60%

TABLE 5 Nature valuation in reference to distance from the road.

Aspect	Effect near the road/high road proximity
Current NN value	Increase
Current NC value	Decrease
Current NS value	Decrease
Probable future NN value	Increase
Probable future NC value	Decrease
Probable future NS value	Increase
Desirable future NN value	Increase
Desirable future NC value	Decrease
Desirable future NS value	Increase
Agency for NN	Increase
Agency for NC	Decrease
Agency for NS	Increase
Average Agency	Increase

greater access to alternative livelihood opportunities, such as roadside shops or small-scale trade, than those in more remote areas. While these livelihood options may be instrumental in nature, their availability can influence how individuals engage with and interpret their relationship with nature. Specifically, economic hardship may erode one's sense of agency in sustaining cultural practices tied to nature, whereas access to income—even through nature-based or instrumental means—can reinforce relational values by enabling individuals to feel more empowered in shaping the nature–culture dynamic. Thus, the presence or absence of livelihood options indirectly affects how people perceive and enact Nature as Culture.

Additionally, gender influences show a positive association, especially in NC, indicating that men report a greater sense of motivation and influence over nature than women. This may reflect prevailing socio-cultural norms in the study area, where men often occupy more visible roles in land management and decision-making processes, potentially shaping their perceived agency. Meanwhile, women's engagement with NC, though vital, may be less publicly acknowledged or shaped by structural constraints, influencing how agency is experienced and expressed. Furthermore, age also demonstrates a statistically significant negative effect on agency for NC among respondents in more remote areas, suggesting that individuals' perceived agency over nature as culture tends to decline with age.

Among respondents living far from the road, we observed a non-significant trend suggesting a potential positive association between age and perceived agency across NN, NS, and overall average scores. While this pattern does not support definitive conclusions, it may indicate that older individuals in these areas perceive slightly greater agency, warranting further investigation. Another consistent observation among those living far from the road is that education seems to be associated with reduced agency for NN, NS, NC, and average agency.

Within the study area, individuals with higher levels of formal education were more frequently observed in areas closer to road infrastructure, where access to schools, services, and employment opportunities is typically greater. In contrast, communities located farther from roads tended to be situated in regions where customary practices, land-based livelihoods, and locally rooted governance systems remain prevalent. These communities often maintain cultural continuity and place-based knowledge, regardless of variation in formal education levels. While causality cannot be inferred, the geographic distribution of respondents suggests differing engagements with both modern and traditional systems. Notably, respondents with lower levels of formal education living farther from roads reported a stronger sense of agency for NC. Although this association appears to persist when considering average agency across NN, NC, and NS, it is no longer statistically significant.

Table 3 presents the coefficients of marginal effects of the demographic and contextual predictors on perceived agency scores across NN, NC, and NS, as well as the average agency score. Based on the sub-sample analysis, the first column represents respondents living near roads, while the second column is for those living far away from the road. The statistical significance for each coefficient is based on the original log-odds estimation, rather than the marginal effects coefficients shown in the table. We preferred showing the marginal effects coefficients to log-odds due to ease of interpretation.

4 Discussion

Intrinsic (NN), relational (NC), and instrumental (NS) values are widely recognized as foundational to conservation efforts. However, focusing solely on these value dimensions without considering people's perceived agency may overlook a critical factor in enabling transformative, nature-positive futures. In this study, NC is interpreted through the lens of relational values as defined by the IPBES Values Assessment, emphasizing meaningful relationships between people and nature, including identity, responsibility, and care. This interpretation differs from broader notions of culture, which often refer to shared traditions or symbolic meanings. Cultural ecosystem services, meanwhile, describe nature's non-material contributions to human wellbeing through interactions with ecosystems, and are closely linked to regulating and provisioning services. These interconnections generate both tangible and intangible benefits. In this context, relational (NC) values can be seen as bridging intrinsic (NN) and instrumental (NS) values by integrating ethical, emotional, and functional dimensions of human–nature relationships. Despite their integrative potential, relational values are often underrepresented

in assessments and policy frameworks, making them difficult to identify within discussions of cultural ecosystem services (Chan et al., 2016; Meyrick and Barnett, 2021).

In addition to these conceptual linkages, empirical findings from this study reveal that respondents exhibited agency in relation to both NN and NS values, though with important contextual differences. For instance, in many far-from-road communities, desirable future maps included both conserved natural areas and expanded infrastructure such as roads, schools, and markets. This illustrates how conservation and development are envisioned not as competing priorities, but as complementary aspirations. The spatial co-occurrence of ecological and social features suggests that communities do not perceive intrinsic and instrumental values as mutually exclusive. Instead, they recognize the interdependence between ecological integrity and social wellbeing, reinforcing the need for integrated approaches that reflect lived experiences and local agency.

Through both linear regression analysis and participatory mapping, it is evident that perceptions of agency are not equally distributed near and far from the road. Statistical analysis on an individual basis indicate that socioeconomic factors such as age, employment, gender, and education significantly influence perceived agency in shaping positive visions of nature as culture, both in communities near and far from the road. This was also reflected in the participatory mapping workshops, where respondents reduced the presence of cultural symbols in their probable and desirable futures, indicating that as road infrastructure expands, cultural elements are becoming less prominent.

4.1 Education

A study by Heisel et al. (2021) ecological knowledge, perceived agency, and motivation regarding wildlife conservation in Kenya found that Nature as Culture—understood here as a relational value—plays a crucial role in shaping knowledge systems. NC reflects the meaningful relationships between people and nature, including identity, responsibility, and care, and extends beyond symbolic or cultural associations to encompass deeper relational dimensions. While national policies do not universally adopt this relational framing, there are context-specific examples where it is reflected. For instance, in Namibia, formal education curricula incorporate regionally tailored content such as environmental education and wildlife conservation, as noted by some of the youth respondents, which aligns with the country's semi-arid ecology and diverse fauna (Harvey and Knox, 2015). However, Linnell et al. (2015) argue that Western education systems often emphasize the direct impacts of human activities on nature while neglecting the relational dimensions of ecological knowledge and the role of individual and community agency in fostering nature-positive futures. This omission weakens the relational lens through which individuals understand the value of nature and may contribute to diminished perceived agency for NC. This dynamic may help explain our finding that, in communities located farther from roads—where cultural traditions and relational ties to nature are more strongly preserved, increased years of formal education are associated with reduced perceived agency for NC.

Findings from this study suggest that individuals residing closer to road infrastructure reported slightly higher perceived agency in achieving positive visions for NC, as reflected in the statistically significant relationship between NC agency and education level in the beta regression results, as well as respondent comments. This trend appears to correlate with increased access to alternative income sources and greater exposure to both the benefits and ecological disruptions associated with road development, such as forest clearing, land fragmentation, and wildlife habitat loss. Additionally, respondents with higher levels of formal education, who were more commonly located near roads, demonstrated greater awareness and engagement with conservation efforts, reinforcing their sense of agency. For example, a 28-year-old added to their valuation that "We live near the road, and I have pursued my degree in the city. Until now, more trees continue to be cut, and the number of shops and firewood businesses along the road is increasing. I appreciate the role that our culture used to play in conserving our ecosystems." These results align with the broader interpretation that ecological education can enhance agency; however, when such education fails to incorporate relational values such as care, stewardship, and identity, it may weaken the very human-nature connections that the concept of Nature as Culture seeks to uphold. Ecological education that embraces NC as a relational value is essential not only for equipping students with the skills to address environmental challenges but also for fostering attitudes that promote sustainable development and deepen human–nature relationships (Chen and Bu, 2019).

4.2 Age

The current generation of educated young people increasingly perceives aspects of their centuries-old culture as "primitive" and gradually becoming "outdated" (Lilemba and Matemba, 2014). Our field visits revealed that cultural heritage sites, such as Luchindo Village and the Masubia Shrine, have deteriorated along with the once-dense forests surrounding the royal family's sacred burial site, located approximately 18 kilometers from the main road. We observed encroachment with individuals constructing houses and engaging in agricultural activities. Additionally, one of the few remaining large trees was being cut down to craft a boat for a member of the royal family.

Overall, younger respondents in our study demonstrated limited knowledge of traditional stories about nature compared to middle-aged and older participants. Elderly respondents attributed the younger generation's diminishing connection to cultural norms to the influence of modern education systems. One 72-year-old participant remarked, "[…] *They are always in school learning different things. When they come home, they are on their phones or doing assignments and do not want to listen to our old and outdated stories* […]."

While Rana et al. (2020) note that many young people experience future-related anxiety due to global challenges such as climate change, they also actively engage in constructing positive future scenarios using the NFF. This was evident in our study, young participants showed enthusiasm in envisioning the current status, desired, and probable futures of their villages. They have gained awareness of potential solutions through formal education, conferences, and other knowledge-sharing platforms (UNDP, 2024). Despite being categorized as a "silent majority" and marginalized group with limited agency in shaping positive future visions, young people have opportunities through technology and information networks to address environmental issues and drive sustainable practices (Vincent

and Gitau, 2022). Our study found that youth residing in more remote communities located farther from major road infrastructure demonstrated higher levels of engagement in participatory mapping exercises and expressed a strong commitment to envisioning desirable futures for nature. In contrast, youth living closer to the road were more frequently involved in economic activities enabled by improved infrastructure or had migrated to urban areas (in some cases, commuting daily) in search of employment. These circumstances may have limited their availability or interest in local environmental planning initiatives. This pattern is consistent with the composition of our sample, which included a greater proportion of youth participants from villages situated farther from the road.

4.3 Gender

Although women in remote areas possess significant knowledge and firsthand experience in nature conservation and land degradation (Vincent and Gitau, 2022), they continue to be marginalized in policy-making processes (Arya et al., 1998). Women are often classified as part of the "silent majority," particularly in remote, roadless areas where economic development is still emerging (Robyn et al., 2021). As a result, their perspectives on land use and conservation efforts are frequently overlooked when implementing sustainable initiatives.

Moreover, certain conservation projects may not directly benefit women due to cultural restrictions limiting their participation in taboo activities within their communities. Findings from this study indicate that men traditionally hold greater decision-making power, often leaving women feeling disempowered in influencing the relationship between culture and nature. This is particularly evident in communities farther from major roads, as demonstrated by the significant relationship between the agency for NC and gender (Table 2). These results underscore the need for increased efforts to promote women's inclusion and enhance their agency in NC, thereby strengthening their engagement in NN conservation (Susilo and Kodir, 2019). However, our study also found that women exhibited a greater level of agency in shaping future visions for Nature for Society (NS) compared to men. Some women commented that they collect firewood for cooking, farm on the land, gather some wild fruits, and grow vegetables and medicinal plants, as was observed with Moringa herbs (highly valuable and used for multiple purposes both traditionally and in modern medicine) in most households.

4.4 Employment

Proximity to the Trans-Caprivi highway appeared to shape how respondents experienced the relationship between unemployment and perceived agency. Most survey participants acknowledged that road infrastructure facilitated mobility, enabling individuals to seek employment opportunities elsewhere and maintain connections beyond their immediate communities. While the statistical relationship between unemployment and agency for NN and NS was not significant, a general trend emerged in which perceived agency tended to decline with increasing unemployment. Notably, a large proportion of unemployed respondents were youth, particularly those residing in remote villages. This demographic pattern may help explain the observed decline in agency, as younger individuals without stable income sources may feel less empowered to influence nature-positive futures. This aligns with findings from Namibia, where high unemployment rates among youth—especially in rural areas—have been linked to diminished agency and reduced engagement in community development (Amadhila, 2025).

Additionally, some unemployed respondents in this study commented that cultural norms and limited infrastructural development in remote villages far from the highway had prevented them from accessing opportunities to improve their lives, resulting in a lower sense of agency for nature conservation. Several participants expressed a desire for improved road infrastructure, believing it would create job opportunities and enhance their ability to shape a better future. This observation is consistent with reports indicating that poor rural infrastructure in Namibia hampers access to essential services and economic opportunities, disproportionately affecting vulnerable groups (Namibian Sun, 2024). Interestingly, Vale and Vale (2013) noted that individuals living farther from roads may express a stronger commitment to envisioning desirable futures for nature, due to limited external employment prospects and a greater reliance on local environmental resources. In this context, unemployment may also drive agency for NS in remote areas, as individuals seek alternative pathways for economic and environmental engagement in the absence of formal employment opportunities.

4.5 Roads and nature conservation

Research in environmental psychology suggests that an individual's belief in their capacity to effect change through their actions (agency) significantly shapes their behavior toward the environment (Kollmuss and Agyeman, 2002; Wolf and Moser, 2011). While roads are widely recognized as catalysts for economic development, our findings indicate that they can also diminish people's ability to engage with nature's cultural and social benefits. This, in turn, contributes to a decline in the agency for nature conservation, particularly in areas close to roads. Some respondents expressed concern that they might never encounter wildlife such as elephants again, which they considered crucial for passing down indigenous knowledge and fostering awareness of nature conservation among future generations.

A middle-aged respondent living near the road shared a perspective on the cultural shift, stating, "[…] *Our parents and grandparents used to tell us stories about nature, animals, and the punishments or taboos associated with harming the environment in our culture. We would see these animals in our surroundings and connect them to the folktales. Unfortunately, today, our children cannot witness wildlife moving freely because of the road* […] *They have disappeared. People must now pay to see them in conservancies* […]."

Furthermore, some respondents believed that nature conservation was primarily the responsibility of conservancies and the relevant government ministries rather than the local community. Some individuals living near the highway expressed limited relational connection to nature (NC), as they did not perceive meaningful cultural or identity-based benefits from top-down conservation programs. Their engagement with nature conservation appeared to be shaped more by the absence of tangible, instrumental benefits (NS), such as economic incentives or livelihood support. This perspective aligns with the argument by Harvey and Knox (2015) that policy

regulations tend to regard people merely as users of nature, often overlooking their local ecological knowledge and potential contributions to conservation. Nevertheless, the participatory maps show the communities' ambition to integrate NN and NS in their desirable futures, indicating a sustainable approach to the future development visions of their villages, especially far from the road.

Overall, roads play a crucial yet complex role in shaping individuals' and communities´ visions of and agency for nature conservation. Despite the diverse perspectives and competing visions surrounding conservation efforts, this research highlights the significance of embracing pluralism, as advocated by the Nature Futures Framework.

4.6 Applicability of NFF and research limitations

In this research, we acknowledge the significance of embracing diverse visions within NN, NC, and NS value perspectives. We highlighted how various factors—both near and distant from the highway—shape different perspectives and levels of agency in envisioning and achieving future human-nature relationships. Thus, while the proximity of villages to roads is a significant consideration, it is only one of many factors influencing these perspectives.

Western worldviews often emphasize direct human influence on nature (Maldonado, 2015). In contrast, many non-Western cultures, particularly in Africa, traditionally attribute environmental changes to external forces such as fate, cultural taboos, or sacred practices that maintain human-nature relationships (Sasaoka and Laumonier, 2012). Several respondents in this study emphasized that cutting certain trees is considered taboo within their cultural traditions. Older participants specifically expressed concern over the declining recognition of sacred sites such as Luchindo Village and the Masubia Shrine, which were historically central to conservation practices. Meanwhile, younger respondents noted that "we no longer practice the 'old' rites of passage in the forest," reflecting a generational shift away from traditional ecological knowledge and the potential decline in NC valuation and agency. This erosion of cultural engagement appears to be contributing to the deterioration and abandonment of these previously protected sites. Integrating such local perspectives on human-nature relationships can enhance the credibility of conservation initiatives, improve their prospects for both short- and long-term success, and promote cultural respect and social justice (Sasaoka and Laumonier, 2012). When Western-centric assumptions about environmental agency are unexamined and implicitly imposed, local stakeholders may not share these perspectives, which can lead to resistance. This highlights the importance of the NFF in fostering capacity building at multiple scales by embracing participatory and multistakeholder approaches. The NFF advocates for integrating diverse knowledge systems, including local ecological knowledge, to support inclusive and culturally informed conservation efforts (Díaz et al., 2015; Lundquist et al., 2021).

Nature connectedness (NC), when understood as a relational value, emphasizes the deep, meaningful relationship between people and the natural world. This connection supports the preservation and conservation of biodiversity, aligning closely with the concept of nature's needs (NN). It also helps address global environmental challenges like climate change, which largely stem from a utilitarian view of nature as a service (NS) to be exploited for human gain. Although NC is challenging to quantify and track due to its diversity across various communities and generations, it is important to understand how different perceptions of human-nature relationships shape individuals' agency towards sustainable action. Understanding the components and applicability of the NFF was not straightforward for the respondents. Nevertheless, by using local examples and engaging in discussions during the participatory mapping exercises, the participants were able to distinguish between NN, NS, and NC and visualize their visions.

Although we attempted statistical analysis using our survey data, we recognize that the small sample size and non-normal distribution of some variables may have biased our results. For example, about 70% of the less educated and unemployed respondents were women. Additionally, we acknowledge that other socio-economic variables, such as household size and wealth (both monetary and material), were not collected. As the omission of these variables was unintentional, we recommend their inclusion in future research to enhance the validity of regression results. Despite these limitations, we believe that this study is a step towards exploring the connection between positive views of human–nature relationships, individuals' ability to realize this vision, and proximity to main roads as key factors influencing these relationships.

5 Conclusion

This study highlights the crucial role of the NFF in understanding how road infrastructure development impacts community-led nature conservation. Envisioning different future scenarios reveals how a single development, such as road infrastructure, can be viewed in various ways. This calls for wider societal debate on the development and management of nature. Our findings reveal that proximity to roads affects individuals' agency toward nature conservation (NN, NS, and NC), with socio-economic factors such as education, employment, gender, and age shaping these values both presently and in the future. We emphasize the importance of integrating diverse cultural perspectives in fostering sustainable action. However, while the NFF advocates for inclusivity, its integration into development policies remains challenging, given the predominance of top-down economic growth models (Harvey and Knox, 2015). Several studies applying the NFF have echoed this concern. Durán et al. (2023) found that dominant growth-oriented paradigms often marginalize alternative value systems, limiting the transformative potential of nature-positive scenarios. Similarly, the IPBES Scenarios and Models Expert Group (2016–2023) highlighted a disconnect between inclusive, nature-centric visions and mainstream policy tools, which prioritize economic indicators over ecological and cultural well-being. Our study offers preliminary insights into the implementation of the Nature Futures Framework, suggesting that its refinement could benefit from integrating perceived agency. These considerations may guide future revisions of the NFF and enhance its relevance in diverse conservation contexts.

Although community engagement in conservation has been documented in regions like KAZA, Namibia (Bollig et al., 2023), future research should explore if and how such initiatives can be integrated with

the ongoing infrastructure expansion, particularly in ways that reflect and support local community aspirations. There is also a need for more studies to assess the impact of major roads on wildlife. To achieve a more inclusive and sustainable future, governments and development partners must align infrastructure development with local conservation priorities, ensuring both economic growth and environmental stewardship.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

JM: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. VM: Conceptualization, Formal analysis, Investigation, Methodology, Software, Supervision, Writing – original draft, Writing – review & editing. LB-F: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. This research was funded by the German Research Foundation (DFG) through the Collaborative Research Centre- Future Rural Africa (TRR228).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2025.1653920/full#supplementary-material

References

Amadhila, E. M. (2025). Generational renewal of and support for agricultural businesses to achieve vision 2030 in Namibia—a focus on social protection. *J. Dev. Policy Practice* 10, 171–191. doi: 10.1177/24551333241263400

Anderson, D. (2001). Recovering humanity: movement, sport, and nature. *J. Philos. Sport* 28, 140–150. doi: 10.1080/00948705.2001.9714609

Arya, S. L., Samra, J. S., and Mittal, S. (1998). Rural women and conservation of natural resources: traps and opportunities. *Gend. Technol. Dev.* 2, 167–185. doi: 10.1080/09718524.1998.11909895

Becker, G. (2023). Disrupted lives: How people create meaning in a chaotic world. Oakland, CA: University of California Press.

Bennett, E. M., Solan, M., Biggs, R., McPhearson, T., Norström, A. V., Olsson, P., et al. (2016). Bright spots: seeds of a good Anthropocene. *Front. Ecol. Environ.* 14, 441–448. doi: 10.1002/fee.1309

Bollig, M., Lendelvo, S., Mosimane, A., and Nghitevelekwa, R. V. (Eds.) (2023). Future rural Africa. Conservation, markets, and the environment in southern and eastern Africa: Commodifying the "wild". Melton: James Currey.

Büscher, B., and Fletcher, R. (2020). The conservation revolution: Radical ideas for saving nature beyond the anthropocene. London: Verso.

Chan, K. M. A., Balvanera, P., Benessaiah, K., Chapman, M., Díaz, S., Gómez-Baggethun, E., et al. (2016). Opinion: why protect nature? Rethinking values and the environment. *Proc. Natl. Acad. Sci. USA* 113, 1462–1465. doi: 10.1073/pnas.1525002113

Chen, H., and Bu, Y. (2019). Anthropocosmic vision, time, and nature: reconnecting humanity and nature. *Educ. Philos. Theory* 51, 1130–1140. doi: 10.1080/00131857.2018.1564660

Constanza, R. (2014). A virtual visit to a sustainable 2050: Creating a sustainable and desirable future. London: World Scientific Publishing.

Constanza, R. (2022). Creating a sustainable and desirable future. Singapore: Springer Nature Singapore.

Curry, A., and Hodgson, A. (2008). Seeing in multiple horizons: connecting futures to strategy. *J. Futures Stud.* 13, 1–20. Available at: https://jfsdigital.org/articles-and-essays/2008-2/vol-13-no-1-august/articles/seeing-in-multiple-horizons-connecting-futures-to-strategy/

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., et al. (2015). The IPBES conceptual framework — connecting nature and people. *Curr. Opin. Environ. Sustain.* 14, 1–16. doi: 10.1016/j.cosust.2014.11.002

Dittman, J., and Müller-Mahn, D. (2023). "Transfrontier conservation governance, commodification of nature, and the new dynamics of sovereignty in Namibia" in Future rural Africa. Conservation, markets, and the environment in southern and eastern Africa: Commodifying the "wild". eds. M. Bollig, S. Lendelvo, A. Mosimane and R. V. Nghitevelekwa (Melton: James Currey), 107–134.

Dou, Y., Zagaria, C., O'Connor, L., Thuiller, W., and Verburg, P. H. (2023). Using the nature futures framework as a lens for developing plural land use scenarios for Europe for 2050. *Glob. Environ. Change* 83:102766. doi: 10.1016/j.gloenvcha.2023.102766

Durán, A. P., Kuiper, J. J., Aguiar, A. P. D., Cheung, W. W. L., Diaw, M. C., Halouani, G., et al. (2023). Bringing the nature futures framework to life: creating a set of illustrative narratives of nature futures. *Sustain. Sci.*:22, 1–20. doi: 10.1007/s11625-023-01316-1

Emirbayer, M., and Mische, A. (1998). What is agency? *Am. J. Sociol.* 103, 962–1023. doi: 10.1086/231294

Ewnetu, A. (2023). The effect of rural road access on rural households livelihood improvement: evidence from selected weredas in Amhara regional state, Ethiopia. *J. Afr. Dev. Stud.* 10, 47–63. doi: 10.56302/jads.v10i1.8780

Fischer, L. B., and Newig, J. (2016). Importance of actors and agency in sustainability transitions: a systematic exploration of the literature. *Sustainability* 8:476. doi: 10.3390/su8050476

Gupta, J., Bai, X., Liverman, D. M., Rockström, J., Qin, D., Stewart-Koster, B., et al. (2024). A just world on a safe planet: a lancet planetary health–earth commission report

on earth-system boundaries, translations, and transformations. *Lancet Planet. Health* 8, e813–e873. doi: 10.1016/S2542-5196(24)00042-1

Haga, C., Maeda, M., Hotta, W., Matsui, T., Nakaoka, M., Morimoto, J., et al. (2023). Modeling desirable futures at local scale by combining the nature futures framework and multi-objective optimization. *Sustain. Sci.* 22, 1–21. doi: 10.1007/s11625-023-01301-8

Hamann, M., Biggs, R., Pereira, L., Preiser, R., Hichert, T., Blanchard, R., et al. (2020). Scenarios of good anthropocenes in southern Africa. *Futures* 118:102526. doi: 10.1016/j.futures.2020.102526

Harms, P., Hofer, M., and Artmann, M. (2024). Planning cities with nature for sustainability transformations—a systematic review. *Urban Transformations* 6:9. doi: 10.1186/s42854-024-00066-2

Harvey, P., and Knox, H. (2015). Roads: An anthropology of infrastructure and expertise. New York, NY: Cornell University Press.

Heisel, S. E., King, E., Lekanta, F., Lemoile, F., Ryan, C., Lemerketo, I., et al. (2021). Assessing ecological knowledge, perceived agency, and motivations regarding wildlife and wildlife conservation in Samburu, Kenya. *Biol. Conserv.* 262:109305. doi: 10.1016/j.biocon.2021.109305

IPBES (2016a). Pollination and scenario assessments are the first two steps to guiding policymakers in the global biodiversity crisis. Bonn: IPBES.

IPBES (2016b). Scenarios and models of biodiversity and ecosystem services. Secretariat of the intergovernmental science-policy platform on biodiversity and ecosystem services. Bonn: IPBES.

IPBES (2022). The Methodological assessment report on the diverse values and valuation of nature of the intergovernmental science-policy platform on biodiversity and ecosystem services. Bonn: IPBES.

James, P. (2015). Urban sustainability in theory and practice: Circles of sustainability. London: Routledge Taylor & Francis Group.

Keller, I., Nentwig, W., and Largiader, C. R. (2004). Recent habitat fragmentation due to roads can lead to significant genetic differentiation in an abundant flightless ground beetle. *Mol. Ecol.* 13, 2983–2994. doi: 10.1111/j.1365-294X.2004.02310.x

Kim, H., Kuiper, J. J., Okayasu, S., Palomo, M. G., Pereira, H. M., Peterson, G., et al. (2020). Developing multiscale and integrative nature–people scenarios using the nature futures framework. *People Nat.* 2, 1172–1195. doi: 10.1002/pan3.10146

Kleinschroth, F., Laporte, N., Laurance, W. F., Goetz, S. J., and Ghazoul, J. (2019). Road expansion and persistence in forests of the Congo basin. *Nat. Sustain.* 2, 628–634. doi: 10.1038/s41893-019-0310-6

Kline, M. A. (2015). How to learn about teaching: an evolutionary framework for the study of teaching behavior in humans and other animals. *Behav. Brain Sci.* 38:e31. doi: 10.1017/S0140525X14000090

Kollmuss, A., and Agyeman, J. (2002). Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environ. Educ. Res.* 8, 239–260. doi: 10.1080/13504620220145401

Kuiper, J. J., Van Wijk, D., Mooij, W. M., Remme, R. P., Peterson, G. D., Karlsson-Vinkhuyzen, S., et al. (2022). Exploring desirable nature futures for Nationaal Park Hollandse Duinen. *Ecosyst. People* 18, 329–347. doi: 10.1080/26395916.2022.2065360

Kuklina, V., Petrov, A. N., Krasnoshtanova, N., and Bogdanov, V. (2020). Mobilizing benefit-sharing through transportation infrastructure: informal roads, extractive industries and benefit-sharing in the Irkutsk oil and gas region, Russia. *Resources* 9:21. doi: 10.3390/resources9030021

Kuncoro, E., Wurarah, R. N., and Erari, I. E. (2024). The impact of road infrastructure development on ecosystems and communities. *Soc. Ecol. Econ. Sust. Dev. Goals Journal* 1:2. doi: 10.61511/seesdgj.v1i2.2024.336

Laurance, W. F., and Arrea, I. B. (Eds.) (2023). Roads to change: Impacts of infrastructure development on ecosystems, ecosystem services, human communities, and biodiversity. Cham: Springer Nature.

Laurance, W. F., Clements, G. R., Sloan, S., O'Connell, C. S., Mueller, N. D., Goosem, M., et al. (2014). A global strategy for road building. *Nature* 513, 229–232. doi: 10.1038/nature13717

Leinfelder, R. (2020). The Anthropocene - the earth in our hands. Freie Universität Berlin, Institute of Geological Sciences. doi: 10.17169/refubium-26459

Lilemba, J. M., and Matemba, Y. (2014). Reclaiming indigenous knowledge of Mafwe in a post-colonial Namibian curriculum. *J. Hum. Ecol.* 48, 115–122. doi: 10.1080/09709274.2014.11906780

Linnell, J. D. C., Kaczensky, P., Wotschikowsky, U., Lescureux, N., and Boitani, L. (2015). Framing the relationship between people and nature in the context of European conservation. *Conservation Biology J. Soc. Conservation Biology* 29, 978–985. doi: 10.1111/cobi.12534

Lundquist, C., Hashimoto, S., Denboba, M. A., Peterson, G., Pereira, L., and Armenteras, D. (2021). Operationalizing the nature futures framework to catalyze the development of nature-future scenarios. *Sustain. Sci.* 16, 1773–1775. doi: 10.1007/s11625-021-01014-w

Lupiya, A. (2019). The Kavango-Zambezi conservation area (KAZA) and its dynamics in Zambia. University of Cape Town, Faculty of Science, Department of Environmental and Geographical Science. Cape Town, South Africa.

Mace, G. M. (2014). Ecology. Whose conservation? *Science* 345, 1558–1560. doi: 10.1126/science.1254704

Maldonado, M. A. (2015). Environment and society: Socionatural relations in the Anthropocene. Cham: Springer.

Meyrick, J., and Barnett, T. (Eds.) (2021). Exploring Cultural Value. New York, NY: Emerald Publishing Limited.

Michio, K. (2011). Visions: How science will revolutionize the 21st century. Norwell, MA: Anchor.

Ministry of Education, Arts and Culture (2022). Education Management Information System (EMIS) report.

Mulgan, T. (2018). Answering to future people: responsibility for climate change in a breaking world. *J. Appl. Philos.* 35, 532–548. doi: 10.1111/japp.12222

NSA (2024). 2023 Namibia Population and Housing Census: Release of main results. Windhoek: Namibia Statistics Agency.

NSA (2025). 2023 Population and Housing Census: Labour Force Report. Windhoek: Namibia Statistics Agency.

Namibian Sun (2024). Energy, economic development by harnessing local potential. Windhoek: Namibia Statistics Agency.

Nwagbara, V. U., and Iyama, W. A. (2019). Assessment of the environmental impact of road infrastructure in countries: a study of the Namibia scenario. *J. Geoscience Environ. Prot.* 7, 86–101. doi: 10.4236/gep.2019.712006

Palacios-Abrantes, J., Badhe, R., Bamford, A., Cheung, W. W. L., Foden, W., Frazão Santos, C., et al. (2022). Managing biodiversity in the Anthropocene: discussing the nature futures framework as a tool for adaptive decision-making for nature under climate change. *Sustain. Sci.* doi: 10.1007/s11625-022-01200-4

Pereira, L. M., Ortuño Crespo, G., Merrie, A., and Homewood, C. (2022). Operationalising the nature futures framework in the high seas. Stockholm: Nereus Workshop.

Pereira, L., Ortuño, C., Guillermo Amon, D. J., Badhe, R., Bandeira, S., Bengtsson, F., et al. (2023). The living infinite: envisioning futures for transformed human-nature relationships on the high seas. *Mar. Policy* 153:105644. doi: 10.1016/j.marpol.2023.105644

Potrzeba-Macrina, A. L., and Zurbenko, I. G. (2020). Numerical predictions for global climate changes. *World Sci. News*. 144, 208–225. Available at: https://worldscientificnews.com/numerical-predictions-for-global-climate-changes/

R Core Team (2024). A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.

Rana, S., Ávila-García, D., Dib, V., Familia, L., Gerhardinger, L. C., Martin, E., et al. (2020). The voices of youth in envisioning positive futures for nature and people. *Ecosyst. People* 16, 326–344. doi: 10.1080/26395916.2020.1821095

Raskin, P. D. (2014). Scenes from the great transition: Creating a sustainable and a desirable future: Insights from 45 global thought leaders. London: World Scientific Publishing. doi: 10.1142/8922

Rea, A. W., and Munns, W. R. (2017). The value of nature: economic, intrinsic, or both? *Integr. Environ. Assess. Manag.* 13, 953–955. doi: 10.1002/ieam.1924

Rembang, D. (2021). Human resources competency in the era of industrial revolution 4.0. *Eco. Bus. Solutions* 5:1. doi: 10.26623/ebsj.v5i1.3334

Robyn, J., Gibbs, B., Whitford, L., Leisher, C., Konia, R., and Butt, N. (2021). Conservation and natural resource management: where are all the women? *Oryx* 55, 860–867. doi: 10.1017/S0030605320001349

Sasaoka, M., and Laumonier, Y. (2012). Suitability of local resource management practices based on supernatural enforcement mechanisms in the local social-cultural context. *Ecol. Soc.* 17:170406. doi: 10.5751/es-05124-170406

Satz, D., Gould, R. K., Chan, K. M. A., Guerry, A., Norton, B., Satterfield, T., et al. (2013). The challenges of incorporating cultural ecosystem services into environmental assessment. *Ambio* 42, 675–684. doi: 10.1007/s13280-013-0386-6

Schmidt, M., Pereira, L. M., and Davies, K. K. (2025). Operationalizing the nature futures framework: challenges and opportunities for transformative change. *Sustain. Sci.*

Schmitt, T. M., Aminian-Biquet, J., Blinova, P., Jimenez, Y. G., Sinav, L., Vašková, H., et al. (2025). The perspective of youth: envisioning transformative pathways and desirable futures for people and nature. *Sustain. Sci.* 22, 1–16. doi: 10.1007/s11625-025-01693-9

Schreuder, W., and Horlings, L. G. (2022). Transforming places together: transformative community strategies. *Nat. Clim. Action.* 1. doi: 10.1007/s44168-022-00024-3

Sharpe, B., Hodgson, A., Leicester, G., Lyon, A., and Fazey, I. (2016). Three horizons: a pathways practice for transformation. *Ecol. Soc.* 21:247. doi: 10.5751/ES-08388-210247

Sills, J. (2017). Global roadless areas: hidden roads. *Science* 355:1381. doi: 10.1126/science.aam6995

Smythe, K. R. (2014). Rethinking humanity in the Anthropocene: the long view of humans and nature. *Sust. J. Record* 7, 146–153. doi: 10.1089/SUS.2014.9791

Stoldt, M., Göttert, T., Mann, C., and Zeller, U. (2020). Transfrontier conservation areas and human-wildlife conflict: the case of the Namibian component of the Kavango-Zambezi (KAZA) TFCA. *Sci. Rep.* 10:7964. doi: 10.1038/s41598-020-64537-9

Susilo, D., and Kodir, A. (2019). Significance of Women Leadership on Natural Conservation Movement at Rembang, Indonesia. doi: 10.4108/eai.8-12-2018.2283846

Tengö, M., Hill, R., Malmer, P., Raymond, C. M., Spierenburg, M., Danielsen, F., et al. (2017). Weaving knowledge systems in IPBES, CBD and beyond—lessons learned for sustainability. *Curr. Opin. Environ. Sustain.* 26, 17–25. doi: 10.1016/j.cosust.2016.12.005

Terry, N., Castro, A., Chibwe, B., Karuri-Sebina, G., Savu, C., and Pereira, L. (2024). Inviting a decolonial praxis for future imaginaries of nature: introducing the entangled time tree. *Environ. Sci. Pol.* 151:103615. doi: 10.1016/j.envsci.2023.103615 (2022) 1.

UNDP (2024). Namibian Youth Lead Climate Action at Local Conference of Youth. Paris: UNDP.

Vale, R., and Vale, B. (Eds.) (2013). Living within a fair share ecological footprint. London: Routledge.

Vilela, T., Malky, A., Bruner, A., Laísa, V., Ribeiro, V., Auxiliadora, A., et al. (2020). A better Amazon road network for people and the environment. *Proc. Natl. Acad. Sci. USA* 117, 7095–7102. doi: 10.1073/pnas.1910853117

Vincent, B. C., and Gitau, J. W. (2022). The societal role of youth and women in global conservation of the environment for sustainability. *Impact: J. Transf.* 5, 1–15. Available at: https://journals.aiu.ac.ke/index.php/impact/article/view/132

Wickham, H. (2017). dplyr: A grammar of data manipulation (R package version 0.7.4) [Computer software].

Wilkie, D., Shaw, E., Rotberg, F., Morelli, G., and Auzel, P. (2000). Roads, development, and conservation in the Congo Basin. *Conserv. Biol. J. Soc. Biol.* 14, 1614–1622. doi: 10.1111/j.1523-1739.2000.99102.x

Wolf, J., and Moser, S. C. (2011). Individual understandings, perceptions, and engagement with climate change: insights from in-depth studies across the world. *WIREs Clim. Change* 2, 547–569. doi: 10.1002/wcc.120