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Lessons from local community perspectives on ecosystem services and disservices of invasive alien plant species in Speke Gulf, Lake Victoria, Tanzania

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Abstract

Assessing the impacts of biological invasions on ecosystems particularly those driven by environmental change, including those caused by invasive plant species, is critical. However, little is known about local perspectives on invasive alien plant species, particularly in Tanzania's lake zones. This study examined community perceptions of ecosystem services (ES) and ecosystem disservices (EDS) associated with five invasive alien plant species: *Eichhornia crassipes*, *Lantana camara*, *Chromolaena odorata*, *Argemone mexicana*, and *Ipomoea hildebrandtii* and the management options used by communities across four villages in the Mara and Simiyu regions. Data were collected through household surveys ($n=120$), focus group discussions ($n=3$), and key informant interviews ($n=11$). Quantitative data were analysed using descriptive statistics and binomial logistic regression, while qualitative data were analysed thematically. Overall, respondents reported ecosystem disservices more frequently than services. While some benefits were identified, including livestock fodder, medicinal use, and fuel, negative impacts dominated local perceptions. The most commonly reported disservices included increased management costs, reduced plant diversity, or disrupted biodiversity loss. Logistic regression results showed that education level and village location significantly influenced perceptions of both ES and EDS, whereas age and gender did not. Among the species studied, *E. crassipes* was perceived as the most difficult and costly to manage, and control efforts for both *E. crassipes* and *L. camara* were widely considered ineffective. These findings highlight the importance of incorporating local knowledge and socio-demographic factors into invasive species management. Context-specific, community-based, and species-specific strategies are needed to improve the effectiveness and sustainability of invasive alien plant species management in the Lake Victoria basin.

Keywords Environmental management, Human well-being, Livelihoods, Non-native species, social dimensions



1 Introduction

Biological invasions by Invasive Alien Plant Species (IAPS) have become a global crisis, significantly impacting both humans and the natural world [1, 2]. These invasions are the second-leading threat to biodiversity and habitat degradation [3, 4]. Ecological impacts often involve alterations to ecosystem structure and function [5]. Socially, the cost of invasive species manifests as financial losses that directly affect human livelihoods and well-being [2, 6]. Although some invasive plants may provide ecosystem services such as erosion control, fuel and fodder supply, carbon sequestration, or aesthetic benefits, their negative impacts often outweigh these advantages over time [7, 8, 9, 10]. The rapid spread of invasive species is alarming, but understanding the drivers of these invasions and their implications (including the balance of benefits and costs) can pave the way for effective management strategies [11].

Tanzania, like many other countries, has adopted a combination of these strategies [12]. Biological control has been applied using *Zygogramma bicolorata* and suppressive plant species to manage the invasive *Parthenium hysterophorus*. Due [13, 14]. However, chemical control methods, particularly herbicides, often yield variable outcomes depending on application rate, target species, and environmental conditions [15]. Moreover, herbicides can cause environmental problems, including contaminating soil and water and affecting non-target organisms and soil microbes, thereby reducing their sustainability over time [16, 17]. These negative impacts include the potential threat to human health in rural areas where communities use untreated water for domestic use [18], the threat of herbicide residues in the aquatic ecosystem, the threat of de-oxygenation of the water column following decomposition of large mats of water hyacinth, and the general perception that herbicides are poisons. Although other methods have disadvantages, biological control with *Neochetina eichhorniae* has been reported to be successful in controlling invasive water hyacinth in Tanzania, resulting in a significant reduction in plant population density from 45 to 7 plants per 0.5 m², along with substantial reductions in surface-area coverage and biomass [19].

Therefore, it is crucial to emphasise that the insights and contributions of local communities, often at the forefront of these issues, are not just helpful but integral to the success of these methods. Their active engagement enhances the sustainability of these control mechanisms [20]. The ecosystem services and disservices framework provides a comprehensive approach to understanding the ecological and socioeconomic impacts of IAPS. Although IAPS are known to seriously harm ecosystems and economies, some species also provide benefits to nearby communities, such as food, fuel, and medical resources [21, 22]. Developing well-rounded and successful management strategies requires an understanding of both the advantages and disadvantages of IAPS. IAPS influence ecosystems in multiple ways by altering provisioning services (e.g., food and water supply), regulating services (e.g., climate regulation and water purification), supporting services (e.g., soil formation and nutrient cycling), and cultural services (e.g., recreation and spiritual values) [23, 24]. However, they also pose health risks, environmental degradation, economic stress, and biodiversity loss [2]. Designing successful, socially inclusive IAPS management solutions requires an understanding of how local populations perceive these consequences [9].

In Tanzania, the spread of invasive species has affected numerous biodiversity hotspots, led to declines in ecosystem services, and impacted human well-being [25–29].

However, much research on IAPS in Tanzania has focused primarily on their distribution, Ecological dynamics, and control measures, with limited attention given to local perspectives. This study fills a significant research gap by evaluating the local community's perceptions of the environmental services and drawbacks of IAPS. The biophysical effects of IAPS have received considerable attention in the literature, but less attention has been paid to how local populations respond to and experience these changes [2]. In line with international initiatives such as the Aichi Biodiversity Targets, the IPBES, and the SDGs, this research contributes to the creation of evidence-based policies that support biodiversity conservation and sustainable livelihoods by integrating local knowledge [30].

This dual perspective is crucial for understanding how IAPs influence local communities and ecosystems, guiding both conservation efforts and sustainable management strategies. Appendices 1 and 2 summarise the baseline on categorisations of ES and EDS from previous studies, providing context for this study.

Therefore, this study examines the ecosystem services and disservices associated with specific invasive plant species in areas surrounding Lake Victoria, particularly within the Mara (Bunda District) and Simiyu (Busega District), with a focus on *Eichhornia crassipes*, *Lantana camara*, *Chromolaena odorata*, *Argemone mexicana*, and *Ipomoea hillebrandtii*. The study hypothesises (H1) Local communities perceive ecosystem disservices from invasive alien plant species to outweigh ecosystem services and addresses the research question (RQ1): *How do invasive plant species affect ecosystem services in the study area?* It further hypothesises (H2) that local communities perceive invasive alien plant species as significantly affecting ecosystem services and ecosystem disservices and addresses (RQ2): *Do the ecosystem disservices of invasive plant species outweigh their ecosystem services?* In addition, the study hypothesises (H3) that socio-demographic characteristics significantly influence local community perceptions of ecosystem services and disservices associated with invasive alien plant species, and addresses (RQ3): *How do socio-demographic factors influence local perceptions of ecosystem services and disservices associated with invasive plant species?* Beyond these hypotheses, the study also examines management and control methods used by local communities and the associated time and financial costs, addressing (RQ4): *What management and control methods are used by local communities to manage invasive plant species, and what are the associated time and financial costs?* Overall, this research aims to bridge the gap between scientific knowledge and traditional practices to inform more effective management of invasive species.

2 Materials and methods

2.1 Study area

The study was conducted in two Lake Zone regions in Tanzania, namely Mara and Simiyu, encompassing four villages: Tamau, Nyatwali, Serengeti, and Lukungu. The villages are very close to the two protected areas, namely Serengeti National Park and Kijereshi Game Reserve. The Mara region has three climatic zones: the northern zone resides in the Tarime District and parts of the Serengeti District. On average, it receives an annual rainfall of 1,250–2,000 mm. The central zone includes much of Musoma District and the eastern parts of Serengeti. It receives an annual rainfall of 900–1300 mm/year [31]. The Lowland zone covers much of Bunda and the lake, and the study is based

on a rainfall range of 700–900 mm per year. The lowland landscape, which receives less rainfall, consists of wooded grassland and dense thickets. The primary vegetation in Busega, Simiyu, Tanzania, consists of savanna woodlands interspersed with grasslands, with dominant species such as *Acacia* and *Commiphora*. Along water bodies, riverine vegetation, and wetlands support diverse flora adapted to seasonal flooding [32, 33]. On the other hand, the Busega district in Simiyu Region is located directly to Lake Victoria in the northwest of the region. Annual rainfall ranges from 700 to 900 mm, and the area is well-suited for agriculture and livestock production [34]. Agriculture and fishing are the primary livelihoods in these regions.

The dominant land uses of these areas are rangeland grazing and cropping, with fishing being important around Lake Victoria [35]. The study site surveyed four villages: Serengeti, Tamau, Nyatwali in Bunda, and Lukungu in Busega (Fig. 1).

2.2 Data collection

Between the end of August and October 2022, a combination of household questionnaires, Focus Group Discussions (FGDs), and interviews with key informants was used to assess the ES and EDS of the selected invasive plant species in the study area.

Households were stratified by village to ensure equal representation across the four study villages. Within each village stratum, households were randomly selected to ensure representation of respondents from diverse socioeconomic backgrounds. A total of 120 respondents were interviewed, comprising 30 respondents per village. This study received formal ethical approval from the Tanzania Wildlife Research Institute (TAWIRI) Joint Management Research Committee (JMRC) and national research clearance from the Tanzania Commission for Science and Technology (COSTECH) prior to data collection. Informed consent was obtained from all participants prior to participation, in accordance with established social science research ethics guidelines [36]. Before the interviews, the semi-structured questionnaires were explained to the participants.

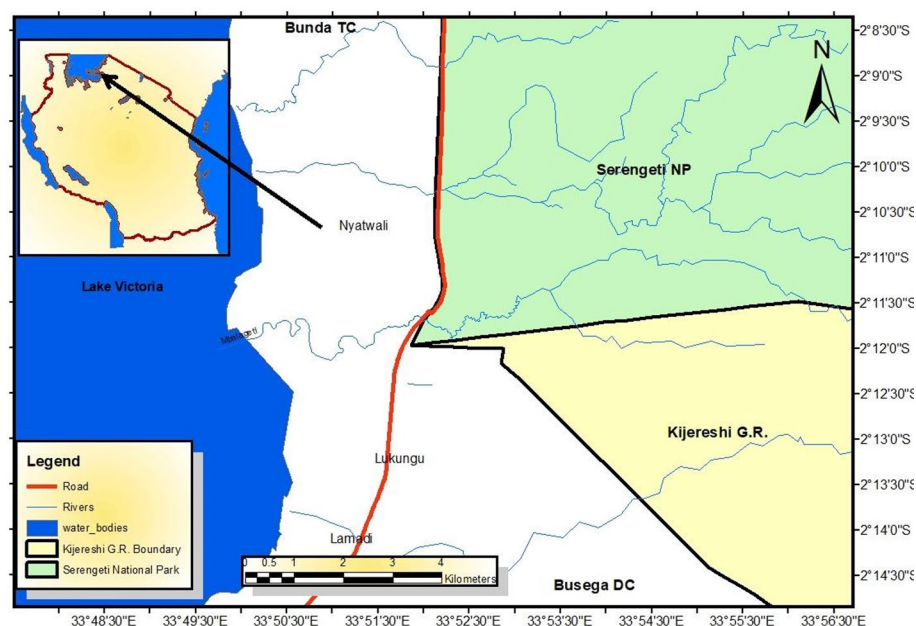


Fig. 1 Location of the study area and the villages surveyed in this study

The questionnaire consisted of three key sections:

1. *Demographic information*: including village name, gender, age, ethnicity, education level, place of birth, duration of residence, main economic activities, household size, and monthly income.
2. *Perceived ecosystem services and disservices*: questions explored respondents' views on the positive (ES) and negative (EDS) impacts of major IAPS (*Eichhornia crassipes*, *Chromolaena odorata*, *Argemone mexicana*, *Lantana camara*, and *Ipomoea hildebrandtii*). Respondents rated the perceived effects on their livelihoods (very harmful to very beneficial), the extent of impacts (very high to very low), and specific positive or negative contributions (e.g., interference with farming, resource competition, medicinal use, fuelwood supply, soil fertility improvement, and other ecosystem functions).
3. *Management and governance of IAPS*: questions assessed local management practices (traditional, manual, chemical, biological, or integrated methods), estimated costs (in time and money), perceived effectiveness of control measures, and the existence of village-level bylaws or governance frameworks for IAPS management.

The questionnaire combined closed- and open-ended items, allowing respondents to provide both quantitative ratings and qualitative opinions regarding the impacts and management of IAPS. Each household survey interview lasted approximately 30–45 min, depending on the respondent and the depth of response.

Three focus group discussions (FGDs) were held, each with 5 to 10 participants, to collect detailed information about community experiences with invasive alien plant species and to support the results from the household surveys. The study included four villages, but only three FGDs took place because one group combined participants from two nearby villages (Nyatwali and Tamau) with similar locations and socio-economic backgrounds. The other two FGDs were held separately in the remaining villages. Village leaders helped select participants to make sure people with relevant knowledge and experience, such as farmers, fishers, pastoralists, and other resource users, were included. Each FGD lasted 60 to 90 min, allowing sufficient time for discussion and interaction (see Table S1 for participant profiles).

Additionally, key informant interviews were conducted to complement and validate data obtained from household surveys and focus group discussions. Key informants were purposively selected based on their roles, professional expertise, and long-term experience in conservation, ecological management, agricultural extension, and village governance within the study area. A total of eleven key informants were interviewed, including two rangers and two ecologists from the Kijereshi Game Management Area, one ecologist from Serengeti National Park, and six village-level informants, comprising four village leaders from all study villages and two agricultural extension officers.

2.3 Data analysis

2.3.1 Quantitative analysis

Data from the household surveys were cleaned, coded, and analysed in Excel 365 and R version 4.4.2 (R Core Team, 2024). During data cleaning, incomplete responses were identified. Unanswered items were coded as NA and excluded from analyses on a

variable-by-variable basis, ensuring that all summaries and models were based solely on valid responses.

Descriptive statistics (frequencies, percentages, and proportions) were used to summarise demographic characteristics and patterns of perception. Before analysis, data were screened for outliers, particularly for variables related to the management and governance of invasive alien plant species. Outliers were assessed using descriptive summaries and cross-checks with original questionnaires, and no implausible values requiring exclusion were identified.

To assess whether demographic factors influenced perceptions of invasive alien plant species (IAPS) services or disservices, binomial logistic regression models were fitted using the `glm()` function in R. Independent variables included age, gender, village, and education level, while dependent variables were binary perception categories (benefits: yes/no; disservices: yes/no). Model fit was assessed using likelihood ratio tests and Pseudo- R^2 , and the statistical significance of explanatory variables was evaluated at the 5% significance level ($p < 0.05$). For the logistic regression models, the reference categories were male (gender), college/university education (education level), and Nyatwali village (village location).

2.3.2 Qualitative analysis statement

The qualitative data from FGDs, open-ended survey responses, and key informant interviews were manually coded. Repeated statements were merged, and only representative quotations that clearly illustrated commonly expressed views were selected. These quotes were used to support and contextualise the quantitative findings in the Results section.

2.3.3 Hypothesis testing

Hypothesis testing was conducted using both descriptive and inferential approaches. H1 was examined using descriptive statistics summarising community perceptions of ecosystem services and disservices associated with invasive alien plant species. H2 was tested by comparing the relative frequencies of reported ecosystem services and ecosystem disservices across species and study sites. H3 was tested using binomial logistic regression models assessing the influence of socio-demographic variables on perceptions of ecosystem services and disservices.

3 Results

3.1 Socio-economic and demographic characteristics of households

Over nine tribes and ethnic groups were identified within the study area. Sukuma was the dominant ethnic group in the study population, accounting for 59%, followed by Kurya (17.50%) and Gita (16.67%). The remaining 6.83% comprised other ethnic groups, including Zanaki, Jalu, Taturu, Fipa, Natta, and Maasai. Most respondents were aged 36–55 (39.17%), followed by 56–75 (28.33%), 15–35 (25.00%), and 76 or older (7.50%).

Women accounted for 61% of respondents ($n = 73$), and men for 39% ($n = 47$), for a total of 120 participants. Farming was the most common occupation, with 46.67% of respondents engaged in it. Other occupations included agro-pastoralism (14.17%), entrepreneurship (9.17%), and pastoralism (3.33%). The remaining 26.67% were employed

in fishing, teaching, or as clinical or veterinary officers, or were students, retired, or unemployed.

Regarding income, 56.67% of respondents earned between TZS 50,000 and 100,000 per month. Another 35.00% earned TZS 200,000–500,000, while 8.33% earned between TZS 600,000 and 1,000,000.

Most respondents (52%) had completed primary education, while 32% had not received any formal education. Only 11% had a secondary school qualification, and 5% held a college or university degree (Table 1).

3.2 Seasonal abundance and distribution of the species

This study employed various indicators to evaluate local knowledge of the species' seasonal distribution and abundance, specifically throughout the year and during the wet and dry seasons. The responses showed that *L. camara*, *E. crassipes*, *C. odorata*, and *A. mexicana* are abundant throughout the year, with percentages ranging from approximately 60% to 90.8%. (Fig. 2) The results showed that most selected species are in the study area yearly. Only *I. hildebrandtii* (55%) is not well known to most respondents. The respondents reported that the species is most abundant during the rainy season, particularly among weeds and shrubs.

3.3 Impacts on livelihoods

Therefore, in relative terms, the negative impact was more frequent than the positive. When respondents were asked about the general impacts of invasive alien plant species in the study area, 80% reported significant negative impacts in the form of ecosystem disservices (EDS), while 20% reported no negative effects (Fig. 3). In contrast, fewer respondents (48%) recognized beneficial effects associated with ecosystem services

Table 1 Demographic characteristics of respondents ($n = 120$)

Demographic variable	Description	Count (n)	Percentage (%)
Gender	Female	73	61.00
	Male	47	39.00
Age group	15–35	30	25.00
	36–55	47	39.17
	56–75	34	28.33
	≥ 76	9	7.50
Ethnic group	Sukuma	71	59.00
	Kurya	21	17.50
	Gita	20	16.67
	Others	8	6.83
Education level	Primary education	62	51.67
	Secondary education	13	10.83
	College/University	6	5.00
	No formal education	39	32.50
Occupation	Farmer	56	46.67
	Agro-pastoralist	17	14.17
	Entrepreneur	11	9.17
	Pastoralist	4	3.33
	Others*	32	26.67
Monthly earnings (TZS)	50,000–100,000	68	56.67
	200,000–500,000	42	35.00
	600,000–1,000,000	10	8.33

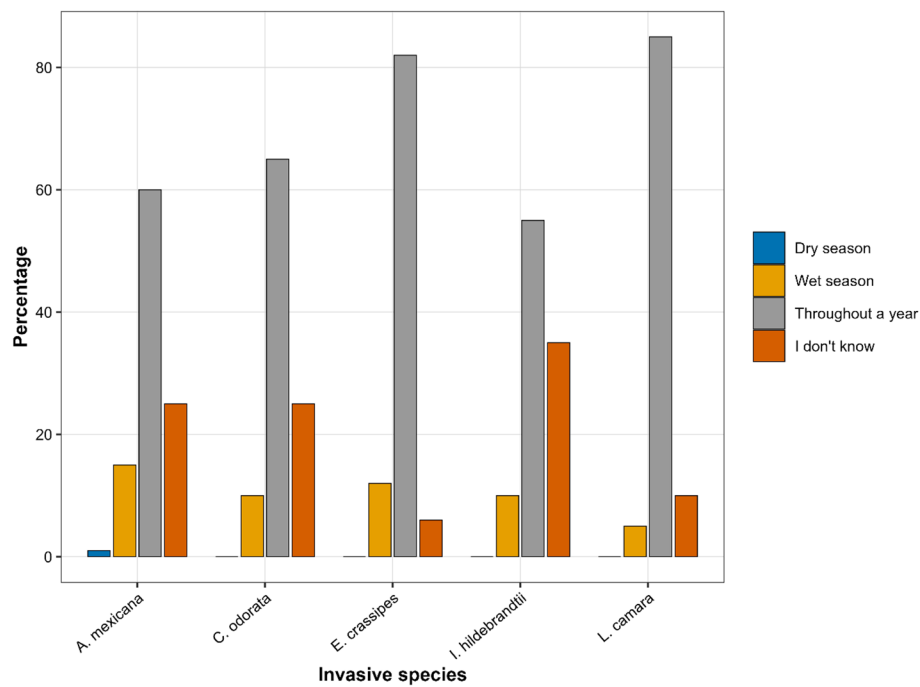


Fig. 2 Seasonal variation in the abundance of invasive alien plant species

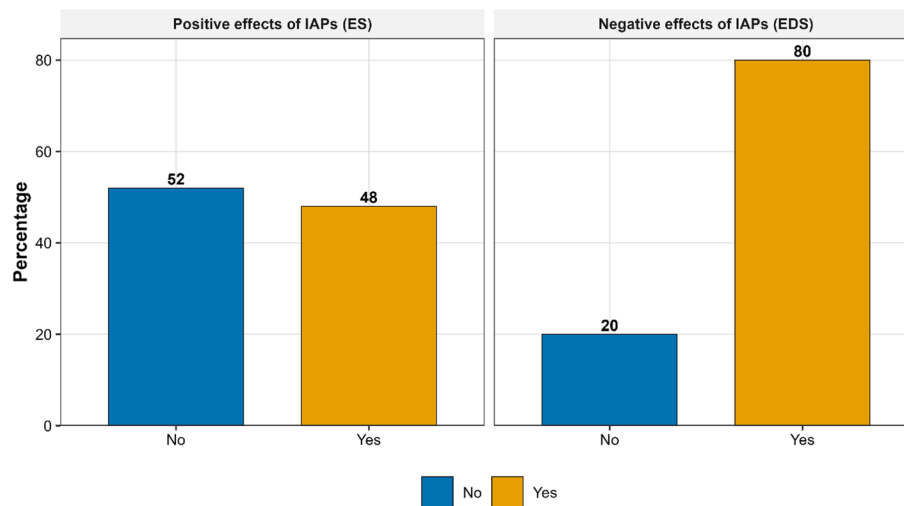


Fig. 3 Percentage distribution of respondents reporting positive (ecosystem services, ES) and negative (ecosystem disservices, EDS) impacts of invasive alien plant species in the study area

(ES), whereas 52% reported no perceived benefits (Fig. 3). These survey results match what participants in focus groups said. They observed reduced pasture availability and increased land-clearing work due to invasive species. In general, people reported more negative than positive impacts, suggesting that ecosystem disservices outweigh the benefits in this area.

More specifically, 84% of respondents reported that *E. crassipes* caused the greatest harm to people's livelihoods, and none considered the species beneficial (Fig. 4). In contrast, 80% of respondents perceived *L. camara* as beneficial, while 32% were undecided

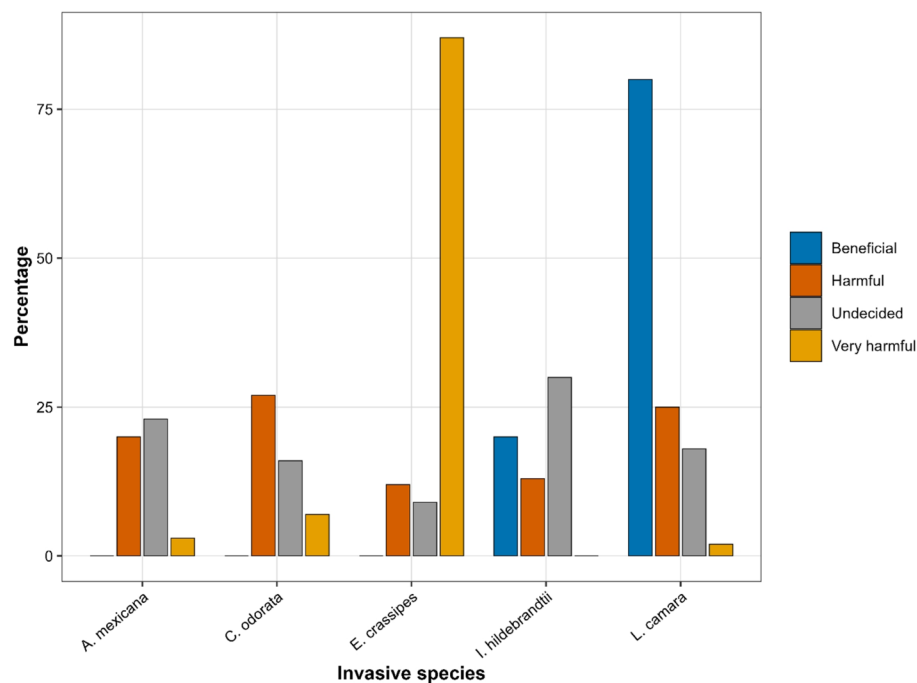


Fig. 4 Species-specific perceptions of the impacts of selected invasive alien plant species in the study area, showing the percentage of respondents who classified each species as beneficial, harmful, very harmful, or undecided

about *I. hildebrandtii* (Fig. 4). These quantitative findings were echoed in the focus group discussions (FGD). One participant explained:

“Water hyacinth (*E. crassipes*) has invaded the Lamadi River and blocked the channels we use for fishing, since the river flows directly into the lake. It has also become a hiding place for dangerous crocodiles. Several people have died because crocodiles hide under the water hyacinth and attack when someone enters the water.” (FGD participant, Bunda, 2022).

Another pastoralist emphasised the broader livelihood impacts: “These invasive plants are not just a nuisance; they affect our livelihoods. The species reduces grazing land and makes it hard to access clean water” (Pastoralist, Bunda & Simiyu 2022).

3.4 Socio-ecological services and disservices of invasive species

3.4.1 Social ecological disservices

Respondents assessed ecosystem disservices (EDS) for each invasive alien plant species (Fig. 5). Resource competition and increased control costs were most frequently linked to *E. crassipes* (76.6%) and *C. odorata* (70%). Reduced plant diversity and broader biodiversity disruption were primarily associated with *L. camara* (74%) and *C. odorata* (73%), while *A. mexicana* was also frequently cited for reducing plant diversity (69%). Other disservices, including livestock and human poisoning, were reported less frequently across all species (Fig. 5).

Qualitative evidence from focus group discussions (FGD) supported these findings. One participant (48-year-old fisherman) noted, “As fishermen, we have seen how *E. crassipes* has hurt Lake Victoria. It has reduced fish populations, especially tilapia and smaller species we rely on.” Similarly, a 67-year-old farmer explained, “Years ago, the Lamadi River was a centre of cultural and ritual activities and celebrations for people

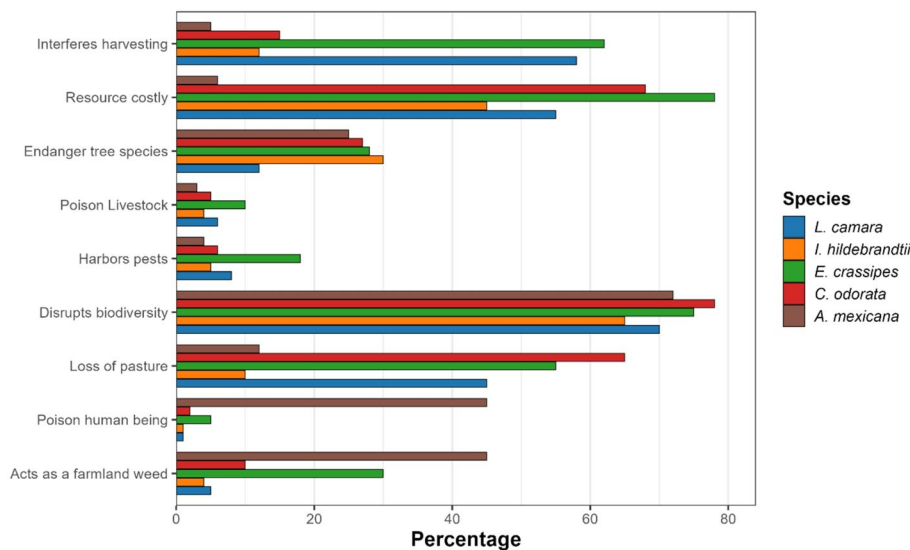


Fig. 5 Respondents' perceptions of ecological disservices associated with selected invasive alien plant species in the study area, expressed as the percentage of respondents identifying specific negative effects

from Lukungu and neighbouring villages. However, no further gatherings were held due to the *E. crassipes* invasion."

On the other hand, *C. odorata* and *L. camara* were most often reported to cause pasture loss in grazing areas, with 65.8% and 57.5% of responses, respectively (Fig. 5). Ecologists from Serengeti National Park and Kijereshi Game Reserve confirmed that *C. odorata* spreads quickly and causes pasture shortages. In farming areas, 46.7% of respondents saw *A. mexicana* as a major threat to crops, while 28.3% named *E. crassipes* as a problem in rice fields (Fig. 5). Respondents also said that when *C. odorata* is common, crop yields drop a lot. One farmer said, "The presence of *C. odorata* in farmland causes land degradation and suppresses crop growth. I experienced this in my field two years ago. "Another community leader added: "We thought these plants were just part of the landscape, but now we understand they can block out native species and harm the entire ecosystem" (Community leader, Busega, 2022).

Overall, factors such as poisoning and the harbouring of pests and diseases were not considered major ecological disservices for any of the studied species (Fig. 5).

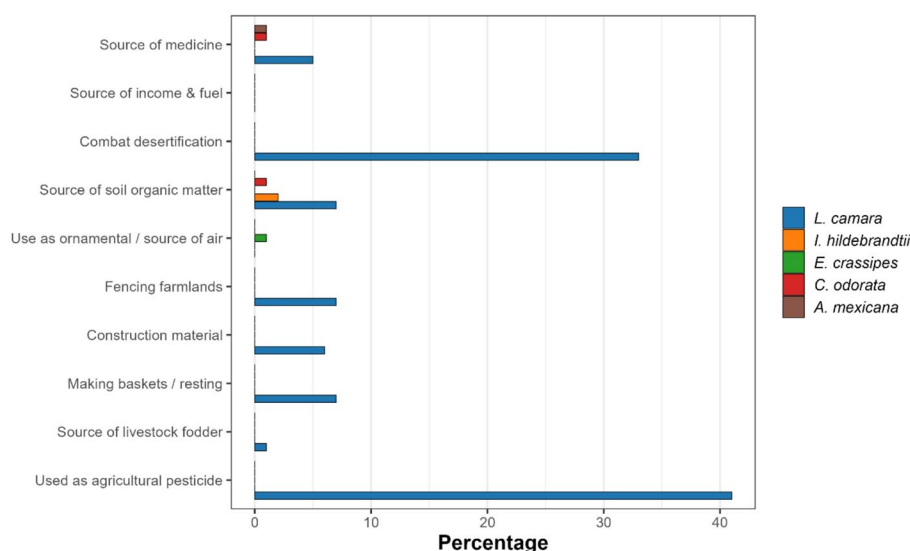
Results from the logistic regression analysis indicated that education level and village location significantly influenced community perceptions of ecosystem disservices caused by invasive alien species. Respondents with primary education were significantly less likely to perceive ecosystem disservices (OR = 0.31, $p = 0.0169$), indicating that they were approximately 69% less likely than respondents with higher levels of education to report negative impacts. Similarly, respondents residing in Tamu village were about 73% less likely to report ecosystem disservices than those in the reference village (OR = 0.27, $p = 0.0304$) (Table 2). Other villages included in the model did not show statistically significant effects ($p > 0.05$).

3.4.2 Socio-ecological services (ES)

Overall, *L. camara* was the only species reported to have benefits (Fig. 6). This was primarily due to its ability to produce fodder, its medicinal properties, and its use as fuel-wood for harvesting and sale.

Table 2 Variables influencing communities' perception of the disservices caused by invasive Alien Plant Species to ecosystems

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	2.269035	1.161233	1.953988	0.050703
Age_years	− 0.00944	0.014884	− 0.63448	0.525765
(Gender_fm) female	− 0.47434	0.400189	− 1.18529	0.235902
(Education_Level) Primary	− 1.18052	0.49417	− 2.3889	0.016899*
(Education_Level) Secondary	− 0.83534	0.834891	− 1.00053	0.317053
(Education_Level) College	− 0.39592	1.050412	− 0.37691	0.706237
(Village_Name) Nyatwali	− 1.05818	0.585933	− 1.80597	0.070922
(Village_Name) Serengeti	− 0.34133	0.58768	− 0.58081	0.561366
(Village_Name) Tamu	− 1.29261	0.597128	− 2.16471	0.03041*

**Fig. 6** Respondents' perceptions of ecological services associated with selected invasive alien plant species in the study area, expressed as the percentage of respondents identifying specific negative effects

In contrast to ecosystem disservices, Perceptions of ecosystem services were also significantly influenced by education level and village location. Respondents with primary education had lower odds of perceiving ecosystem services compared to those with higher education levels (OR=0.31, $p=0.0216$), indicating that a smaller proportion of respondents in this group recognised benefits from invasive alien plant species. Likewise, residents of Tamu village were less likely to report ecosystem services than those in the reference village (OR=0.27, $p=0.0314$). Other socio-demographic variables did not show statistically significant effects (Table 3).

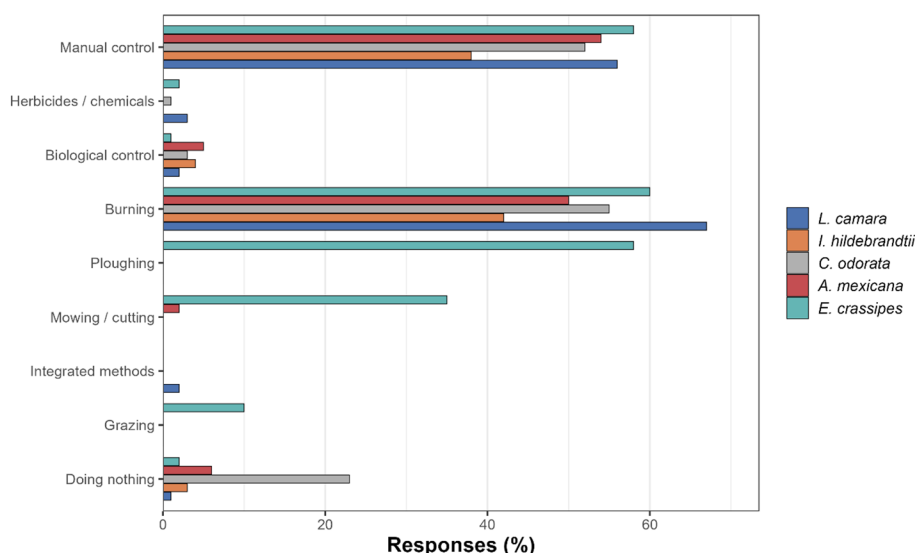
3.5 Management strategies and local by-laws

3.5.1 Perspectives on management/control methods

Our evaluation of methods for controlling invasive alien plant species revealed that manual removal and burning were the most commonly used methods across the study area. These methods were particularly prevalent in *E. crassipes* (55%) and *L. camara* (55%) and were also reported in *C. odorata* (50%), *A. mexicana* (44%), and *I. hildebrandtii* (34%). Insights from the focus group discussions further confirmed these findings, with participants emphasising reliance on manual methods due to limited knowledge of

Table 3 Variables influencing local communities' perceptions of ecosystem services (ES) provided by invasive alien plant species

	Estimate	Std. Error	z value	Pr(> z)
(Intercept)	2.2690351	1.1231351	− 1.8698	0.06151
Age_years	− 0.00944	0.0155630	− 0.6068	0.54397
(Gender_fm) female	− 0.47434	0.424181	− 1.1183	0.26346
(Education_Level) Primary	− 1.18052	0.513958	− 2.2969	0.02162*
(Education_Level) Secondary	− 0.83534	0.877492	− 0.95520	0.35112
(Education_Level) College	− 0.39592	1.259472	− 0.3144	0.75325
(Village_Name) Nyatwali	− 1.05818	0.617535	− 1.7136	0.08661
(Village_Name) Serengeti	− 0.34133	0.613805	− 0.5556	0.57815
(Village_Name) Tamau	− 1.29261	0.600492	− 2.1526	0.03135*

**Fig. 7** Perceived control measures used by local communities to manage selected invasive alien plant species in the study area, expressed as the percentage of respondents reporting each method

alternative control options. As one FGD participant noted, “We decided to use manual removal because we are not sure which other method can be used, but sometimes we also burn the plants after removing them.”

Mowing or cutting was frequently used for *E. crassipes* (58%) and *L. camara* (38%), whereas other species were used infrequently. However, it is worth noting that, although practical, biological control and integrated methods were rarely employed, with minimal application to *E. crassipes* and *A. mexicana* (3% and 4%, respectively). Herbicides were rarely reported, used only for *L. camara* (0.83%) and *E. crassipes* (2%), whereas grazing was observed exclusively for *L. camara* (7%).

Notably, inaction (or ‘doing nothing’) was reported for *A. mexicana* (23%), *C. odorata* (6%), and *L. camara* (3%). (Fig. 7).

We further evaluate the effectiveness of control methods for invasive species, revealing mixed results. Most species, including *E. crassipes* (70%) and *L. camara* (66%), showed no significant decrease, underscoring the persistence of these challenges. Some species, such as *A. mexicana* (25%) and *I. hildebrandtii* (25%), are still expanding moderately, while rapid expansion is evident in *A. mexicana* (8%). Limited progress is observed, with

Table 4 Perceived outcomes of control measures applied to selected invasive alien plant species in the study area, expressed as the percentage of respondents reporting changes in species abundance

Management outcome	<i>E. crassipes</i> (%)	<i>A. mexicana</i> (%)	<i>C. odorata</i> (%)	<i>I. Hildebrandtii</i> (%)	<i>L. camara</i> (%)
Not decreasing	70	47	63	52	66
Expanding	12	25	17	25	13
Decreasing very little	8	13	12	5	12
Decreasing considerably	7	7	13	6	6
Expanding very quickly	3	8	2	5	3

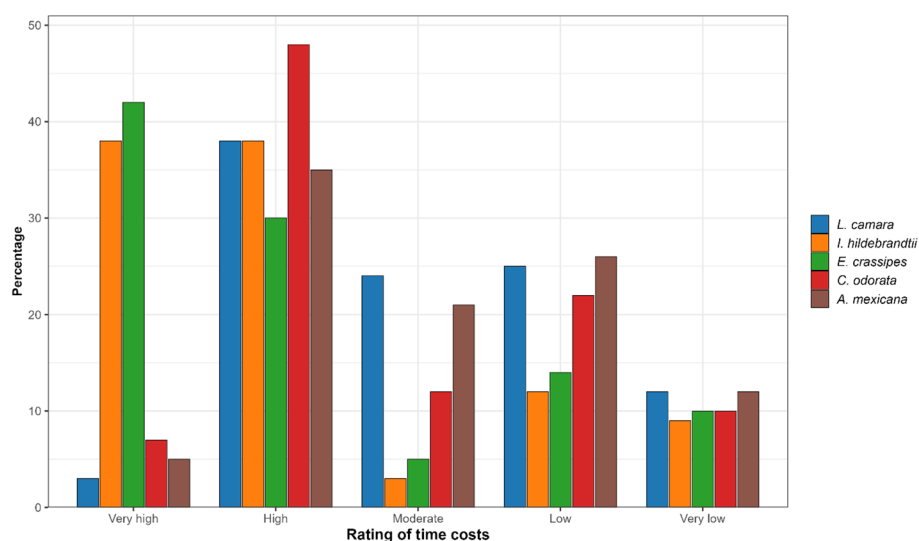


Fig. 8 Perceived time costs associated with the management of selected invasive alien plant species in the study area, expressed as percentages of respondents across time-cost rating categories

slight decreases for species such as *C. odorata* (12%) and more significant reductions for *I. hildebrandtii* (13%). See Table 4.

3.5.2 Perspective on management cost in terms of time and money per species

Based on this study, management time cost refers to the perceived time required to control invasive alien plant species, while Management monetary cost refers to the perceived financial expenditure required for invasive species control and was measured using a five-point scale (very low to very high).

According to our results, management time costs varied among invasive alien plant species (Fig. 8). *E. crassipes* was associated with the highest time burden, with 42% of respondents reporting very high costs and 30% reporting high costs, while only 10% considered the time costs inadequate. In contrast, for *C. odorata*, *I. hildebrandtii*, *L. camara*, and *A. mexicana*, the dominant response category was high time costs, reported by 48%, 38%, 38%, and 36% of respondents, respectively (Fig. 8). Very high time costs were reported by relatively few respondents for these species compared to *E. crassipes*.

Our survey revealed a diverse range of responses regarding the management costs of individual invasive species. In monetary terms, these costs are not insignificant. Notably, 38% of respondents reported extremely high management costs for *E. crassipes*, 49%

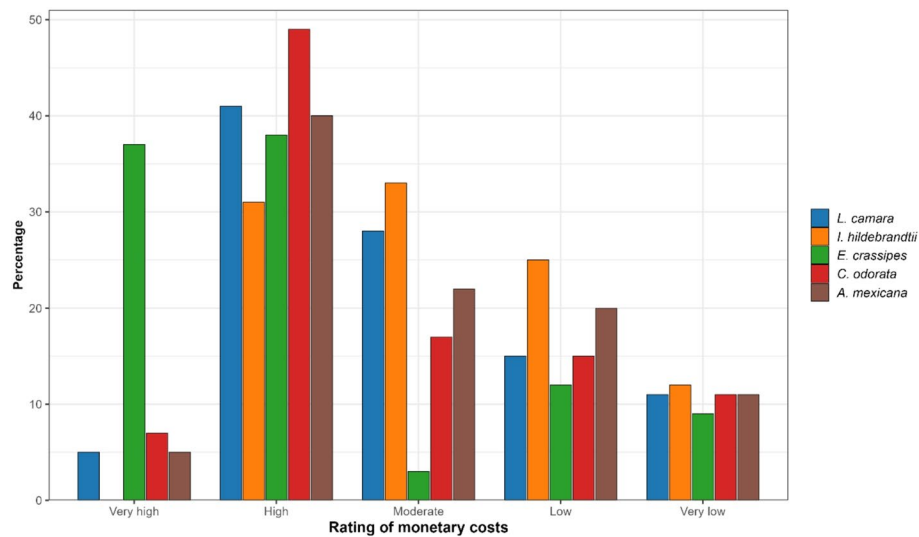


Fig. 9 Perceived time costs associated with the management of selected invasive alien plant species in the study area, expressed as percentages of respondents across monetary-cost rating categories

for *C. odorata*, and 41% for *A. mexicana* and *L. camara*. The remaining invasive species incurred moderate or low management costs (Fig. 9).

3.5.3 Bylaws and opinions on invasive species

According to our findings, all respondents (100%) reported that no bylaws were in place for environmental protection or for the control of invasive alien species. This was consistently emphasised during FGDs, where participants highlighted the lack of formal guidance and enforcement mechanisms as a key barrier to effective control. When asked about the management and governance of invasive alien plants, 81.67% of respondents rated management as difficult/very difficult. In a separate question, 73% indicated that invasive alien species are a major problem in the village, while 27% indicated they are not.

4 Discussion

4.1 Key findings and hypothesis evaluation

This study found evidence supporting all three proposed hypotheses. For Hypothesis 1 (H1), respondents consistently said that invasive alien plant species (IAPS) affect both ecosystem services and disservices at all study sites. However, people mentioned ecosystem services such as fodder, medicinal use, and fuel less often than they mentioned negative impacts. Hypothesis 2 (H2) was also supported, as people saw ecosystem disservices such as resource competition, reduced plant diversity, biodiversity loss, and higher management costs as more severe and common than ecosystem services. These findings indicate that negative impacts dominate local experiences with invasive alien plant species in the study area.

Moreover, the results also supported Hypothesis 3 (H3). Logistic regression analysis showed that education level and village location significantly affected how people viewed both ecosystem services and disservices. Age and gender did not have a significant impact. Together, these findings highlight the importance of socio-demographic

and contextual factors in shaping community responses to invasive alien plant species and provide a foundation for the thematic discussions that follow.

4.2 ES–EDS trade-offs and livelihood implications

Invasive alien plant species can impact ecosystem services and human well-being [20]. This study offers new evidence from Tanzania, where such effects are rarely reported. Unlike studies from other regions [37–40], most respondents here saw few benefits from invasive species. The main exception was *Lantana camara*, which has also shown similar benefits in regions such as India [41].

Among the species studied, *E. crassipes* had the greatest negative impact on local livelihoods, particularly in fishing communities. Respondents linked its spread to a decline in papyrus sedge (*Cyperus papyrus*), which is important for fish breeding. These results align with earlier studies showing that *E. crassipes* disrupts freshwater ecosystems [42–44]. Participants also reported problems with navigation, fishing access, and damaged gear, findings that support those from Lake Victoria and other African lakes [45–48]. Similar effects on fishing communities have been reported in Benin, Kenya, Uganda, and Ghana, where *E. crassipes* invasions have reduced fish stocks, limited fishing activities, and affected household incomes [49–51].

Qualitative results also showed a loss of cultural ecosystem services along the Lamadi River, where *E. crassipes* has disrupted traditional gatherings and rituals. These impacts show that invasive species can affect not only ecological processes but also the cultural and social practices associated with aquatic environments.

Chromolaena odorata has been reported to reduce crop yields and degrade grazing land, particularly in lowland and agricultural areas. Respondents noted that removing it by hand is labour-intensive and diverts resources from other activities. These results are consistent with earlier research on the plant's competitive strength, allelopathic effects, and broader ecological and economic impacts [26, 52, 53].

Argemone mexicana is primarily regarded as a troublesome weed in agriculture because it produces numerous seeds and interferes with staple crops such as maize and cassava. These findings align with studies showing its allelopathic effects and competition for water and nutrients in farm fields [25].

While *Lantana camara* is globally recognised as a highly invasive plant species [26, 54], respondents in this study acknowledged its local utility, particularly as goat fodder. However, respondents also reported that its dense growth suppresses other vegetation and limits agricultural productivity. These observations are supported by studies documenting reduced species diversity, altered fire regimes, and economic losses resulting from *L. camara* invasions [55–59]. In contrast, *Ipomoea hildebrandtii* was reported to have relatively limited impacts, primarily near protected areas such as the Kijereshi Game Reserve, suggesting species-specific differences in invasion intensity and perceived effects.

Overall, the findings indicate that while some invasive alien plant species provide limited short-term benefits, these are outweighed by widespread ecological degradation and livelihood costs. The ES–EDS trade-offs observed are highly context- and species-specific but consistently skewed toward disservices. This reinforces the need for management approaches that prioritise reducing negative impacts while cautiously considering any locally perceived benefits.

4.3 Socio-demographic influences on perceptions

The logistic regression analysis shows that both education level and village location have a significant impact on communities' perceptions of ecosystem services and disservices, supporting Hypothesis 3. People with higher levels of education were more likely to recognise both the benefits and drawbacks of IAPS, consistent with earlier research showing that education increases environmental awareness [60, 61].

Village-level differences highlight the importance of local context. People in Tamau village were less likely to mention both ecosystem services and disservices. This could be due to differences in their livelihoods, the extent to which they encounter invasive species, or local ecological conditions. Similar patterns have been observed in other studies examining how social, cultural, and environmental factors shape views on invasive species [62].

4.4 Management implications and governance gaps

Manual control was the primary management method used for all invasive alien plant species (IAPS), particularly *Eichhornia crassipes* and *Lantana camara*. This suggests that labour-based approaches are perceived as the most accessible and feasible for managing local infestations. Although manual control is labour-intensive and, in some cases, requires additional resources such as boats for aquatic species, communities continue to rely on available means to manage invasive plants [63]. A similar reliance on manual methods was reported for *Chromolaena odorata*, *Argemone mexicana*, and *Ipomoea hildebrandtii*, suggesting widespread use of this approach.

Other control methods, including cutting, mowing, biological control, herbicide application, and integrated approaches, were used less frequently. The limited adoption of biological and combined methods is likely due to constraints on awareness, technical capacity, and resource availability, despite evidence that these approaches can yield more effective long-term outcomes [64]. Respondents also reported that current control efforts have had limited success, as invasive species populations have not declined noticeably, underscoring the need for improved coordination, increased resources, and stronger institutional support.

Furthermore, respondents identified *E. crassipes* as the most difficult and costly species to manage because of its rapid growth and persistence. The absence of local bylaws or formal management frameworks points to a significant governance gap. Similar institutional challenges have been documented in other parts of sub-Saharan Africa [2, 65]. Raising public awareness and strengthening community involvement in conservation efforts may therefore play a critical role in improving support for invasive species management, as increased awareness has been shown to enhance public acceptance and engagement across diverse taxa and landscapes [66].

5 Conclusion, policy highlights

5.1 Conclusion

This study demonstrates that local communities in Tanzania predominantly perceive invasive alien plant species as detrimental to livelihoods and ecosystems, with ecosystem disservices outweighing ecosystem services. Among the five species examined, *Lantana camara* was the only species perceived to provide notable local benefits, although these are outweighed by broader negative ecological and livelihood impacts. Perceptions

varied by education level and village context, highlighting the importance of socio-demographic factors in shaping responses to invasive species.

To address these challenges, management should adopt context-specific, community-based approaches, including integrating local bylaws, tailoring awareness programmes to educational levels, and employing species-specific strategies that distinguish aquatic species such as *Eichhornia crassipes* from terrestrial invaders such as *Chromolaena odorata* and *Lantana camara*. Incorporating local knowledge into policy and planning can enhance the effectiveness and sustainability of the management of invasive alien plant species in Tanzania.

5.2 Limitations & future research

This study has several limitations. First, relying on perception-based data may highlight invasive alien plant species that are more visible, widely recognised, or important to local culture and economy, while overlooking less noticeable species with significant ecological effects. Second, the cross-sectional design prevents establishing causal relationships and tracking changes over time, such as seasonal or long-term variations in species impacts. Future research should include ecological assessments, long-term monitoring, and economic valuation to provide more comprehensive estimates of these impacts. Expanding the geographic scope of similar studies and incorporating experimental or participatory management trials would further strengthen evidence on the effectiveness and sustainability of control strategies for invasive alien plant species.

Appendix 1

See Table 5.

Table 5 Evidence from literature: ecosystem services associated with invasive species

Category	Description	Examples	References
Supporting services	Certain invasive species, such as <i>Acacia</i> and <i>Prosopis juliflora</i> , increase nitrogen levels and enhance soil fertility, benefiting degraded ecosystems. In areas with sparse native vegetation, invasive plants like <i>Lantana camara</i> provide shelter and resources for wildlife, thus supporting biodiversity in altered landscapes	-Soil Fertility Improvement -Habitat Provision	Hagos and Smit (2005), Sharma et al. (2005)
Regulating services	Invasive species like <i>Acacia mearnsii</i> can contribute to carbon storage, helping mitigate climate change through biomass accumulation -Species such as <i>Tamarix spp.</i> stabilize soils in arid areas, reducing erosion and maintaining soil integrity -Water hyacinth absorbs pollutants, including heavy	Carbon Sequestration and Climate Regulation Erosion Control and Soil Stabilization Water Purification	Le Maitre et al. (2011), Zavaleta (2000), Singh and Kalamdhad (2013)
Provisional services	Some invasive species act as sources of food, medicine, raw materials, and Agriculture pests.	-fuel or firewood -Agriculture pests/animal fodder -Medicinal values	Simberloff and Gibbons (2004), Kumar and Singh (2015), Naylor and Stein (2002), González-Moreno and Quesada (2017)
Cultural services	Some invasive species create habitats that support tourism, such as <i>Phragmites australis</i> , which attracts birdwatchers in wetlands and benefits local economies.	Recreational and Economic Benefits	Meyerson et al. (2000)

Appendix 2

See Table 6.

Table 6 Evidence from literature: ecosystem disservices linked to invasive species

Categories/ type	Description	Examples	References
Biodiversity loss (Supporting disservices)	IAS causes land degradation and disrupts ecosystem processes and services that support the systems	-Displacement of native plants -Reduction of habitats for animals and reduction of grazing land -Endangered tree species	Carruthers et al. (2011), Dickie et al. (2014), Kull et al. (2011), Le Maitre et al. (2011), Shackleton et al. (2016), van Wilgen and Richardson (2014), Vicente et al. (2013)
Environmental and agricultural problems	Harm to farming and Livestock waste - Generating green waste - Reduced soil quality	-Horror pest -Toxic to livestock -Reduce pastureland -Act as a weed -Invades cropland and Interfere harvesting -Alteration of soil quality and enhancement of soil erosion	Yelenik et al. (2004), Gaertner et al. (2014), Qiu (2015), Carruthers et al. (2011), Kull et al. (2011), Le Maitre et al. (2002, 2011), van Wilgen and Richardson (2014), de Wit et al. (2001), Shackleton et al. (2016), Zhang, Kremen and Chen (2007)
Fire risk	Alter natural fire cycles and increase fire hazards.	Highly flammable, Increases wildlife fire	Gaertner et al. (2014), Le Maitre et al. (2011), van Wilgen and Richardson (2014), Potgieter et al. (2018)
Toxicity	Harmful to Flora and Fauna	Toxic compounds affect local ecosystems, including species such as Chromolaena and Lantana, which are also present in the study site.	Rentería and Saavedra (2013), Koutika and Rainey (2010), Sharma, Raghubanshi and Singh (2005)
Health and safety	A direct threat to human health and safety	-Human poisoning Skin Irritation -Diseases Vector -Increasing attacks by associated insects and other animals	Roy et al. (2012), Pyšek and Richardson (2010)
Cultural and aesthetic	Loss of sense of place and aesthetic values	Loss of sense of place and aesthetic values due to the presence of invasive alien plant species	de Wit et al. (2001), Le Maitre et al. (2011)

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Author contributions

Neema C. Mtenga: Conceptualisation, Methodology, Data Collection, Formal Analysis, Writing – Original Draft Preparation, Visualisation. Dickson G. Mauki: Analysis, Validation, Writing – Review and Editing. Tillmann K. Buttschardt: Supervision, Methodological Guidance, Writing – Review and Editing, Funding Acquisition. All authors have read and approved the final manuscript.

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Data availability

The datasets generated and/or analysed during this study are archived in DataSAFE (<https://datasafe.uni-muenster.de/records/k2w94-whj56>), the research data repository of the University of Münster. Due to institutional and data protection regulations, the data are not publicly available but can be accessed by authorised University of Münster users upon authentication. Requests for data access can be directed to the corresponding author.

Declarations

Ethics approval and consent to participate

All procedures involving human participants complied with the ethical requirements of TAWIRI and COSTECH, including guidelines on voluntary participation, informed consent, confidentiality, and responsible data management. The questionnaire design and data handling also adhered to the German Data Forum (RatSWD) Research Ethics Guidelines (2017) for social science research. This research was reviewed and approved by the Tanzania Wildlife Research Institute (TAWIRI) Joint Management Research Committee (JMRC) during its 67th meeting held on 17–18 February 2022 at TAWIRI Headquarters (Ref. No. AB.235/325/01/66). Following JMRC approval, the study received national research clearance from the Tanzania Commission for Science and Technology (COSTECH) under the Ministry of Education, Science and Technology (Research Permit No. 2022-389-NA-2022-021). Informed consent was obtained from all participants prior to interviews and questionnaire administration. Participation was voluntary and anonymous, and respondents were informed of the study's purpose and their right to withdraw at any time. For participants below 18 years of age, consent was obtained from a parent and/or legal guardian prior to data collection.

Consent for publication

No personally identifiable information (images, videos, identifiable quotations, etc.) is included in this manuscript; therefore, consent for publication is not applicable.

Competing interests

The authors declare no competing interests.

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