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Community Awareness of Invasive Alien Plant Species in Ngorongoro, Manyara, and Tarangire Conservation Areas

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Abstract

Invasive alien species are a major driver of biodiversity loss, despite global, regional, and domestic efforts to address them. This study aims to assess community awareness and engagement in combating invasive alien plant species in Tanzania, using a cross-sectional questionnaire survey of 208 respondents. Eight villages around Ngorongoro, Tarangire, and Manyara ecosystems were surveyed using questionnaires to gather information on awareness of Invasive Alien Plant Species presence, affected areas, means of spread, harmful effects, and community involvement. Results show that over 65% of respondents were aware of Invasive Alien Plant Species, with impacts observed on farms and grazing lands. However, there was limited knowledge about specific harmful effects. Community involvement in combating Invasive Alien Plant Species was lacking, with minimal direct engagement from authorities and stakeholders. Control methods primarily involved burning and cutting, while biological and chemical approaches were less favored. The study underscores the need for enhanced community involvement and recommends greater collaboration between stakeholders to effectively manage Invasive Alien Plant Species and mitigate their impacts on ecosystems.

Keywords: *Awareness; Invasive Plant; conservation; Ngorongoro ecosystem*

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Introduction

Invasive Alien Plant Species (IAPS) are plants introduced, intentionally or unintentionally, into areas where they are not native, causing negative impacts on local biodiversity and ecosystem services (CBD, 2009). These species often outcompete, consume, hybridize with, or infect native species, leading to a loss of ecological value (Pathak *et al.,* 2021; Shuvar *et al.,* 2021). According to IPBES (2023), IAPS have contributed to the extinction of 60% of global flora and fauna and currently cost about $423 billion annually. In Tanzania, IAPS were first recorded in 1945 in sisal, later appearing in groundnuts and bananas (Lyimo *et al.,* 2009). Many protected areas, including Ngorongoro Conservation Area Authority and Serengeti National Park, face challenges from IAPS (Alick *et al.,* 2007; Bukombe *et al.,* 2018; Britton and Orr, 2002; Makunga and Gobolo, 2020). The Global Invasive Species Database (GISD) lists 88 IAPS in Tanzania, including 46 exotic species, 31 native species, and 11 unspecified species (Bukombe *et al.,* 2021). For instance, a study by Wakibara and Mnaya (2002) found that *Senna spectabilis* suppressed native tree regeneration in Mahale Mountains National Park, with a density of 586

trees per hectare. Similarly, Lyimo *et al.* (2009) reported the presence of *Lantana camara*, *Datura stramonium*, and *Argemone mexicana* near roads in Ngorongoro, likely due to construction materials imported from nearby areas. Other invasive species, such as *Gutenbergia cordifolia*, *Tagetes minuta*, *Caesalpinia decapetala*, *Acacia mearnsii*, *Eucalyptus camaldulensis*, and *Lonicera japonica*, also threaten ecosystem stability (Kideghesho *et al.,* 2013; Ngondya and Munishi, 2021).

Globally, the management of invasive species involves a combination of international, regional, and local regulations developed over the past 50 years (Mogomotsi *et al.,* 2022). Legal instruments like the World Trade Organization (WTO) ensure that international trade does not facilitate the spread of harmful alien species through sanitary and phytosanitary measures (Alam, 2023; Brockett *et al.,* 2023; Eckersley, 2004; Moore, 2003). The IUCN and 32 other organizations launched the Honolulu Challenge on Invasive Alien Species, calling for urgent action and cooperation among stakeholders to address IAPS through biosecurity measures and eradication efforts (IUCN, 2016). Africa's Strategy for Managing Invasive Species (2021–2030) aims to support and enhance member states' responses, including prevention, early detection, control, and ecosystem restoration (CABI, 2021). In Tanzania, the National Invasive Species Strategy and Action Plan (NISSAP, 2019) focuses on building community capacity for ecosystem restoration through education and awareness programs. Despite these efforts, invasive species issues remain largely unaddressed by communities and decision-makers (TANAPA, 2017). Communities surrounding Tarangire, Manyara, and Ngorongoro conservation areas, which are highly involved in activities like grazing, agriculture, transport, and settlement, are particularly vulnerable to the spread of IAPS (Elisante *et al.,* 2013; Malila *et al.,* 2023). Raising community awareness could improve livelihoods by sustaining agriculture and grazing while protecting areas from invasive pressures (Novoa, 2017).

Despite international, regional, and domestic guidelines promoting community involvement, Invasive Alien Plant Species (IAPS) continue to spread in Tanzania, particularly affecting the Ngorongoro, Tarangire, and Manyara ecosystems (Alick *et al.,* 2007; Musese *et al.,* 2020; National Audit Office, 2022). Existing research has largely concentrated on the ecological distribution of IAPS, often neglecting community awareness and engagement. This study aims to fill this gap by assessing community knowledge about IAPS, focusing on their presence, affected areas, modes of spread, harmful effects, and local engagement in combating these species.

Additionally, this research explores how communities utilize invasive species for medicinal purposes and fodder. By evaluating local involvement in management efforts, the study highlights the need for improved education and community participation. The findings offer valuable insights into the local impact of IAPS and support the development of more effective strategies for invasive species management. This study is crucial for several reasons. First, it contributes to the knowledge base by assessing community awareness of the impacts of IAPS, which could facilitate comparative analysis and interdisciplinary collaboration. Second, the findings can help policymakers develop effective strategies to combat IAPS. Third, the study explores local involvement and management practices for these invasive species, providing insights into community-based solutions.

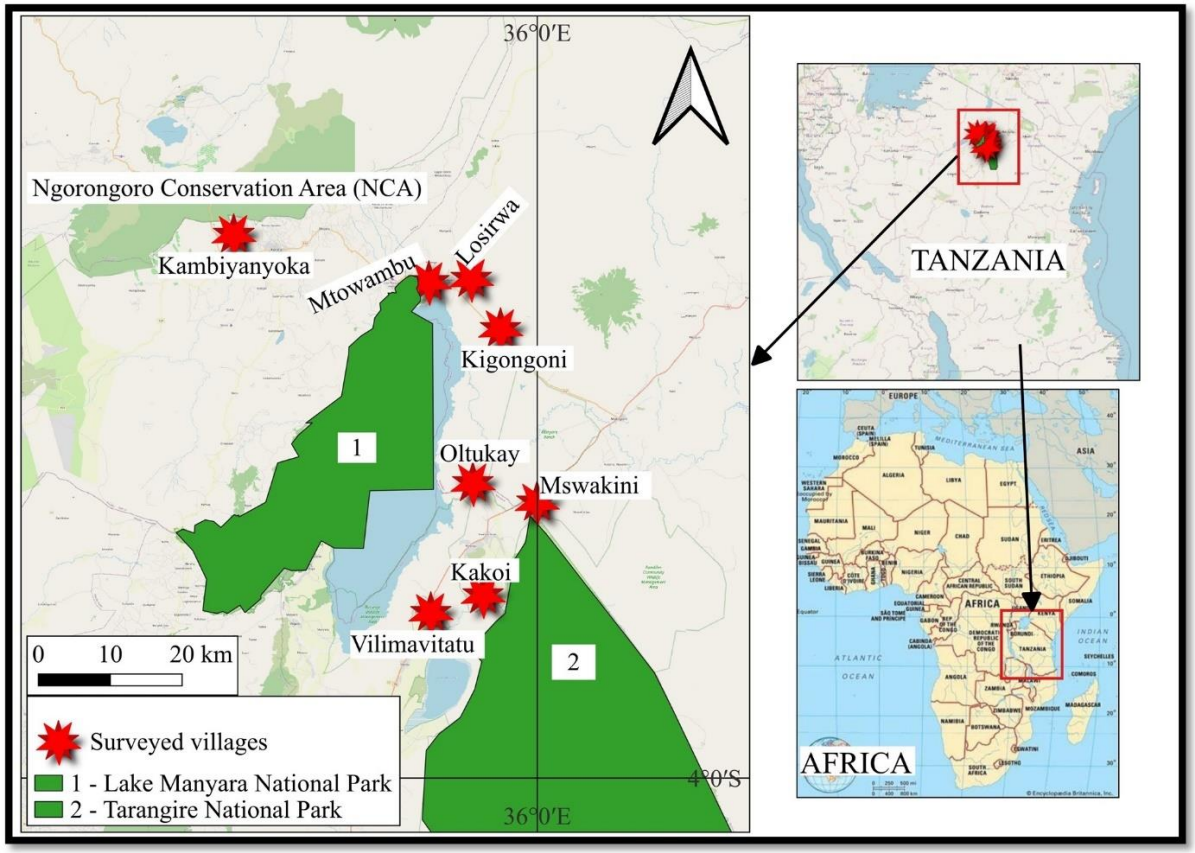
Materials and Methods

Study area

The Tarangire, Manyara, and Ngorongoro ecosystems are located in northern Tanzania (Figure 1) and are among the key World Heritage areas for conserving thousands of flora and fauna species. The Tarangire-Manyara ecosystem spans 16,521 square kilometers, with more than 60% located outside core protected areas, while the Ngorongoro Conservation Area covers approximately 8,292 square kilometers. These ecosystems feature diverse vegetation, including *Combretum*, *Dalbergia*, *Acacia*, and *Commiphora* woodlands, grasslands, and floodplains. *Themeda* grasslands dominate, along with species such as *Heteropogon*, *Sporobolus spicatus*, *Robustus* sp., *Marginatus* sp., *Cyperus laevigatus*, *Panicum* sp., *Hyparrhenia* sp., *Digitaria* sp., and *Pennisetum* sp. (Amiyo, 2006; Johnson and Ebersole, 2017; Prins, 1988).

Figure 1

Map of study area showing villages around Tarangire, Manyara and Ngorongoro conservation areas. Created by author using ArcGIS Desktop version 10.8.2, (2023)



Sample size for the study

The study used a cross-sectional design to gather data from communities around the Ngorongoro Conservation Area. Villages within the Ngorongoro ecosystem were randomly selected, and respondents were randomly chosen from each village, serving as the sampling units. This method resulted in a total sample size of 208 individuals, distributed across the following villages: Mdori (n=40), Magadini (n=15), Mto wa Mbu (n=30), Oloirobi (n=33), Kisutu (n=25), Loswira (n=15), Kambi ya Nyoka (n=10), and Vilima Vitatu (n=40). Participants were randomly selected from village residents who had lived in the area for at least three years, ensuring they were well-acquainted with the local ecosystem and the impacts of Invasive Alien Plant Species.

Questionnaire Administration and Data Collection

A semi-structured questionnaire was used during interviews to collect data from local communities. Respondents were randomly selected using a simple random sampling method among individuals aged 12 and above who were familiar with the local geography. The questionnaire was designed to assess community awareness of Invasive Alien Plant Species, including knowledge of affected areas, understanding of harmful effects, modes of transport, and uses of these species. It also explored community engagement in efforts to combat invasive species.

The questionnaire comprised 13 questions organized into four sections: Section I gathered

demographic information, including personal and location data; Section II assessed awareness of Invasive Alien Plant Species (IAPS), including affected areas, transport methods, and harmful effects; Section III explored the perceived value of invasive species; and Section IV evaluated community efforts to combat these species. The questionnaire featured both closed and open-ended questions, enabling respondents to express their opinions and rate their awareness levels on various aspects of IAPS. Additionally, there was a section focused on the demographic structure of the respondents, including gender, age, and education level.

Data processing and analysis

The analysis employed various statistical methods to examine respondents' perceptions of Invasive Alien Plant Species. Chi-square tests were used to compare response frequencies regarding the effects and control measures of Invasive Alien Plant Species. A Kolmogorov-Smirnov test was performed to determine whether the data followed a normal distribution, indicating if it was parametric or non-parametric. Descriptive statistics were also applied to summarize the data into meaningful information. All analyses were conducted using the Statistical package for social science (SPSS) version 28 software, with the significance level set at $\alpha<0.05$ to ensure robust findings.

Results

Community awareness on the presence of Invasive Alien Plant Species around the surroundings

Out of the 208 respondents interviewed, over 65% of community members were aware of the presence of selected Invasive Alien Plant Species. *Datura stramonium* and *Argemone mexicana* were the most recognized, with awareness levels at 83.7% and 82.7%, respectively. Other species, including *Dichrostachys cinerea, Parthenium hysterophorus, Gutenbergia cordifolia, Bidens schimperi, Prosopis africana,* and *Calotropis procera*, had awareness rates of 73.1%, 69.2%, 65.4%, 69.2%, 66.3%, and 70%, respectively. A chi-square statistical test revealed a significant difference ($p < 0.05$) between awareness and non-awareness of the presence of these species in the surrounding communities (Table 1).

Table 1

Community awareness on the presence of Invasive Alien Plant Species

Name of the species	Aware on the presence of AIS (%)	Non aware on the presence of AIS (%)	P- Value (Chi-Square) *at 95% CI, df=1*
Argomene mexicana	82.7	17.3	$p < 0.05$
Dichrostachys cinerea	73.1	16.9	$p < 0.05$
Datura stramonium	83.7	16.3	$p < 0.05$
Parthenium hystereophorus	69.2	30.8	$p < 0.05$
Gutenbejia codifolia	65.4	34.6	$p < 0.05$
Bidens schmperi	69.2	30.7	$p < 0.05$
Prosopis Africana	66.3	33.7	$p < 0.05$
Calotropis procera	70.2	29.8	$p < 0.05$
			$p < 0.05$
Total number of respondents			104
Normality Test (Kolmogorov- Simrnov) P- Value			$p < 0.001$

Awareness on the areas affected by Invasive alien species

Table 2 shows that out of the 208 respondents interviewed, 76.9% and 63.5% were aware that farms and grazing lands, respectively, are affected by Invasive Alien Plant Species. In contrast, 61.5% of respondents were unaware of whether national parks were impacted by Invasive Alien Plant Species. The data distribution was not normal, as indicated by a p-value of less than 0.05 (Kolmogorov-Smirnov test). Additionally, there was a significant variation in awareness regarding the impact of Invasive Alien Plant Species on parks, grazing lands, and farms ($p < 0.05$).

Table 2

Awareness on the areas that are affected by Invasive Alien Plant Species

Area affected	Aware on areas affected (%)	Not aware on the areas affected (%)	P-value Chi-Square) at 95% CI, df=1)
Within the park	38.5	61.5	*0.005*
Within grazing lands	63.5	36.5	*< 0.005*
Within farms	76.9	23.1	*0.009*
Along the roads	43.3	56.7	0.83
Normality Test P-Value- (Kolmogorov- Simirnov)		*< 0.001*	

Awareness on harmful effects of ***Invasive Alien Plant Species***

Of 208 respondents interviewed, 51.0% and 52.9% suggested that, Invasive Alien Plant Species are both poisonous and cause body itching respectively. However, most of community members didn't know whether Invasive Alien Plant Species cause local extinction of palatable forages (49 %), soil damage (55.8 %), bloating of animals (46.2%), death of animals (41.3%), attraction of vectors (71.2%) and attraction of predators (70.2%). (Table 3).

Table 3

Awareness on harmful effects of the selected Invasive Alien Plant Species

Area Affected	Effects	Percentage of awareness			
		Yes	No	Don't Know	P-value (Chi-Square) at 95% CI, df=2
Harmful effect to people	Poisonous	51.0	18.3	30.8	0.0008
	Body itching	52.9	14.4	32.7	< 0.0001
Harmful effect to environment					0.002
	Loss of indigenous species	48.1	12.5	39.4	
	Soil damage	20.2	24.0	55.8	0.001
	Extinction of palatable forages	32.7	18.3	49.0	0.003
					0.001
Harmful effect to animals	Bloating	31.7	22.1	46.2	< 0.005
	Death	36.5	22.1	41.3	0.002
	Attracts Vector	16.3	12.5	71.2	< 0.005
	Attract predators	18.3	11.5	70.2	0.0006
P- Value (One sample Kolmogorov Smirnov test)					0.0003

Awareness on means of transport of Invasive Alien Plant Species

A total of 208 individuals were interviewed, with 70.2%, 60.6%, 58.8%, and 58.7% identifying livestock, wind, people, and moving water, respectively, as agents of the spread of Invasive Alien Plant Species. Conversely, 78.8% of respondents were unaware of whether cars contribute to the spread of these species. The difference between those aware and not aware of the means of transport was statistically significant, with a p-value < 0.05 at a 95% confidence interval (Table 4).

Uses of Invasive Alien Plant Species

In the community, Invasive Alien Plant Species were associated with uses as 69.2% and 56.7% out of 104 individuals responded about using the selected **Invasive Alien Plant Species** for medicine and livestock feeding. In addition, 46.2% were aware about ecological use of the **Invasive Alien Plant Species** for pollination (Figure 2).

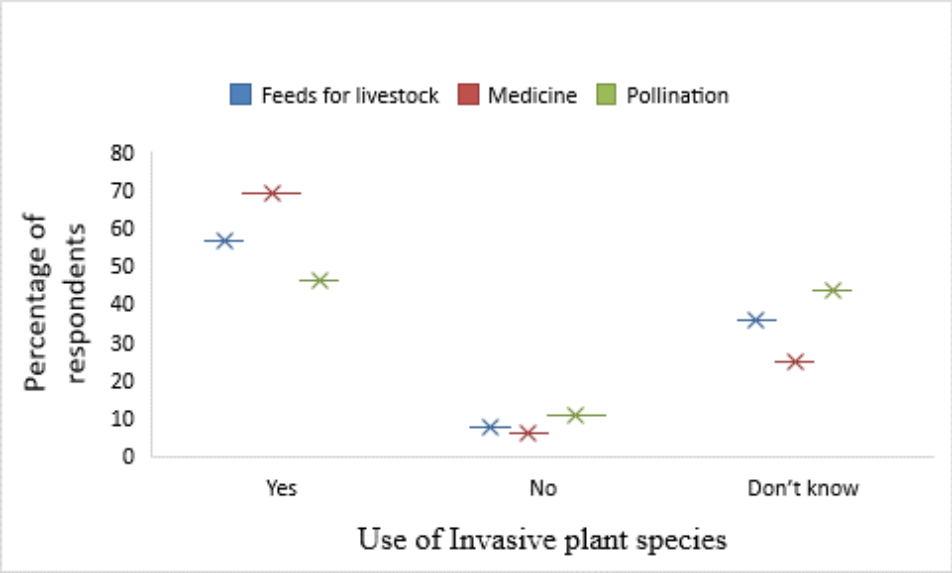
Table 4

Means of transport of Invasive Alien Plant Species

Means of transport	Awareness on means of transport (%)	No awareness on means of transport (%)	P-value (Chi-Square) at 95% CI, df=1
Transmission by cars	20.2	78.8	0.001
Transmission by livestock	70.2.	29.8	0.007
Transmission by people	55.8	44.2	0.01
Transmission by moving water	58.7	41.3	0.002
Transmission wind	60.6	39.4	0.0005
Normality test p-value- (kolmogorov- simirnov)			0.001

Figure 2

Community response on the use of invasive alien species in three ranks (Yes, No and don't know



Community engagement on combating Invasive Alien Plant Species

Community engagement in combating Invasive Alien Plant Species showed a significance difference P value < 0.05 (Table 5) as many individuals responded not engaged by either the responsible authorities or non-government authorities. Out of 208 individuals, 78.8% and 88.5 % are not directly involved by responsible authorities and other stakeholders respectively.

Table 5

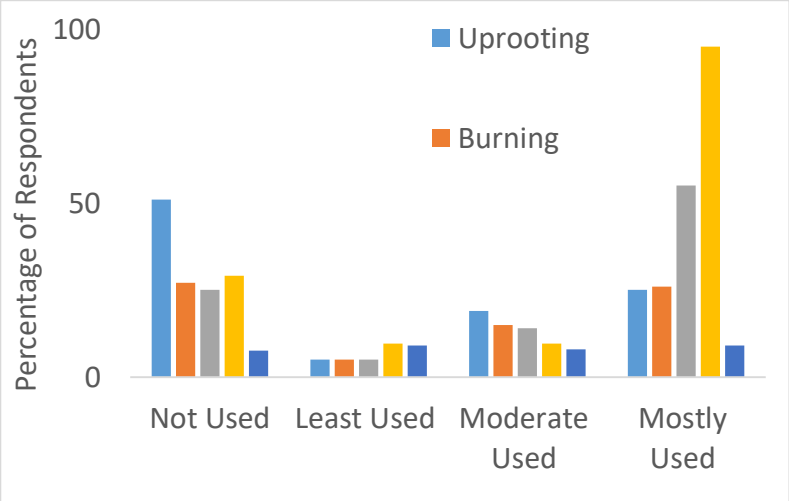
Community involvement on combating Invasive Alien Plant Species

Individuals	Responsible authorities	Other stakeholders
Percentage of individuals involved (%)	14.4	5.8
Percentage of individuals who didn't involve (%)	78.8	88.5
Percentage of individuals who didn't knew any involvement (%)	6.8	5.7
P-Value (Chi-square)	<0.001'	<0.001'

However, methods employed by community in combating the species were assessed (Figure 3), in which 54.8% and 51.9% views relied on the use of burning and cutting methods. While 95% and 75.2% of views relied on not using biological methods and chemical methods respectively.

Figure 3

Methods used by communities in combating invasive plant species



Discussion

The study assessed community awareness of Invasive Alien Plant Species (IAPS), focusing on their presence, the affected areas, and the means of their spread. It also examined the uses of these species and community engagement in efforts to combat them. The results indicate that the community is aware of the presence of selected IAPS in their vicinity, consistent with the findings of Namkeleja *et al*. (2014). The community showed a strong awareness of the impact of IAPS on farms and grazing lands, while awareness was lower regarding their presence along roads and in national parks. These findings align with those of Kanagwa (2020), who assessed 123 farmers and 128 pastoralists in the Mbuguni, Olasiti, Murieti, and Sepeko wards of the Arusha district, revealing community awareness of the presence of the *Parthenium hysterophorus* weed. The greater awareness of the impact on farms and grazing lands may be attributed to the higher frequency of human activities in these areas. In contrast, the lower awareness of IAPS in parks may be due to these areas being less frequently visited by surrounding communities, making the invasive species less visible or less concerning to them. This finding corresponds with a study by Macha and Kimaro (2019) which showed that rangelands around the Ngorongoro Conservation Area face threats from invasive plant species, impacting Maasai pastoralists' livestock and livelihoods, with 50% of pastoralists aware of and perceiving these species as harmful.

Given that the community is generally aware of the presence of Invasive Alien Plant Species (IAPS), several species were identified, including *Datura stramonium*, *Argemone mexicana*, *Dichrostachys cinerea*, *Parthenium hysterophorus*, *Gutenbergia cordifolia*, *Bidens schimperi*, *Prosopis africana*, and *Calotropis procera*. This aligns with the findings of a study by Runyoro *et al.* 2011 which identified *Datura stramonium*, *Argemone mexicana*, and *Nicandra phaseoloides* as some of the species present in the ecosystem. The study also highlighted that the majority of these species belonged to 43 plant families, with Fabaceae, Solanaceae, and Myrtaceae being the three most dominant families (Runyoro *et al.,* 2011). The knowledge of these species suggests a potential for targeted community-based management and eradication efforts. This awareness is crucial for developing effective strategies to combat the spread of IAPS and mitigate their impact on local ecosystems and livelihoods.

Community awareness and perceptions regarding the spread of Invasive Alien Plant Species (IAPS) indicated that human activities, livestock, moving water, and wind are among the primary agents of dispersion. Additionally, individuals are aware of the toxic and irritating effects of these species, although there is less awareness about their broader impacts, such as the loss of palatable plant species, soil degradation, attraction of disease vectors, bloating, and animal deaths. These findings are consistent with other studies that have reported low levels of awareness about IAPS and their effects on ecosystems (Cordier *et al.,* 2020; Keller *et al.,* 2011; Nkombe *et al.,* 2018; Pyšek *et al*., 2012). Similarly, Jubase *et al*. (2021) found that people in the Berg River Catchment in South Africa were largely unaware of invasive alien species and their environmental impacts. However, the Tanzania National Invasive Species Strategy and Action Plan (NISSAP) 2019-2029 (2019) has noted that communities around Serengeti National Park have reported concerns about the presence of Siam weeds, which displace palatable species for grazing animals. A lack of awareness can hinder effective management and control of IAPS, as community support and engagement are essential for the success of such management programs (Epanchin-Niell, 2017). Community awareness is a key pillar for the sustainable conservation of biodiversity resources and for addressing challenges that arise in biodiversity conservation efforts (Chebby *et al.,* 2024; Ngongolo *et al.,* 2019; Ngongolo and Kilonzo, 2022; Sigala *et al.,* 2021)

Moreover, communities around the Ngorongoro, Tarangire, and Manyara conservation areas associate certain Invasive Alien Plant Species (IAPS) with beneficial uses, such as medicinal purposes and livestock fodder. For instance, *Argemone mexicana* and *Parthenium hysterophorus* are used for treating skin inflammation, while a few respondents valued these species, including *Argemone mexicana* and *Calotropis procera*, for ornamental purposes and as goat fodder.

Similarly, Kumar *et al*. (2023) reported that communities in Mirzapur, India, utilized *Ipomoea carnea*, *Calotropis procera*, *Saccharum spontaneum*, and *Stylosanthes hamata* for medicine, fibers, fencing, fodder, and fuel. The use of these species might lead communities to prioritize their conservation for future use, which could negatively impact ecological conservation efforts. Additionally, a study in Dar es Salaam revealed that while *Leucaena leucocephala* is considered invasive in other areas, it can attract pollinators and provide fodder and firewood to local communities (Ngongolo *et al.,* 2014a; Ngongolo *et al.,* 2014b). Similarly, *Ageratum conyzoides* in Tanga was observed to have medicinal benefits for local communities (Ngongolo *et al.,* 2014c).

The findings also revealed limited community involvement in efforts to combat Invasive Alien Plant Species (IAPS). Respondents expressed that they were not adequately involved by responsible authorities or non-governmental organizations in combating these species. However, communities have their own mechanisms for managing IAPS, primarily using burning and cutting methods, while biological and chemical methods were not utilized. Despite the perceived lack of engagement, the Tanzanian government has initiated various programs to address IAPS, such as the National Forest Resources Monitoring and Assessment Program (MNRT, 2015), educational initiatives like the "Malihai Clubs," which are present in about 1,687 primary and secondary schools in Tanzania (URT, 2012), and the National Invasive Species Strategy and Action Plan 2019-2029 (NISSAP, 2019). Additionally, the Ministry of Natural Resources and Tourism has implemented the National Forest Policy Implementation Strategy, which includes a commitment in section 4.2 (xiii) to reduce IAPS by 60% in affected natural forests by 2031 (URT, 2021). Giovos *et al*. (2019) emphasized that involving communities in combating IAPS is crucial for environmental sustainability and for addressing the social challenges posed by these species. A bottom-up approach in conservation fosters a sense of ownership over the problems associated with invasive species, thereby increasing public support for management actions.

Conclusion

This study reveals a significant gap in community awareness concerning the impacts, spread, and management of invasive alien plant species (IAPS). While the community recognizes the presence and harmful effects of certain IAPS, there is limited engagement in active management and control efforts. Enhancing community education on the ecological and economic impacts of IAPS is vital for more effective management strategies. A collaborative approach that integrates local knowledge with broader conservation efforts is crucial to safeguard biodiversity and promote ecosystem sustainability.

Recommendations

To address the identified gaps, it is recommended to develop targeted educational awareness programs to close existing knowledge gaps and increase local engagement. Fostering cooperation between community groups, conservation organizations, and policymakers will be critical in driving eradication efforts. Additionally, exploring policies and regulations that support proactive prevention and management measures is necessary. Future research should focus on larger-scale surveys, alternative uses of invasive species, community engagement incentives, and identifying barriers to achieving higher awareness levels.

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