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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 and documenting the impacts of biological invasions on ecosystems driven by environmental change, such as invasive plant species, is critical. However, little is known about local perspectives on invasive species, especially in Tanzania's lake zones. We used social surveys and interviews to identify local communities' perceptions of the ecosystem services (ES) and ecosystem disservices (EDS) provided by selected invasive plant species, including Argemone mexicana, Chromolaena odorata, Eichhornia crassipes, Ipomoea hildebrandtii, and *Lantana camara.* Overall, 81% of the respondents acknowledged the negative impacts of the species (EDS), and 19% acknowledged the positive effects (ES). The noted ES were a source of livestock fodder (41%), medicinal value (35%), and a fuel source (33%). On the other hand, the highest ecosystem disservices (EDS) were resource costs at 77% and reduced plant diversity at 74. %, and Biodiversity loss at 73%. The results from the logistic regression model suggest that education level and village location were significant predictors of the likelihood of experiencing ES and EDS from invasive plant species. At the same time, age and gender did not affect the results. Again, the respondents reported that *E. crassipes* is the costliest in terms of time and money, at 42% and 38%, respectively. The most reported outcomes for the control methods did not decrease for *E. crassipes* (70%) and *L. camara* (66%). Evaluating local knowledge and perspectives on invasive species offers valuable insights that can inform future biodiversity conservation planning and decision-making.

Key Policy Highlights

- Urgency of Addressing Biological Invasions: Invasive plant species such as *Argemone mexicana, Chromolaena odorata, Eichhornia crassipes, Ipomoea hildebrandtii,* and *Lantana camara* are significantly impacting ecosystems in the Lake Zone. Develop strategies to mitigate biodiversity loss while considering the socio-economic benefits that invasive species provide.
- Potential Benefits (ES): Certain invasive species have advantages despite their detrimental effects. Policy should strike a balance between the demands of communities that depend on these ecosystem services and eradication efforts. To reduce dependency on invasive species, encouraging the use of alternative fuels, medicines, and fodder sources can be achieved.
- Why Community Views Are Important: Of those surveyed, 81% identify the detrimental effects (EDS) of invasive species, but just 19% recognise their benefits. Incorporating local knowledge enhances the efficacy of biodiversity conservation initiatives and gives the audience a sense of importance and involvement.
- The community's location and level of education are significant sociodemographic factors that impact the likelihood of experiencing ecological benefits and challenges from invasive species. Because age and gender have no notable impacts, awareness and experiences are universal across demographic groups, thereby making the audience feel included and part of a collective effort

1. Introduction

Biological invasions by alien invasive plant species 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].

Several methods, including physical, chemical, biological, natural, and pest-integrated management, are employed worldwide to control and manage the spread of invasive species. Like other countries, Tanzania has adopted these methods [12]. For example, Tanzania has adopted the biological method of controlling Invasive *Parthenium hysterophorus* using *Zygogramma bicolorata* and suppressive plant species [13, 14]. However, chemical control methods, particularly herbicides, do not always yield the same results. For example, herbicides have been reported to harm the environment [15]. These negative impacts include the potential threat to human health in rural areas where communities use untreated water for domestic use [16], 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 using Neochetina eichhorniae has been reported to be successful in controlling invasive water hyacinths in Tanzania [17]. at an 82% success rate. 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 [18]. The ecosystem services and disservices framework provides a comprehensive approach to understanding the ecological and socioeconomic impacts of invasive alien species (IAS). Although IAS are known to seriously harm ecosystems and economies, some species also provide benefits to nearby communities, such as food, fuel, and medical resources [19, 20]. Developing well-rounded and successful management strategies requires an understanding of both the advantages and disadvantages of IAS. IAS 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) [21, 22]. However, they also pose health risks, environmental degradation, economic stress, and biodiversity loss [2]. Designing successful, socially inclusive IAS management solutions requires an understanding of how local populations perceive these consequences [9].

In Tanzania, the spread of invasive species has impacted numerous biodiversity hotspots, led to a decline in ecosystem services, and affected human well-being [23, 24, 25, 26, 27]. However, much research on invasive alien species 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 IAS. The biophysical effects of IAS 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 [28].

This dual perspective is crucial for understanding how IAS 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 species in areas surrounding Lake Victoria, particularly within the Mara (Bunda District) and Simiyu (Busega District), with a focus on five invasive species, namely *Eichhornia crassipes*, *Lantana camara, Chromolaena odorata*, *Argemone mexicana*, and *Ipomoea hildebrandtii*. The study hypothesises (H1) that the presence of invasive plant species significantly impacts ecosystem services within the study area. Additionally, it is hypothesised (H2) that the adverse effects (disservices) outweigh the positive impact (ES) provided by these invasive species. Finally, the study hypothesises (H3) that socio-demographic characteristics play a crucial role in shaping perceptions and understanding of the benefits and costs associated with invasive plant species. Along with these, the study also assesses the management and control methods utilised by local people and the associated cost implications. This research aims to bridge the gap between scientific knowledge and traditional practices

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. The Lowland zone covers much of Bunda and the lake, and the study is based on a maximum rainfall range of 700 to 900 mm per year. The landscape of the lowland part, which experiences less rainfall, consists of wooded grassland and bushes of 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 [29, 30]. 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 mm to 900 mm, and the area is ideal for agriculture and livestock breeding [31]. 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 [32]. The study site surveyed four villages: Serengeti, Tamau, Nyatwali in Bunda, and Lukungu in Busega.

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 and then randomly selected from each stratum to represent respondents with diverse socioeconomic backgrounds from each village. A total of 120 people were interviewed: 30 respondents per village. Participants were asked for their consent to participate in the survey and to meet the standards for social science research as outlined by [33]. Prior to the interview, the semi-structured questionnaires were presented to the participants. The questionnaire consisted of three key sections:

(i) *Demographic information* — including village name, gender, age, ethnicity, education level, place of birth, duration of residence, main economic activities, household size, and monthly income.

(ii) *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).

(iii) *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 about IAPS impacts and management.

Three focus group discussions, each with 5 to 10 participants, were conducted to gather in-depth information on the topic and to consolidate findings from the household questionnaire surveys. Additionally, key informant interviews were conducted with experts from the Kijereshi Game, Serengeti National Park, and the villages to validate the responses gathered through household questionnaires.

2.3. Data Analysis

Data Analysis

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).

Descriptive statistics (frequencies, percentages, and proportions) were used to summarise demographic characteristics and perception patterns.

To assess whether demographic factors influenced perceptions of 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 the dependent variables were binary perception categories (benefits: yes/no; disservices: yes/no).

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.

3. Results

3.1. Socio-economic and demographic characteristics of households

Over nine tribes and ethnic groups are found within the study area. Sukuma was the dominant ethnic group in the study population, accounting for 59%, followed by Kurya (18%) and Gita (16%). Most of the age groups fall within the 36-55 age group (40.00%). Younger participants aged 15-35 accounted for 23.33%, while a smaller proportion were 76 years and above (7.50%) (**Table 1).** Most respondents (61%) were women (**Table 1**). Of all respondents, 46.67% were farmers, 14.17% were agro-pastoralists, 3.33% were pastoralists, 9.17% were entrepreneurs, and 26.67% had monthly earnings ranging between 21 and 42 USD, equivalent to 50,000 and 100,000 TZS (57%) (**Table 1**). The majority of respondents had primary education (52%), followed by those with no formal education (32%), with very few holding a secondary school or college/University degree (11% and 5%, respectively) (**Table 1)**.

Table 1: Demographic information about respondents

Demographic variables	Description	Count	Percentage%
Age Group	15-35	25	25
	36-55	47	39.17
	56-75	34	28.17
	76 -above	9	7.5
Tribes	Sukuma	71	59
	Kurya	21	18
	Gita	20	16
	Others	8	7
Education Level	Primary Education	62	51.67
	Secondary Education	13	10.8
	College/University	6	5
	No formal Education	39	32
Occupation	Agro -Pastoralist	17	14
	Entrepreneurs	11	9
	Farmer	56	47
	Pastoralist	4	3
	Others	32	27
Earnings	50,000-100,000	68	56.67
	200,000-500,000	42	35
	600,000-1,000,000	10	8.33

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 explained that the species is most abundant during the rainy season, especially for the weeds and shrubs.

3.3. Impacts on Livelihoods

Approximately 80% of respondents agreed that the focal invasive species had significant negative impacts (EDS), while approximately 20% disagreed (Fig.3). Also, approximately 47% of respondents recognised these plants' beneficial aspects (ES), while 53% stated otherwise (Fig. 3). Therefore, in relative terms, the negative impact was more frequent than positive**.**

More specifically, 84% of respondents reported that E. crassipes causes the greatest harm to people's livelihoods, and none considered the species to be beneficial (Fig. 4). In contrast, nearly 80% of respondents perceived *L. camara* as beneficial, while 32% were undecided about *I. hildebrandtii* (Fig. 4). These quantitative findings were echoed during the focus group discussions. 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 emphasized 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, 2022)

*3.*4 Socio-Ecological Services and Disservices of Invasive Species

3.4.1 Social Ecological Disservices

Overall, the highest ecosystem disservices, which were substantial for all the case study invasive plants, were resource competition and control costs (77%), reduced plant diversity (74%), and biodiversity loss (73%) (Fig. 5). More specifically, 62% of respondents identified *E. crassipes* as interfering with harvesting, while 57.5% expressed the same for *A. mexicana*. This issue was less of a problem for the other case study species. As one FD (48 years) explained, "As fishermen, we have seen how *E. crassipes* has hurt Lake Victoria. It has reduced fish populations, especially Tilapia and the smaller species we rely on. Years ago, the Lamadi River was a centre of cultural and ritual activities and celebrations for the people from Lukungu village. However, no further gatherings were held due to the water hyacinth invasion." (67-year-old man).

On the other hand, C. odorata and *L. camara* were seen to impact grazing, as confirmed by 65.8% and 57.5% of respondents, respectively. The effects of the species on the grazing land were also explained by an officer during FGD from Serengeti National Park and Kijereshi Game Reserve*. C. odorata's* dominance in certain areas, linked with its rapid spread, leads to a scarcity of pastures. Additionally, 46.7% of respondents agreed that *A. mexicana* posed a threat in their fields, while 28.3% acknowledged that *E. crassipes* was a threat in the rice fields (Fig. 5). Respondents also explained that when *C. odorata* is abundant, it leads to a significant decline in crop yield. As one farmer stated, "I can say that the presence of *C. odorata* in the farmland causes land degradation and suppresses crop growth. I encountered this in my field two years back." 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).

Factors such as poisoning and harbouring pests and diseases were not considered significant issues for any of the case study species (Fig. 5).

Results from the logistic regression analysis model show that education and the village location were statistically significant in explaining the local community's perspectives on the costs. Primary education decreased the probability by 1.18 (p-value = 0.0169), while living in Tamau village decreased the probability by 1.29 (p-value = 0.0304).

Table 02 ***Variables influencing communities' perspectives on the disservices of ecosystems from invasive Alien Species.***

	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*

*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 fuelwood for harvesting and sale.

On the other hand, the logistic model results show that education and the village location were statistically significant, explaining the local community perspectives on the ecological services (ES) derived from Invasive Alien Species. Primary education decreased the probability by 1.18 (p-value = 0.0216), while living in Tamau village decreased the probability by 1.29 (p-value = 0.0314).

Table 03: Variables Influencing Local Communities' Perspectives on Services (ES) of Invasive Alien 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*

3.5 Management Strategies and Local By-laws

3.5.1 Perspectives on Management/Control Methods

Our evaluation of various methods to control invasive species has revealed the significant popularity of manual control and burning. This method has emerged as a commonly employed strategy, particularly for *E. crassipes* (55%) and *L. camara* (55%), and was also used for *C. odorata* (50%), *A. mexicana* (44%), and *I. hildebrandtii* (34%).

Mowing or cutting was frequently used for *E. crassipes* (58%) and *L. camara* (38%), with minimal use for other species. 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, such as *E. crassipes* (70%) and *L. camara* (66%), showed no significant decrease, highlighting 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 slight decreases for species such as *C. odorata* (12%) and more significant reductions for *I. hildebrandtii* (13%).

Table 2: Outcome of the Control Measures

Mgt _Results	*E. crassipes*	*A. mexicana*	C. odorata	*I. hildebrandtii*	*L. camara*
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

3.5.2 Perspective on Management cost in terms of Time and Money per species

The management costs per species varied among respondents. For *E. crassipes*, 42% of respondents reported that management time costs were very high, 30% indicated they were high, and only 10% considered the time costs inadequate. In contrast, for *C. odorata, I. hildebrandtii*, *L. camara*, and *A. mexicana*, the percentages of respondents who considered management costs high were 48%, 38%, 37.50%, and 36%, respectively (Fig 8). To reiterate, our findings indicate that only a small proportion of respondents reported very high time costs for management of these species, except for *E. crassipes*, which has notably high time costs.

Our survey revealed a diverse range of responses regarding the management costs of individual invasive species. In terms of monetary value, these costs are not insignificant. Notably, 38% of respondents reported extremely high management costs for *E. crassipes*, 49% for C. odorata, and 41% for *A. mexicana* and *L. camara.* The remaining invasive species had management costs that were either moderate or low (Fig.9).

3.5.3 Bylaws and Opinions on Invasive Species

According to our findings, all respondents (100%) stated that there were no bylaws in place regarding environmental protection or invasive species control. The results also reveal that most respondents (81.67%) find it difficult to manage invasive species. Interestingly, while 27% disagreed, 73% of respondents agreed that invasive species pose a significant problem in their areas, suggesting this is a common concern.

4. Discussion

Our study demonstrates how the spread of invasive plant species is impacted by climate change. Invasive species, such as *E. crassipes*, *L. camara*, and *C. odorata*, are resilient to changing climatic conditions and flourish year-round, including during droughts, unlike native plants. This finding is consistent with research [34, 35]. demonstrating that climate change enhances the ecological dominance and adaptability of invasive species. Their capacity to compete with native species, alter soil chemistry, and store seeds year-round is confirmed by personal observations from 2022 to 2024. These changes may expand invasion pathways, enabling non-native species to establish in previously unsuitable areas [36].

4.1. Local knowledge and perspectives on the social-ecological Services and Disservices

Invasive alien species have a profound impact on ecosystem services and human well-being [20]. This study provides further evidence for this in Tanzania, where such impacts have yet to be well documented. Unlike in other studies [37, 38, 39, 40], significantly fewer benefits were mentioned for four of our five case study invasive plant species, except for *L. camara*, for which similar benefits have been noted in India [41].

Our results show that *E. crassipes* is the species that most significantly affects the livelihoods of the local communities around the study sites. The species contributed to the decline in the diversity and abundance of the native weed papyrus sedge (Cyperus papyrus), which provides good breeding habitat for fish. The findings align with studies by [42, 43], which demonstrated that *E. crassipes* has a significant impact on the ecological balance of freshwater environments. Aquatic biodiversity is at risk because this species frequently outcompetes local plants. Furthermore, it hinders the development of native plants, disrupts microbial communities, and prevents phytoplankton from growing under large mats, all of which affect fisheries [44].

The results revealed that E. crassipes had impacted the fishing sector, bringing about a financial crisis, as most local fishermen were unable to use their traditional boats. These results align with the study by [45], who reported that the existence of Water hyacinth (*E. crassipes*) in Lake Victoria has interfered with fish production. It obstructed waterways and boat movement, damaged water supply intakes, contributed to the spread of disease, and increased water loss through evaporation [46]. The information is also consistent with studies by [47, 48], which reported that when water hyacinth impedes water flow, waste accumulates near the shore, where residents usually bathe, launder clothes, or fetch water for household use. Additionally, *E. crassipes* mats foster the proliferation of indigenous diseases. Instances and severity of malaria and schistosomiasis have risen notably in correlation with *E. crassipes* mats. Also, according to [49], the weeds trigger the demolition of fishing.

Fish prices and availability are now a more significant problem in the Lake regions and Tanzania. The study by [50]. suggested that fishermen and consumers have been economically affected by reduced fish quality and production due to dense *E. crassipes*. The same findings were reported by a study conducted by [51] in River Tano, Ghana, which found that the invasion of *E. crassipes* created several challenges for fishing and fish trading, including restricted access to fishing grounds, delays in preparatory activities, siltation of fishing traps, decreased fish supply, and lower profits. In this case, the fishermen must cover the costs of repairing their fishing gear out of pocket, which leads to higher prices and influences changes in community behaviour due to the crisis.

Additionally, the species has impacted the cultural services conducted along the Lamadi River. Here is the respondent's quote.

The communities have reported *that C. odorata has spread rapidly, especially in the lowlands and farmlands of the Bunda Mountains*. Therefore, the species reduces crop production, reducing grazing land for both livestock and wildlife. The respondents justified the resource competition issue by citing manual removal. The respondent quoted: *"Most of the energy is being used to remove it, which affects other economic activities."* *C. odorata* is the second species reported to impact pastureland. Information from an SN officer stated that C. odorata dominated most areas. Grazing land is scarce for wild animals due to the rapid spread of the introduced species into their ecology. They maintained in that conversation that invasive species have had a detrimental impact on ecosystem services and substantially contributed to biodiversity loss. These species have led to land degradation, reducing grazing areas and limiting the availability of potential grass [52]. This study supported the findings and insights by reporting that Chromolaena causes detrimental impacts on biodiversity through various means, including suppressing indigenous grassland and savanna vegetation via physical smothering and allelopathy. Additionally, it outcompetes native vegetation at forest ecotones, thereby increasing plant biomass. Additionally, [26] reported that *C. odorata* has a negative impact on the economy, ecology, society, and health. When it invades natural areas, it causes degradation, threatens biodiversity in the Savanna grassland, and undermines conservation and ecotourism [53]. In our context, the respondents make no claims about the health effects of *C. odorata*.

A. mexicana was reported by most respondents to act as a weed in most of the farmland at the study sites. According to our results and discussion with the local people, *A. mexicana* was reported to have thorns and produce many seeds, which results in lower production, especially when cassava and maize fields are invaded. Furthermore, *A. mexicana* competes with money, time, water, and human resources. [25]. reported that *A. mexicana* has allelopathic effects on the germination, growth, and development of *C. ternatea and B. dictyoneura*, suggesting that the allelochemical compounds in *A. mexicana* inhibit the growth of other plants or crops grown together in farmland.

Lantana camara is an invasive alien species that the IUCN considers one of the world's 100 most invasive species and among the world's ten worst weeds. In our study, we identified *L. camara* as one of the invasive species found in the study area and well-established within a wide range. [26] reported that *L. camara* is a significant invasive shrub that affects economies, ecosystem services, biodiversity, and socio-ecological change globally. According to [54], *L. camara* is a common and hazardous invasive plant that negatively impacts more than 60 nations. The findings of this study highlight that lantana invasions negatively impact rural livelihoods and other ecosystem services. The findings are supported by [55], who reported that *L. camara* invades both natural and agricultural ecosystems, posing challenges to the tourism industry and crop production in Tanzania. This is due to its capacity to create dense thickets that outcompete preferred species and disrupt fire patterns by altering fuel levels in natural environments [56]. The species compete for resources in farmland and nearby protected areas, leading to a loss of forage in grazing areas. The evidence from [57] indicates that L. camara is associated with lower tree density and typically invades areas with low tree density. Also, the study by [58] reported that Lantana reduced yield by 29% in the field where it was grown together with Lantana compared to the field without *Lantana*. In focus group discussions, people said that although most livestock, especially goats, feed on *L. camara*, the species is unsuitable because no other plants or crops can grow nearby. The respondents' arguments are supported by scientific research showing that Lantana's presence reduced species abundance and diversity in forests and wild areas [59]. On the other hand, [26]. also emphasised that Lantana species increased fire risk, had detrimental effects on tourism, increased management burdens for communities, and diminished the landscape's aesthetic value. These are only a few of the socio-ecological adverse impacts. Furthermore, this study highlighted that the invasive *L. camara* provides habitat for the tsetse fly, a vector of sleeping sickness.

Ipomoea hildebrandtii is the species most commonly found near the Kijereshi Game Reserve, although most respondents reported encountering it at different sites in their villages. This study's results highlighted only a few impacts on biodiversity and resource competition.

4.2. Influence of Demographic Factors on Local People's Perspectives of Disservices and Services from Invasive Plant Species

The findings from the logistic model analysis shed light on the relationship between socio-demographic factors and local community perspectives regarding both the disservices and ecosystem services associated with invasive alien species (IAS). The significant effects of village location and education underscore the importance of considering sociocultural factors when evaluating human attitudes towards environmental and ecological issues.

Higher education may lead to a deeper understanding of the complexity underlying IAS impacts, as evidenced by the negative correlation between elementary education and the likelihood of experiencing ecosystem services and disservices. On the other hand, those with only an elementary education might be less conscious of these effects. However, we are aware that their experiences are vital in understanding the impact that invasive species can have on the surroundings. These observations are supported by previous research by [60], who reported that a high level of education tends to be more aware of environmental phenomena and, therefore, is likely to other Services (ES) categories provided by Invasive Alien Species, as well as disservices, and are reflected in the differing perceptions found in Tamau village. This suggests the influence of localised factors on perspectives towards IAS, emphasising the importance of context-specific interventions and management strategies. The findings of this study are supported by those of [61], who reported that experience and interaction with social, cultural, and natural environments influence people's perspectives on the positive or negative impacts of invasive species in their areas, findings that align with ours. However, based on this further investigation into localised attitudes and experiences, it is reasonable to gain a better understanding of these dynamics.

4.3 Management Strategies and Local By-laws

4.3.1 Community-Based Approaches

Our results showed that the control methods used by local communities in the study area exhibited significant inconsistencies in their application across the studied species, reflecting both the adaptability of management practices and the challenges of controlling specific invasives. The most popular approach was manual control, especially for *E. crassipes* and *L. camara*, which had respective % application rates of 55% (Fig. 5). This preference may be explained by the effectiveness of manual control for localised infestations, as well as its accessibility and comparatively low cost. Although manual control requires human resources and resources, such as boats for *E. crassipes* along the River Lamadi and Lake Victoria, the community's unwavering commitment to utilising available resources to remove the species [62] is truly inspiring. Similarly, notable usage rates for *A. mexicana* (44%), *C. odorata* (50%), and *I. hildebrandtii* (34%) demonstrate the usefulness of this approach across various species.

Moreover, cutting or mowing was also more focused, mainly on *L. camara* (38%) and *E. crassipes* (58%). According to [63], mowing efficiency may depend more on the surrounding conditions, perhaps on the growth patterns or densities of certain species. According to the survey, people were also trying to cut *E. crassipes*, particularly those planted along the routes to their fishing catchments. These results are consistent with a study by Indian [64], which showed that cutting invasive species reduces post-removal recovery more effectively than uprooting them. This emphasises the preference for cutting over uprooting for some species, such as *L. camara* and *C. odorata*, a key research conclusion

Conversely, underutilising biological control and integrated methods, with application rates below 5% for all species, highlights a gap in adopting potentially sustainable approaches to the Lake Zone of Tanzania. Despite the limited application of biological methods in controlling invasives, the study by [65]. shows that integrated control approaches combining biological and physical methods have been identified as the most sustainable and cost-effective for managing invasive aquatic plants, such as water hyacinth (*E. crassipes*). The herbicide application rates for *L. camara* (0.83%) *and E. crassipe*s (2%) were relatively low. This highlights the pressing need to develop alternative techniques to address the risks of non-target effects and environmental health concerns. Similarly, grazing, which has only been documented for *L. camara (*7%), demonstrates the method's restricted suitability for specific species and environments

Surprisingly, inaction (doing nothing) indicates gaps in management efforts and potential obstacles such as low perceived urgency, lack of awareness, or inadequate resources, especially for *A. mexicana* (23%) and *C. odorata* (6%). This delay underscores the importance of engaging stakeholders through awareness-raising campaigns and capacity-building initiatives. Their involvement is beneficial and integral to reinforcing invasive species management efforts. Our findings, which highlight these variabilities in control methods, align with the studies by [66, 67, 68, 69]. which highlight the importance of stakeholder engagement, influenced by factors such as species characteristics, invaded ecosystems, and resource availability.

On the other hand, the results show that outcomes from using control methods for invasive alien plant species highlight perceived examples of management effectiveness. Across the species studied, the majority of respondents reported that interventions aimed at reducing invasive species outcomes were 'not decreasing,' with values ranging from 47% (*A. mexicana)* to 70% (*E. crassipes*) (Table 2). This suggests that the effectiveness of measures to prevent the spread of these species has been uneven. The findings underscore the need for collaboration to enhance current methods, increase resources, and implement alternative control mechanisms. If we band together, we can improve management results for these invasive species and feel like we are part of the solution [70].

4.2.1 Management Outcomes and Local Bylaws.

Based on a comprehensive survey of 120 participants from the study site, our findings highlight significant differences in the perceived management costs associated with invasive species. In contrast to other species, such as *L. camara* and *A. mexicana*, which received high evaluations from only 37.5% and 36% of respondents, respectively, *E. crassipes* stands out, with 42% of respondents evaluating time-related management expenses as extremely high (Fig. 3). Similarly, monetary costs for *E. crassipes* were estimated as extremely high by 38% of respondents, aligning with its reputation for aggressive spread, high seed production, wide physiological tolerance, and challenging control measures [71].

These results highlight the need for targeted resource allocation, particularly for species such as *E. crassipes*, which impose an undue cost and time burden on stakeholders. Comparable research suggests that improved management techniques and increased funding could effectively reduce these expenses. Thus, there is optimism [72]. Given that 100% of respondents acknowledged the lack of local bylaws and frameworks to control invasive species, our results highlight the critical need for such regulations. This aligns with [2], who emphasised the difficulties many communities face due to inadequate legal frameworks. Despite this gap, 73% of respondents recognised invasive species as a significant problem due to poor governance, thereby echoing global concerns raised by [73] about their role in biodiversity loss.

The 27% of respondents who did not consider invasive species an issue may indicate different levels of environmental knowledge. According to [74], public involvement and education are essential for effectively managing invasive species. Engaging the public and raising awareness of invasive species can help prevent the introduction and spread of invasive alien species (IAS) while establishing effective control efforts [75]. Therefore, we can play a crucial role in addressing this issue by raising awareness and involving communities in conservation efforts.

Conclusion and recommendation

This study revealed that perceptions of invasive plant species among local communities in Tanzania vary, with only one of the five species examined (*Lantana camara*) being perceived as providing any notable benefits. Overall, all five species were considered predominantly detrimental to local livelihoods and the environment. These findings highlight the urgent need to strengthen efforts to manage and mitigate the impacts of invasive plant species in Tanzania.

To sustain healthy, functional ecosystems that support biodiversity, human well-being, and sustainable development, further action is required to develop and implement effective management strategies and policies to address biological invasions. Moreover, the results demonstrate that invasive species control should adopt a more integrated and species-specific approach, supported by stronger legal frameworks and active community participation in management initiatives.

Declarations

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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Ethics Approval

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).

No live vertebrate animals were handled in this study.

Ethics Statement (Human Participants)

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.

Consent to Participate

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 purpose and their right to withdraw at any time.

Consent to Publish

Not applicable. The study does not contain any identifiable personal images or information requiring publication consent.

Data Availability Statement

The datasets generated and/or analyzed 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 authorized University of Münster users upon authentication. Requests for data access can be directed to the corresponding author.

Competing Interests

The authors declare no competing interests.

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Figures

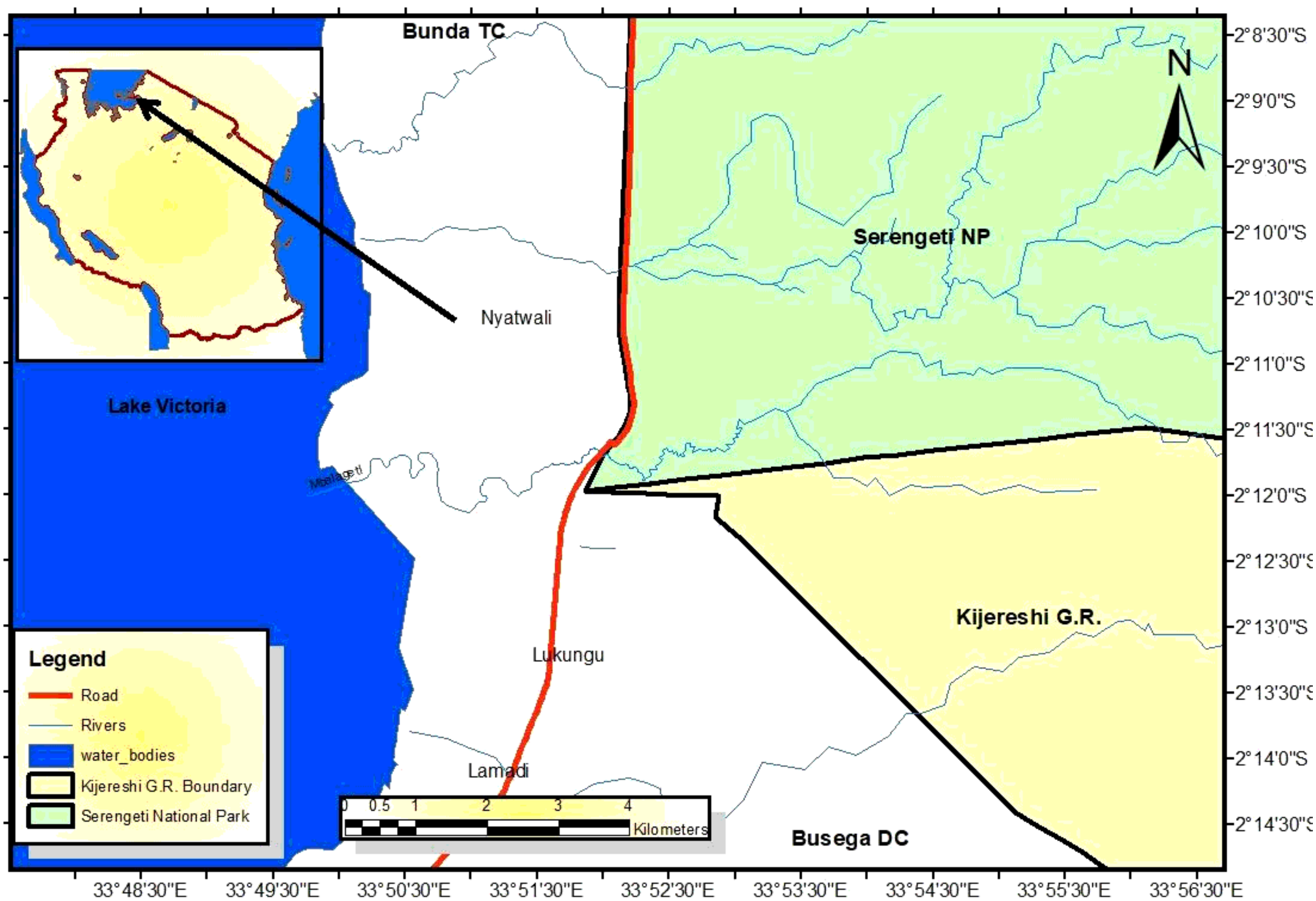

Figure 1

The study region and the villages surveyed in this study.

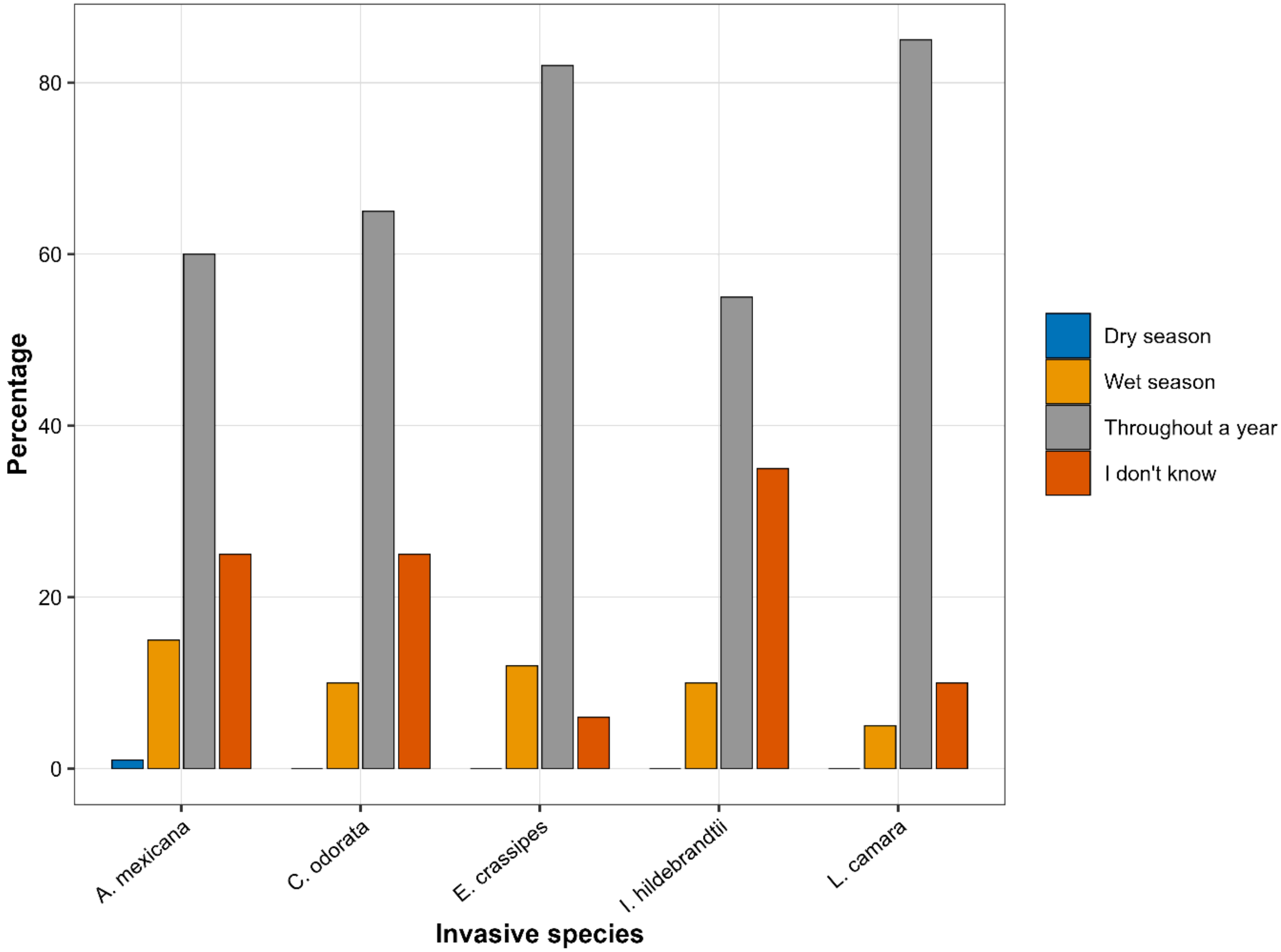

Figure 2

Seasonal abundance of invasive Abundance

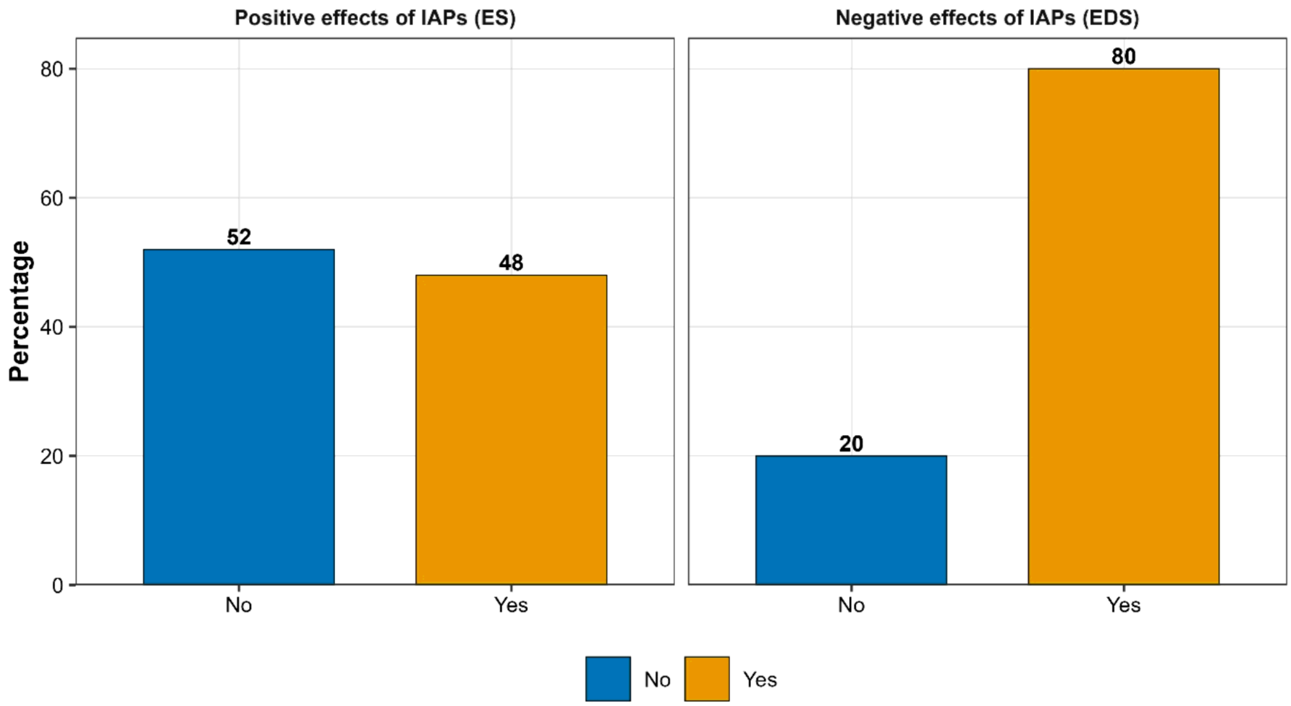

Figure 3

General overview of the impacts of invasive species in the study area.

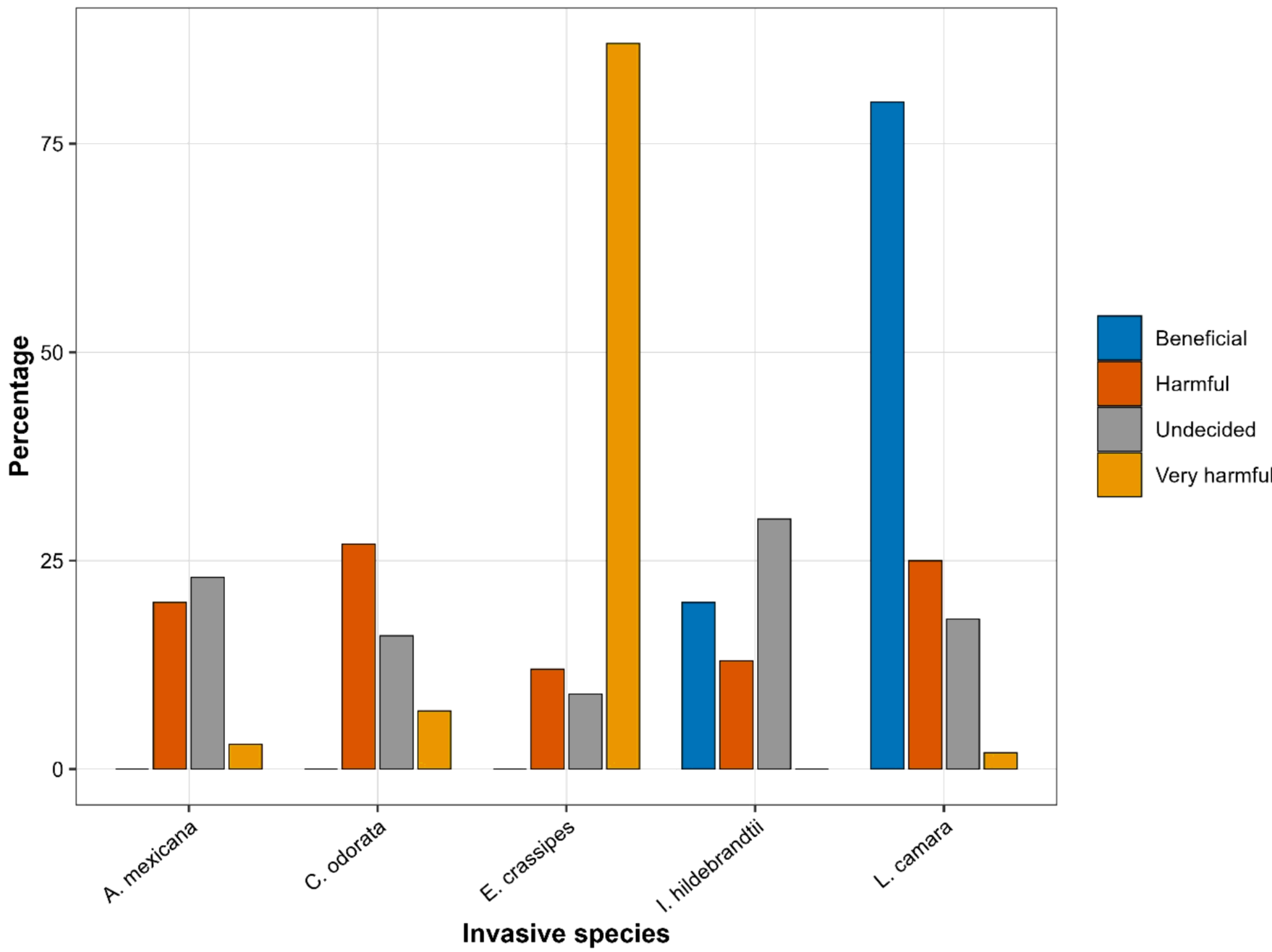

Figure 4

The perceived impacts of the individual selected invasive alien species on people's livelihoods

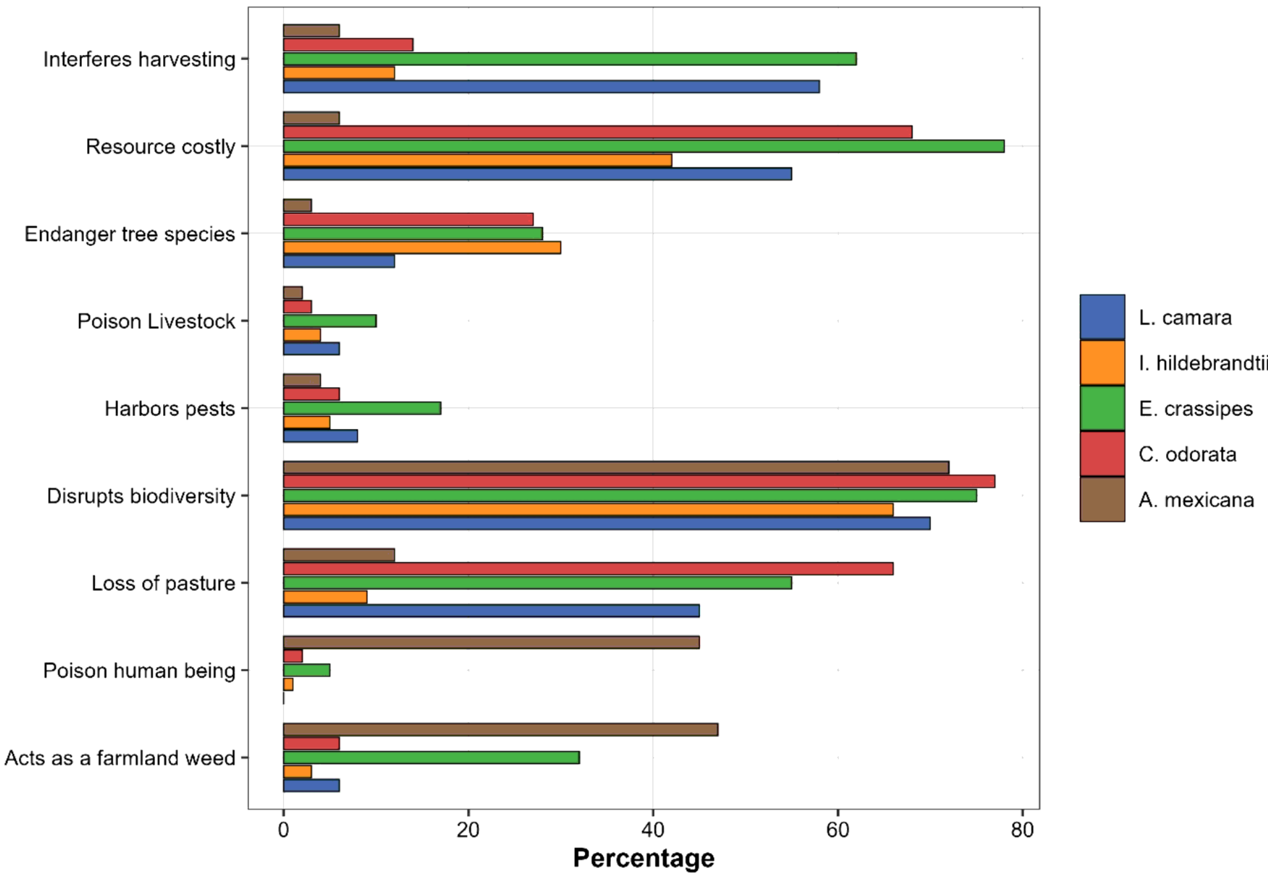

Figure 5

Respondents' opinions and perspectives on the Ecological disservices of the selected invasive species.

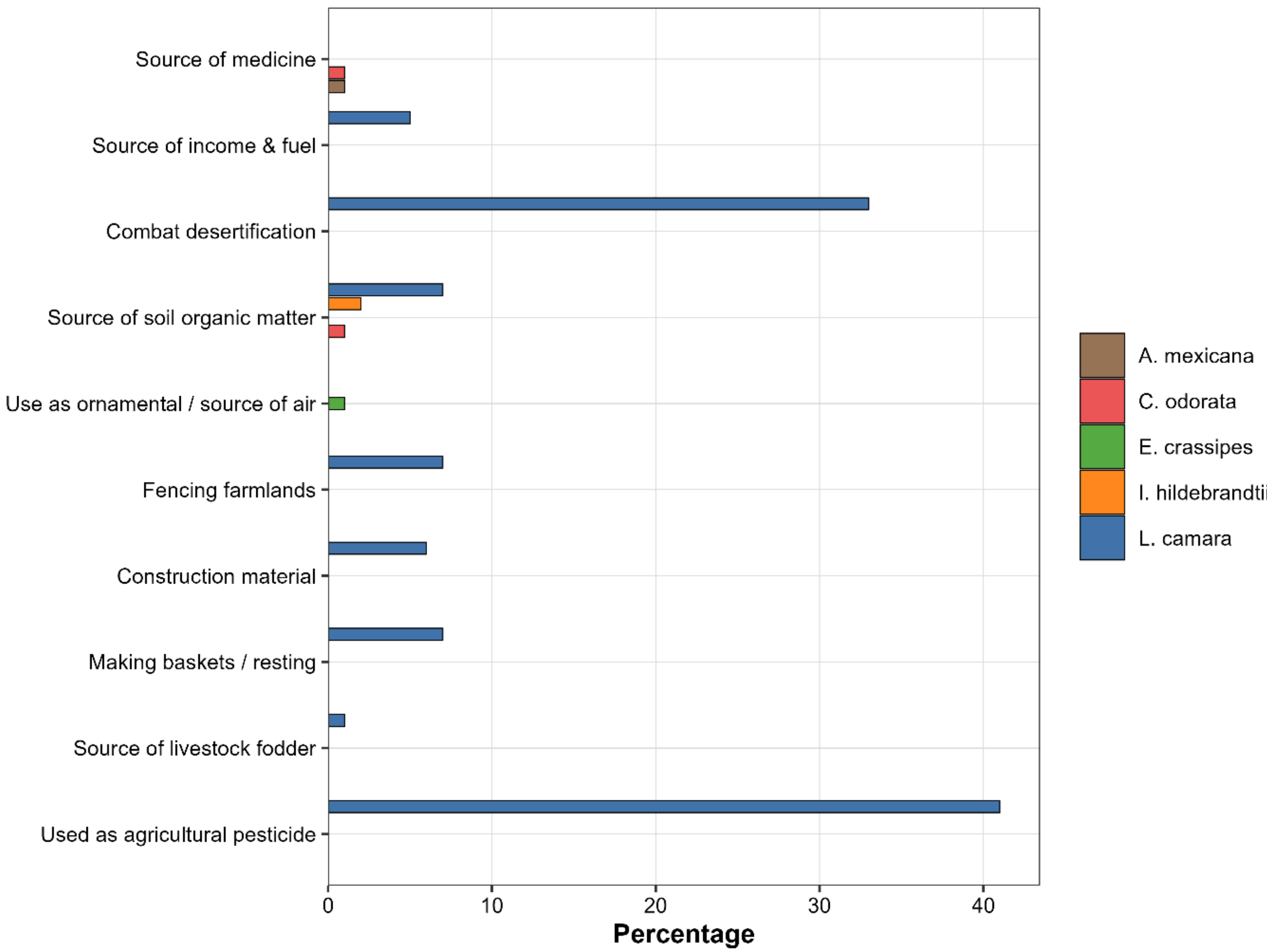

Figure 6

Respondents' opinions and perspectives on the Ecosystem's services of the selected invasive species.

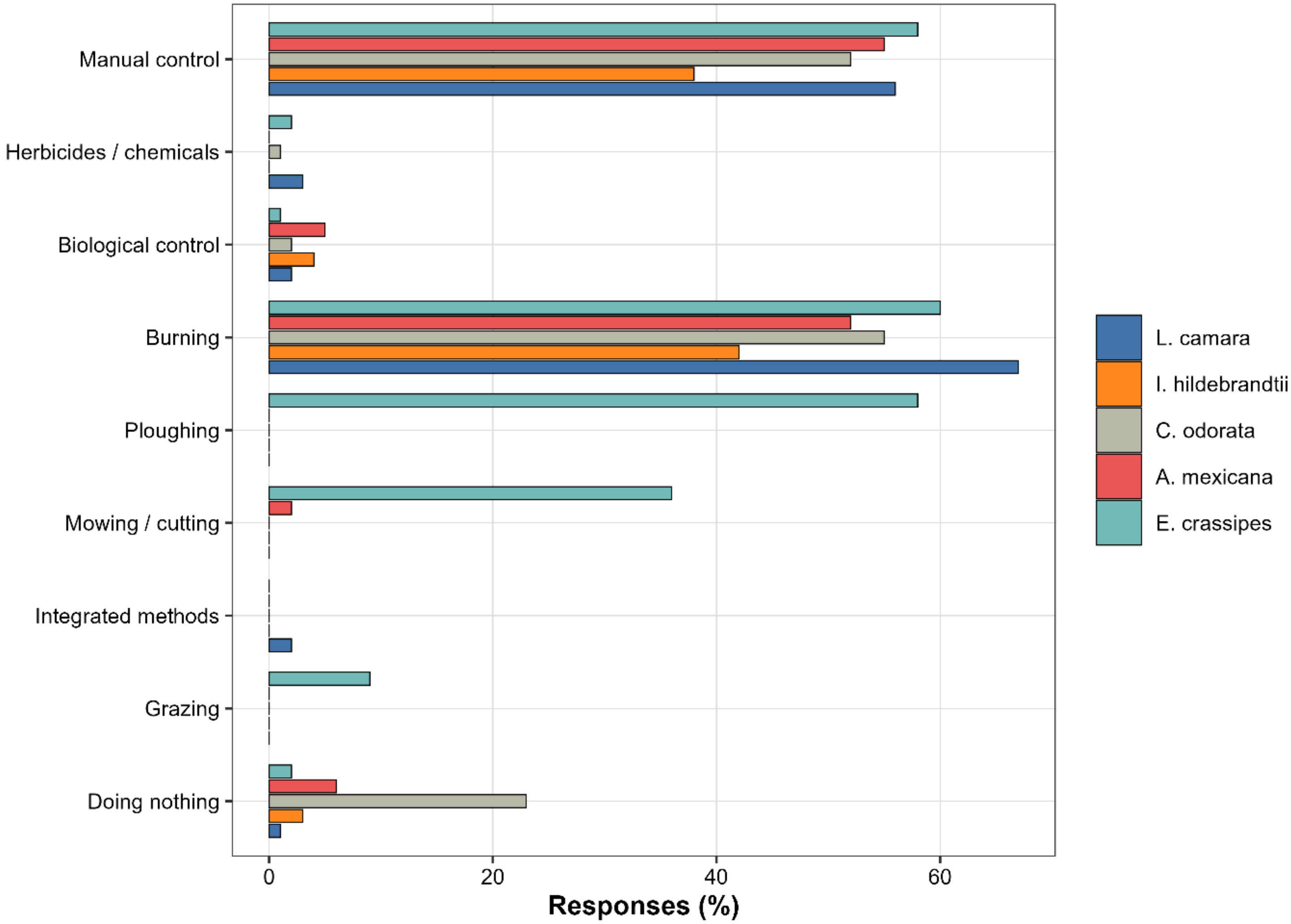

Figure 7

Control Measures for Invasive Alien Species used by local communities

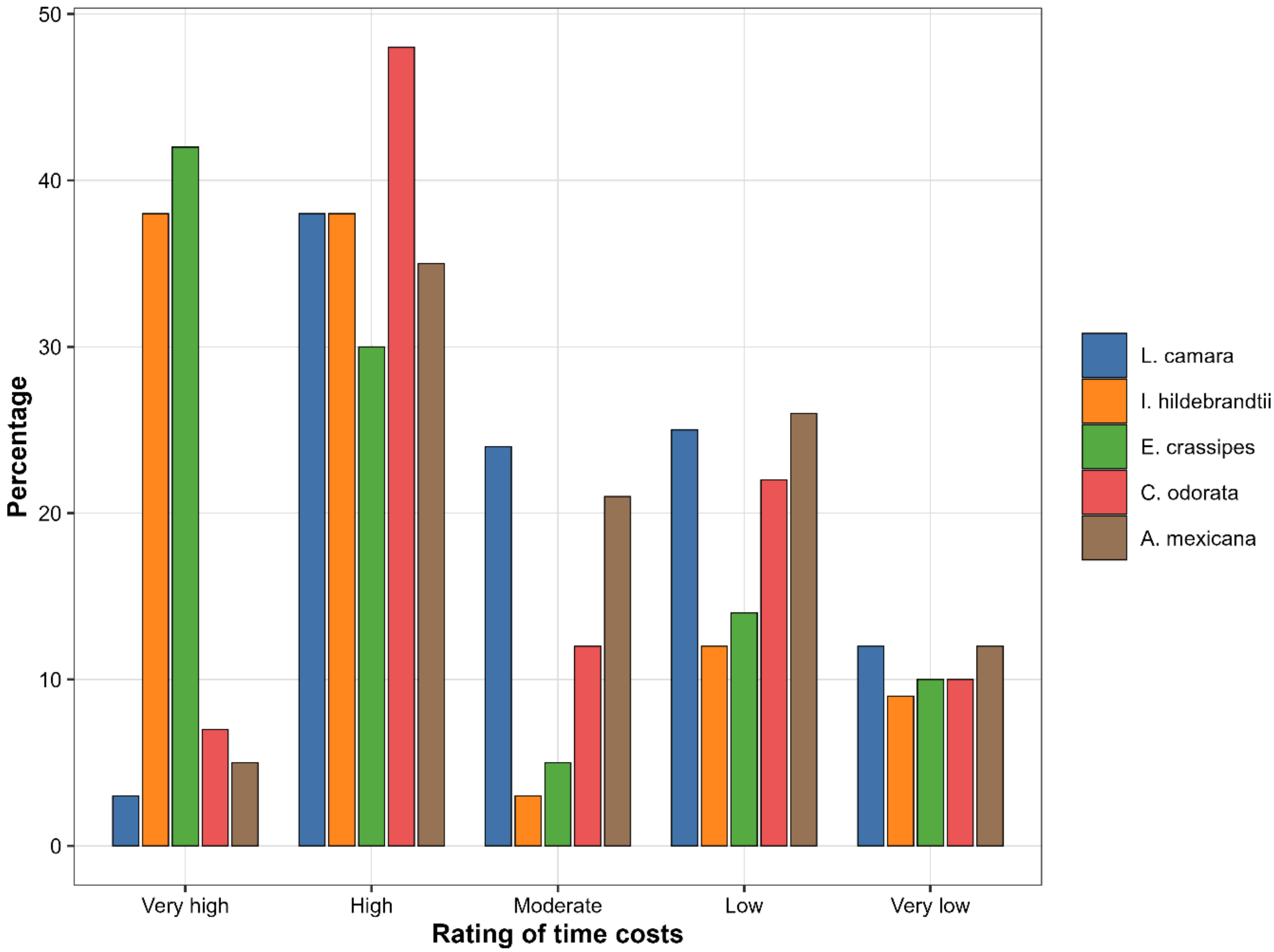

Figure 8

Management costs of Invasive species in terms of Time

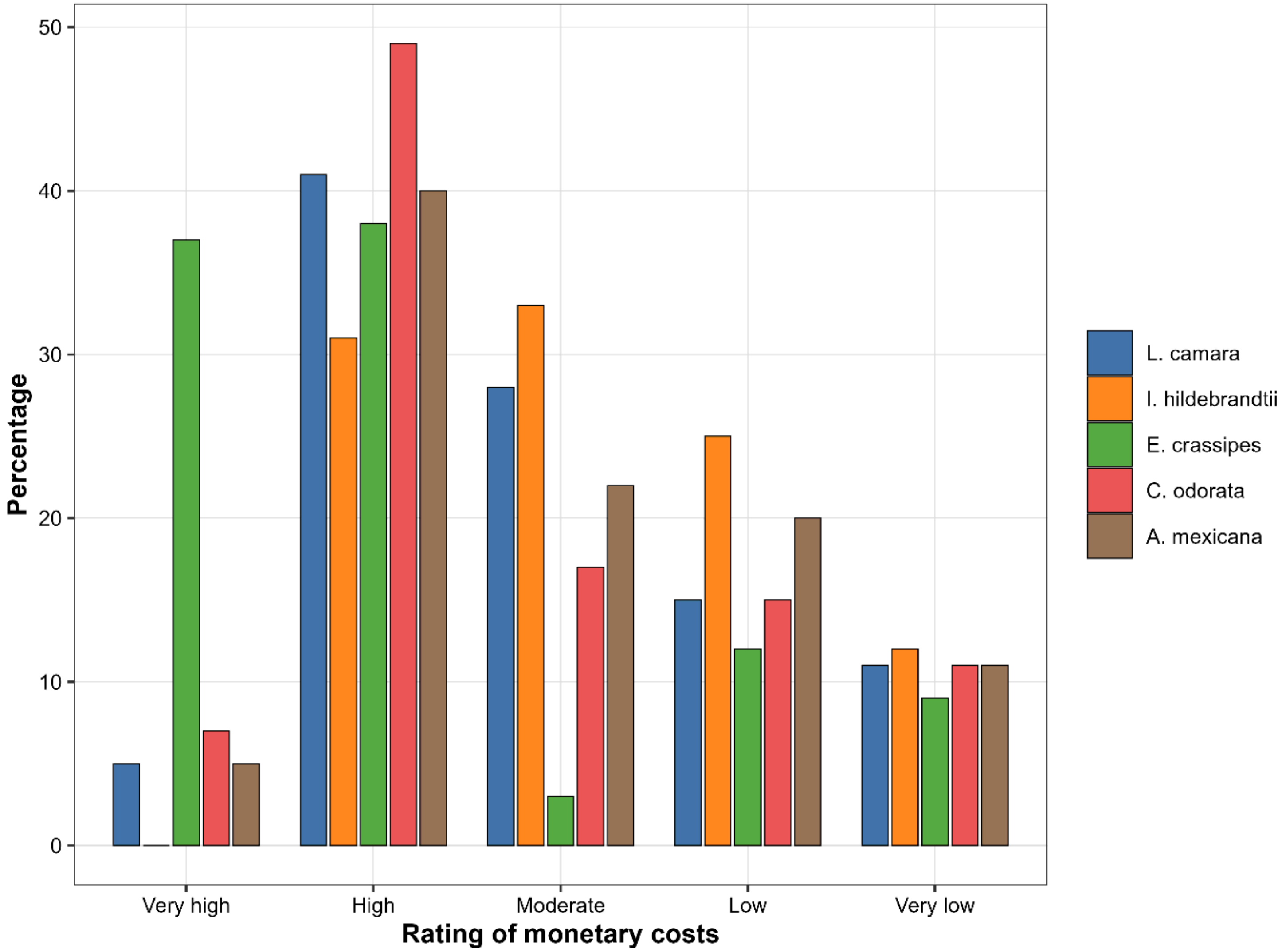

Figure 9

Management costs of Invasive species in terms of money

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SuplimentaryMaterialS1ES.docx
- Appendix1.docx