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Research Article

Human–Wildlife Conflict Dynamics and Conservation Challenges in Gullele Botanic Garden, Ethiopia

Yihew B. Woldegiorgis,[1] **Mekbib M. Yimberber**,[1] **and Zelalem T. Assaye**[2]

[1]*Gullele Botanic Garden, P.O. Box 153/1029, Addis Ababa, Ethiopia*
[2]*Ethiopian Biodiversity Institute, P.O. Box 30726, Addis Ababa, Ethiopia*

Correspondence should be addressed to Yihew B. Woldegiorgis; asse.biru@gmail.com

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Human–wildlife conflict (HWC) commonly arises in areas where human settlements and wildlife habitats intersect, particularly around the border of conservation zones. This study assessed the status of HWC, in Gullele Botanic Garden (GBG), Ethiopia. We conducted 120 questionnaire interviews with selected employees of the garden; moreover, focus group discussions, key informant interviews, and observations were also used during data collection. Nearly 70% of the respondents confirmed the existence of severe HWC in the garden. Statistically significant variation was recorded among respondents about severity ($\chi^2 = 14.79$, df = 2, and $p \leq 0.05$) of the conflict. Our findings indicated that most of the conflicts occurred at night (75.8%) and during the dry season (40%). Warthog (25%), porcupine (20%), and hyena (18%) were reported as the top three wild animals involved in HWC. Feeding on planted seedlings (38.6%), damage to prepared seedlings in the nursery sites (21.7%), and destruction to infrastructure (18.1%) were the three principal causes of the conflict. A total of 26,406 USD per annum is lost due to HWC. Awareness creation campaigns, construction of nature-based live fences, and application of mechanical rodent management technologies should be applied as HWC mitigation strategies in the garden.

Keywords: conflict; conservation; economic loss; mitigation strategies

1. Introduction

Continuous human population growth and the increasing demands for new resources result in destruction and transformation of natural habitats which negatively affects various ecosystem and the services they provide [1]. The rapid expansion of urban areas is expected to persist, further transforming global environments and having profound consequences on biodiversity [2]. Even though urbanization generally reduces species diversity and leads to homogenization, there is evidence suggesting that urban ecosystems can offer valuable habitats for several wildlife species that exhibit plasticity and adaptability to specific urban and suburban conditions [3].

Wildlife has existed in urban areas since humans lived [4] and has interacted frequently with humans. Thus, the city would no longer exist solely to meet the demands of humans but also to serve as home to a largely abundant native flora and fauna, highlighting the need for finding ways for people and wildlife to coexist [5]. Hence, how wildlife species use urban areas, and how they utilize the available resources, has a profound impact on human–wildlife interactions [4]. The habituation of wildlife to humans and urban environments leads to a growing number of wild animals that show little or no fear of humans, which consequently increases human–wildlife conflict (HWC) [6].

HWC often arises when wild animals damage crops, poultry, livestock, framed game, and fisheries and jeopardize human safety [7–9]. Such incidents frequently lead to the intentional persecution of conservation priority species, both within and beyond the boundaries of protected areas (PAs) [10]. Although livestock predation and crop raiding are the primary drivers of HWC in developing countries, the

severity and nature of these conflicts vary across regions, depending on the species involved and the types of crops cultivated [11]. Due to subsistence livelihood, many of the people in developing countries are exerting pressure on wildlife populations. To this end, a reliable identification of problem animals and effective governance over damage-causing animal control are required for effective HWC mitigation.

Gullele Botanic Garden (GBG) is a unique urban ecosystem in Addis Ababa established for conservation, research, environmental education, and provisioning of nature-based ecotourism services [12]. The garden is home for enormous plant species and wildlife with significant national and international conservation value. The dominant flora of the garden includes *Juniperus* (*Juniperus procera*), Ethiopian rose (*Rosa abyssinica*), *Maytenus* (*Maytenus arbutifolia*), *Myrsine africana*, *Maytenus* (*Maytenus addat*), and *Olinia* (*Olinia rochetiana*) ([13, 14]).

Besides, GBG is home for diverse wild animal species. Notable mammals include Menelik's bushbuck (*Tragelaphus scriptus meneliki*), warthog (*Phacochoerus africanus*), crested porcupine (*Hystrix cristata*), bush duiker (*Sylvicapra grimmia*), African civet (*Civettictis civetta*), leopard (*Panthera pardus*), and spotted hyena (*Crocuta crocuta*) (Correspondent author unpublished data, 2024). Additionally, 95 bird species have been recorded, with flagship species such as the Abyssinian catbird (*Sylvia galinieri*), Abyssinian slaty flycatcher (*Melaenornis chocolatinus*), black-winged lovebird (*Agapornis taranta*), and Ethiopian boubou (*Laniarius aethiopicus*) (Correspondent author unpublished data, 2024). The garden also harbors rich herpetofauna and insect diversity, which calls for further intensive expeditions. Due to its exceptional biological, ecological, and topographic diversity, GBG attracts approximately 200,000 local and international visitors annually. Furthermore, it serves as an outdoor classroom, providing practical environmental education to nearly 30,000 students each year [15].

Due to the higher biological diversity, there exist frequent HWC incidences affecting the conservation and research efforts of the garden. Unlike many PAs, GBG experiences a unique challenge: a tension between conservation goals and development endeavors. For instance, plant conservation activities require the establishment of nursery sites and thematic gardens for propagating indigenous, endemic, endangered, and economically important species. Meanwhile, ecotourism development involves constructing different recreational infrastructures to accommodate visitors. These activities inadvertently attract wildlife by providing shelter and easily accessible food, leading to increased interactions between animals and garden staff. As a result, conflicts between wildlife and GBG employees have become a recurring issue, complicating both conservation and operational activities.

The most frequently reported conflict involved damage to plants in thematic gardens and nursery sites, as well as destruction of infrastructures. These incidents have led to significant biological and economic losses, highlighting the urgent need for systematic conflict management strategies. Effective HWC mitigation remains a critical conservation priority to ensure sustainable human–wildlife coexistence in the garden. Despite its importance, the nature and intensity of HWC in GBG have not been thoroughly investigated. Therefore, this study was designed (1) to assess the nature, trend, and major causes of HWC, (2) to identify the main wild animals involved in the conflict, (3) to assess the economic losses happened due to wild animal damage, and (4) to identify the major mitigation measures taken by the employees, in GBG, Addis Ababa, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area. GBG is located in 38.688902 West, 38.738727 East, 9.095127 North, and 9.063120 South coordinates in North Addis Ababa, with an altitude range of 2575 and 3000 m a.s.l (Figure 1). The garden is home to riverine vegetation and remnants of indigenous trees of the city. The greater part of the garden is covered by *Juniperus procera* tree species, but the land closer to the river banks and inaccessible areas are covered by different trees, shrubs, herbs, climbers, and fern species [12], whereas peak points of the garden are dominated by *Erica arborea* and *Helichrysum* species [14]. The mean annual minimum and maximum temperature of the garden is 7.5 and 20.7°C, respectively. The annual average precipitation of the garden is 1215.4 mm [12]. Such physiographic and climatic variations provided suitable habitats for diverse group of wild animals found in and around the garden. The garden was established in November 2009 with a total area of 705 ha [12].

2.2. Sampling Design. Employees of GBG were first purposively stratified based on their working responsibilities into two main groups: temporary site workers ($n = 400$) including those in horticulture nursery, research nursery, horticulture beautification, and horticulture biodiversity conservation and permanent staff ($n = 182$). From the temporary site workers, 120 individuals were systematically selected for the survey (considering factors such as work experience and gender representatives). Additionally, 45 experienced site workers (22 from permanent staff and 23 from temporary staff) were selected to participate in the focus group discussion (FGD). Furthermore, 15 skilled senior permanent employees with in-depth knowledge of conflict situation in the garden were selected as key informants. A total of six FGDs were held, with group size from 6 to 12 participants with an average of 7 individual per group, hence a total of 45 individuals (18 male and 27 female). In total, 180 individuals (approximately 31% of GBG's employees, $N = 582$) were included in the data collection process.

2.3. Data Collection Methods. Data on HWC were collected between September 2023 and February 2024 using a combination of data collection methods, including interview-administered questionnaires, FGDs, key informant interviews (KIIs), and field observations. The structured

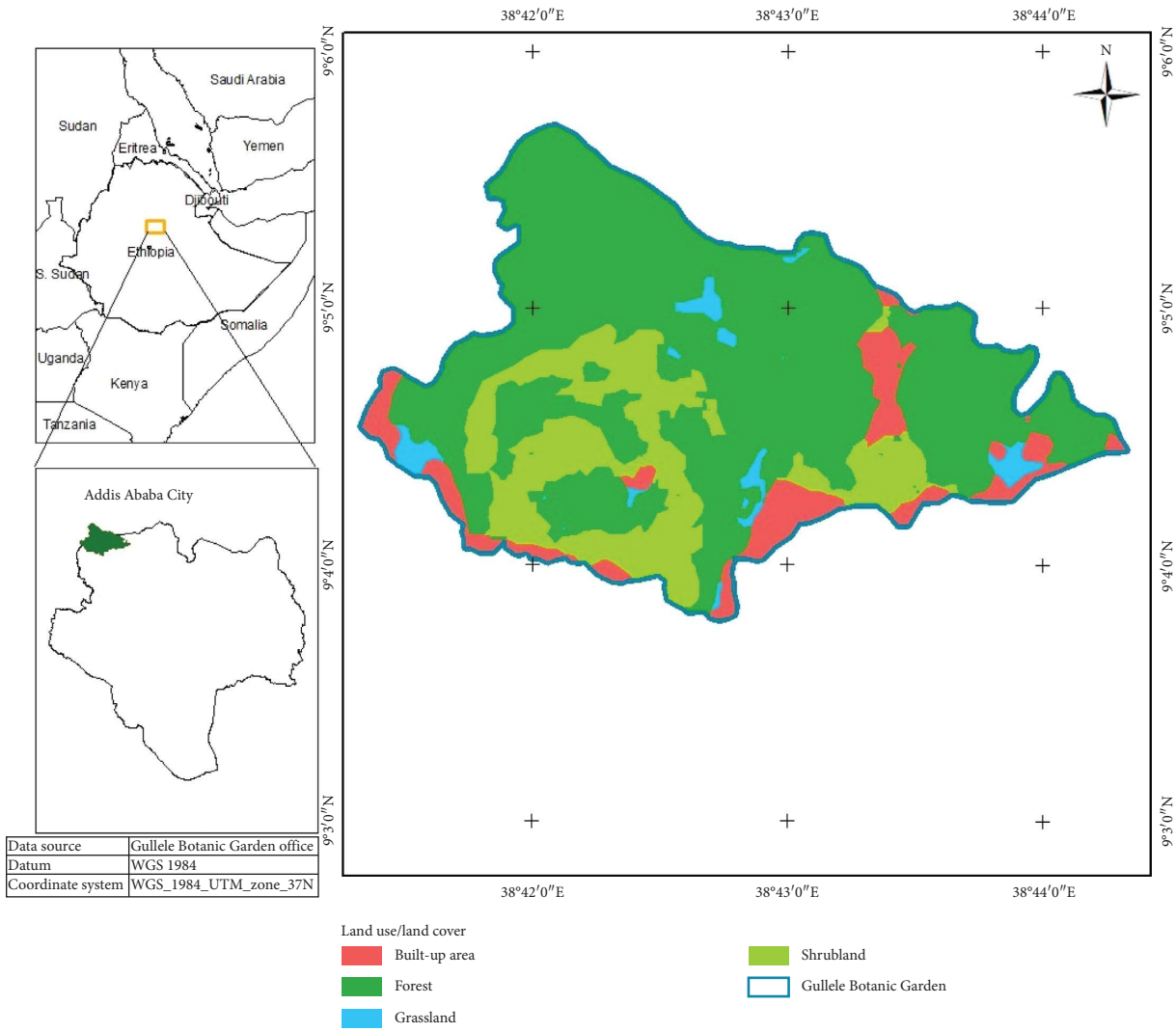

Figure 1: Map of Ethiopia showing Gullele Botanic Garden.

questionnaire survey was designed to acquire comprehensive information on respondents' profiles, perceived role of the garden, causes and seasonal pattern of HWC, types of damage, commonly involved wild animal species, preferably affected plant species, estimated annual economic losses, employees attitude toward wildlife, and suggested mitigation measures. Participants for FGDs were systematically selected from experienced employees working at different sites within the garden. Discussion topics included were perceptions of wildlife importance, extent and cause of damage, economic losses, human impacts, and potential mitigation measures.

Key informants included senior experts, directorate directors, and team leaders from both core and administrative units, selected for their overarching knowledge of the garden's operations and developments. The KII guide questions focused on understanding the broader impact of HWC on the garden's conservation efforts. All the questions were prepared in English, translated into Amharic local language, and administered through individual interview by the researcher.

2.4. Data Analysis. SPSS software Version 28 was used to analyze data. Descriptive statistics such as mean comparisons, percentages, and frequency were used to summarize socioeconomic characteristics of respondents. To examine responses related to wildlife species responsible for damage, associated economic losses, and the nature and extent of the conflict, cross-tabulations, Pearson's chi-square (χ^2) tests, and post hoc mean comparisons were employed. Conflict management options suggested by respondents were analyzed using the ranking index (RI) method adopted from [16]. In this approach, the RI for a given strategy was calculated by dividing the total number of citations for that strategy by the sum citations for all strategy mentioned. A significant level of p value < 0.05 was used to determine statistical significance.

2.5. Respondents' Profile. Out of the 120 respondents, 83% ($n = 100$) were women and 17% ($n = 20$) men. The ages of the respondents ranged from 18 to > 65 with mean of 37 years (Table 1). Thirty-six percent ($n = 43$) of the respondents do not have formal education, and 43% ($n = 51$) attended primary education, whereas 21% ($n = 26$) attended secondary school. The majority (51.7%) had less than 5 years of work experience while 27.5% had up to 10 years, whereas 20.8% had experience since establishment of the garden.

3. Results

3.1. Wildlife Population Trends in GBG. When asked about trends in wildlife population, 78.3% of respondents ($n = 94$) reported that most animal populations have increased in recent years. In contrast, 12.5% ($n = 15$) reported a decline, while 5% ($n = 6$) were uncertain about the wildlife population status, and a small portion, 4.1% ($n = 5$), believed that wildlife population have remained stable in the garden. Overall, employees' perceptions of wildlife population trends at GBG showed statistically significant differences ($\chi^2 = 26.57$, df = 3, and $p \leq 0.05$).

3.2. Respondents' Perceived Reasons for the Purpose of Wildlife Conservation in the Garden. All surveyed respondents acknowledged the importance of wildlife conservation in GBG for various reasons: (1): ecotourism value (59%; $n = 74$), (2) recognition of wildlife as God's creatures (17%; $n = 22$), ecological significance (14%; $n = 18$), ethnozoological importance (6%), and as a sources of bush meat (4%) (Figure 2).

3.3. Trends of HWC in GBG. Out of the 120 respondents, 76.7% ($n = 92$) perceived HWC increasing followed by 17.5% ($n = 21$) who reported a decreasing trend. A small proportion (5.8%; $n = 7$) claimed that they had no knowledge on HWC trend in the garden (Figure 3). The perception of HWC trend varied significantly among the study participants ($\chi^2 = 36.42$, df = 3, and $p \leq 0.05$).

3.4. Causes of HWC in GBG. Based on respondents and field observations, the major causes of HWC in GBG were as follows: wild animals feeding on planted seedlings (38%; $n = 64$), destruction of prepared seedlings in the nursery sites (21%; $n = 36$), damage to infrastructure especially water pipelines (18%; $n = 30$) (Figure 4), and destruction of stored seeds (12%; $n = 20$) as well as human attacks (9%; $n = 16$) (Table 2). There was no statistically significant difference in the perceived causes of HWC among GBG employees ($\chi^2 = 2.35$, df = 3, and $p \geq 0.05$).

3.5. Time and Season of HWC in GBG. Among the respondents, 75.8% reported that most wildlife-related damage occurred during the night, followed by 15.8% who indicated day-time incidents. Additionally, 8.4% reported that the conflict occurred both during the day and at night. The level of damage differed significantly with the time of the day ($\chi^2 = 24.78$, df = 1, and $P \leq 0.05$). Regarding the seasonal occurrence of conflict, 40% ($n = 48$) of the respondents replied that most incidents occurred during the dry season, whereas 34% ($n = 41$) identified the rainy season as the peak period. Meanwhile, 26% ($n = 31$) indicated that HWC occurs throughout the year without noticeable seasonal variations (Figure 5).

3.6. The Status of HWC in GBG. The survey respondents reported the severity of HWC as a severe (70%; $n = 84$) and as a moderate (26.7%; $n = 32$) problem, whereas only a few of the respondents (3.3%; $n = 4$) stated that HWC is not considered as a problem in the garden (Figure 6). The views of the respondents about the status of HWC were statistically significant ($\chi^2 = 14.79$, df = 2, and $p \leq 0.05$).

3.7. Rank of Wild Animals Involved in HWC in GBG. In terms of species involved in HWC, a total of six (6) wild animal species were identified by respondents as "conflict species" in the garden. Among these, the warthog (*Phacochoerus africanus*) received the highest ranking, reported by 25% of respondents ($n = 87$) followed by the porcupine (*Hystrix cristata*) at 20% ($n = 71$), and spotted hyena (*Crocuta crocuta*) at 18% ($n = 64$). Rodents were ranked by comparatively fewer respondents, accounting for only 10% ($n = 34$) (Figure 7). Statistical analysis revealed a significant variation in respondents' perception regarding the wild animal involved in the conflict ($\chi^2 = 25.18$, df = 5, and $p \leq 0.05$).

3.8. Rank of Frequently Damaged Plant Species. Concerning the dominant plants affected by wild animals, *Millettia*, *Ensete*, and different flowers planted for ornamental purposes were ranked on the first three top positions, while the least cited species is *Juniperus* (Table 3).

3.9. Estimated Economic Loss due to HWC. As shown in Table 4, the total annual estimated loss due to HWC in GBG is nearly 26,604 USD. There was a significant difference on the economic loss due to problematic animals among respondent groups ($F = 6.84$, df = 3, and $p \leq 0.05$). The highest loss is reported from research nursery (7320.60), while the lowest loss (5664.75) is verified by horticulture biodiversity conservation workers.

3.10. HWC Mitigation Measures in GBG. In this study, GBG employees used various HWC mitigation strategies to keep susceptible areas of the garden against conflict-causing wild animals (Table 5). Physical barrier such as fencing, guarding, and frustrating stimuli like the use of scarecrows were commonly used interventions with the RI of 0.4, 0.34, and 0.26, respectively.

4. Discussion

The study revealed an increasing trend in wild animal populations in the GBG. A significant factor contributing to this rise appears to be the replacement of former eucalyptus

Table 1: General profile of survey respondents in Gullele Botanic Garden.

Variables	Working areas				Total
	RN	HN	HB	HBC	
Number of respondents	30	30	30	30	120
Mean age	37.3	37.7	34.8	39.2	
Male	5	3	4	8	20
Female	25	27	26	22	100
Educational status					
No formal education	12	9	10	12	43
Primary education	14	13	13	11	51
Secondary education	4	8	7	7	26
Work experience in Gullele Botanic Garden					
≤ 5 years	19	10	21	12	62
Between 5 and 10 years	7	11	3	12	33
> 10 years	4	9	6	6	25

Abbreviations: HB, Horticulture Beautification; HBC, Horticulture Biodiversity Conservation; HN, Horticulture Nursery; RN, Research Nursery.

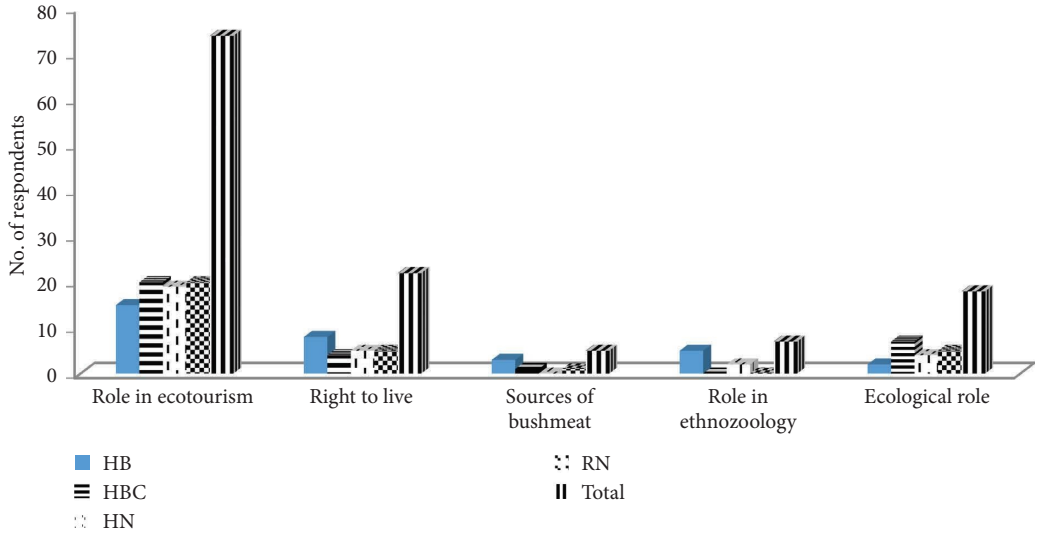

Figure 2: Reason of wildlife conservation in Gullele Botanic Garden.

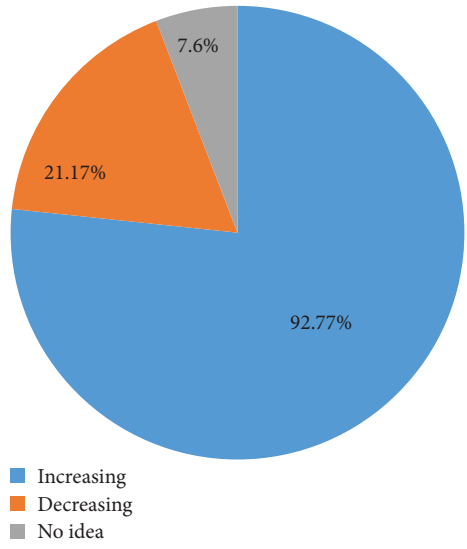

Figure 3: Human–wildlife conflict trends in Gullele Botanic Garden.

(a) (b) (c) (d)

Figure 4: Effect of problematic animals in Gullele Botanic Garden: (a) uprooted *Ensete* by warthog, (b) destruction of prepared seedling by hyena, and (c, d) chewed and broken water pipelines by hyena.

Table 2: Causes of human–wildlife conflict in Gullele Botanic Garden.

Causes of HWC	Destruction of seedlings in the nursery site	Feeding on planted seedlings	Damage to infrastructure	Feeding on stored seeds	Human attacks
HB	0	22	9	0	5
HBC	7	19	8	0	10
HN	16	11	5	8	0
RN	13	12	8	12	1
Total	36	64	30	20	16
%	21.7	38.6	18.1	12.0	9.6

plantation with indigenous tree species, which has improved habitat quality and made the area more suitable for wildlife. Effective habitat management is essential for meeting the ecological requirements of wildlife populations, highlighting the important role urban ecosystems can play in supporting biodiversity and contributing to wildlife conservation efforts [17, 18]. The respondents acknowledged the existence of wildlife in GBG due to their role in tourist attraction, research, traditional medicine, and cultural significance [19–22]. The positive perceptions suggest promising implications for the long-term sustainability of wildlife conservation initiatives in the garden.

The findings indicate that HWC in GBG is increasing, which may be attributed to the increasing wildlife population resulting from improved habitat suitability in the garden. Higher wildlife populations in gardens and PAs have led to higher incidence of HWC in different areas of the country [23, 24]. As wildlife populations in PAs grow, their demand for ecological resources intensifies, often overlapping with the resource requirements and development activities of local communities [23]. According to the result, the primary cause of HWC in GBG included the loss of planted seedling due to herbivory and infrastructure damage by carnivores; additionally, a few incidents of human injury with snake bites were also reported. These causes of conflict are consistent with findings from other similar studies [24–26].

Similar to previous HWC studies, majority of the plant and property damage was reported during the night [27], which could be related to the nocturnal nature of most

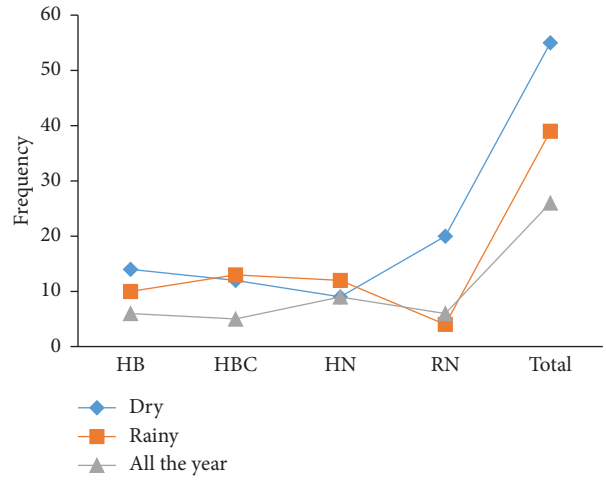

Figure 5: Frequency of human–wildlife conflict across seasons in Gullele Botanic Garden.

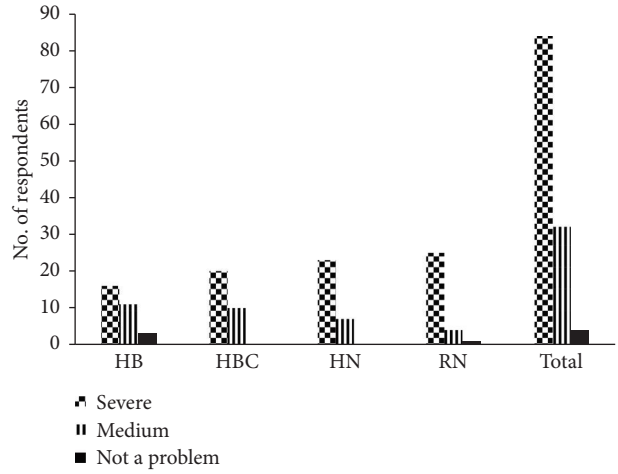

Figure 6: The status of human–wildlife conflict in Gullele Botanic Garden.

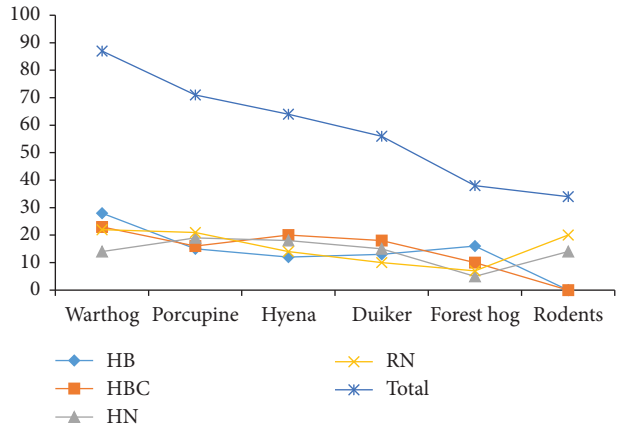

Figure 7: Rank of problematic animals in Gullele Botanic Garden.

Table 3: Rank of plant species affected by problematic animals in Gullele Botanic Garden.

Rank of plant spp.	*Ensete ventricosum*	*Grass* spp., in lawn	*Millettia ferruginea*	Ornamental flowers	*Olea europaea*	*Juniperus procera*	Vegetables
HB	3	27	0	27	0	0	2
HBC	4	0	24	2	20	5	1
HN	5	1	8	0	10	12	8
RN	23	1	7	4	0	9	18
Total	35	29	39	33	30	26	29
%	15.8	13.1	17.6	15	13.6	11.8	13.1

Table 4: Economic loss due to human–wildlife conflict in Gullele Botanic Garden.

Working areas	Annual estimated loss $
HB	6797.70
HBC	6623.40
HN	5664.75
RN	7320.60
Total	26,406.45
Mean ± SD	6601.61 ± 691.27

conflict involved animals like porcupines and hyena; even warthogs were also observed grazing and uprooting flowers around dusk where human activities decrease in the garden (Figure 8) while most of the conflict occurred during the dry season where food and water access is insufficient, which is in agreement with previous HWC studies elsewhere in Ethiopia [27, 28].

Participants in the group discussants confirmed that HWC is more severe during the dry season, a period characterized by limited availability of water and palatable food sources within wildlife habitats compared to the rainy seasons. Similar patterns have been reported in conservations areas across Africa, including Ethiopia [29]. In some cases, increasing wildlife populations resulting from successful conservation efforts can lead to heightened competition for natural resources between human and wild animals. This overlap in resource use may intensify conflict between both parties [30]. In this study, most of the respondents perceived the severity of HWC in GBG as high, involving a range of losses including damage to plants and infrastructure. Similarly, in areas with diverse wildlife species coexisting with human settlements, the severity of HWC has also been reported to be significant [31, 32].

The study identified warthog, porcupine, hyena, duiker, forest hog, and rodents as the major wildlife species involved in HWC. Among these, warthogs, porcupines, and hyenas were the most frequently reported in conflict incidents. Similar findings have been reported in Banja Woreda, Awi Zone [33], and the Wondo Genet district [34] in Ethiopia. Additionally, bush duiker and forest hog have been documented as conflict species in various studies conducted across Africa and Ethiopia [35–37]. In the current study, rodents and termites were also recorded as significant contributors to HWC. This might be attributed to the specific nature of the study area, which involves plant propagation and plantation activities. Stored seeds and the roots of seedlings are particularly vulnerable to damage by rodents and termites, respectively. Notably, *Millettia*, *Ensete*, and various ornamental flowers planted for conservation, research, and esthetic purposes were preferentially damaged. Consistent with these finding, *Ensete* has also been reported as a target species for wildlife damage around Midre-Kebid Abo Monastery, Southern Ethiopia [38], and around Amba Forest areas of Gurage Zone [37]. Numerous studies have confirmed the preferential damage of these plant species in various conservation areas and adjacent agricultural lands, likely due to their high nutritional value and palatability [36–38].

Our study revealed an estimated loss of 1,515,000 Ethiopian Birr (approximately 26,376 USD) due to HWC in GBG. Such financial estimations were reported around agricultural fields where there are frequent cases of HWC. As reported in [39], significantly higher economic loss was recorded due to HWC in Lupande Game Management Area, Zambia. For instance, 16,000 Birr (355 USD) for *Ensete* and 23,520 Birr (522 USD) for maize were recorded due to conflict animals around Midre-Kebid Monastery, Ethiopia [38]. Relatively higher economic loss estimation by the research nursery and horticulture beautification team could be associated with their closer experience and understanding on the overall efforts invested during collection of plant materials and the management activities during multiplication and propagation steps in the nursery sites.

Physical barriers such as fencing (Figure 9), active guarding, chasing, and the use of fear-inducing stimuli were the main mitigation strategies employed to minimize HWC in GBG. Consistent with the present findings, local communities in different parts of Ethiopia have also adopted different mitigation measures simultaneously to protect their properties from conflict species [37, 39]. A notable and unique approach reported by the garden employees in the study was the use of rodenticides to prevent seed damage by rodents. Similar practices have been observed among farmers in agricultural regions [26, 29].

However, the application of rodenticides poses ecological risks, potentially harming nontarget species that prey on poisoned rodents within the food chain. Despite the relatively higher economic losses reported in this study compared to earlier findings in Ethiopia [30], most respondents maintained a positive attitude toward wildlife. This could be related to the fact that the losses primarily impact the

Table 5: Human–wildlife conflict mitigation strategies used by Gullele Botanic Garden employees.

Conflict management actions	Guarding (%)	Scarecrows (%)	Fencing (%)	Total
Frequency	100	80	118	298
Ranking index	0.34	0.26	0.4	1

Figure 8: Herds of warthog grazing in lawn, Gullele Botanic Garden.

Figure 9: Fencing individual seedlings in Gullele Botanic Garden to increase survival rate of planted seedlings.

organization, not the individuals directly. Such positive perceptions present an opportunity to integrate wildlife conservation initiatives with the garden's ongoing plant conservation efforts.

5. Conclusions

Based on the findings, we can conclude that the status of HWC in GBG is severe which calls for on board feasible conflict mitigation measures. The severity of the conflict is attributed to the significant financial and infrastructural losses due to conflict animals. Wild animals were observed digging and uprooting, grazing, and browsing of important plants having enormous conservation and economic values. Occasional human attacks, damage to water pipelines, destruction of prepared seedlings in nursery sites, and putrefaction of stored seeds collected for research and propagation purposes were also reported. In order to minimize the increasing HWC incidents in the garden, use of durable live fences especially around nursery sites and thematic gardens should be strengthened. Fencing of individual plants especially on the time of plantation in the rainy season will also help to discourage early loss of seedlings due to browsers. Planting of palatable browse plants in buffer zones will be essential, and use of underground installation of water pipelines having better durability is also recommended. More significantly, use of rodenticides in the garden should be stopped and other mechanical control measures should be applied to control rodents to an acceptable level. Use of personal protective equipment should be habituated during the fieldwork to minimize risk of snake bites. Awareness training campaigns should be given regularly for the GBG employees to achieve sustainable wildlife conservation goals and enhance ecotourism and practical environmental education services provided by the garden. However, lack of HWC studies inside botanic gardens limited better discussion of our findings; therefore, such studies should be conducted in

different botanic gardens of the country and across regions at large.

Data Availability Statement

The data used for the study are available from the corresponding author upon request.

Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Conceptualization, methodology, and validation, Yihew B. Woldegiorgis; software, Yihew B. Woldegiorgis; formal analysis and investigation, Yihew B. Woldegiorgis, Mekbib M. Yimberber, and Zelalem T. Assaye; data curation, Yihew B. Woldegiorgis and Mekbib M. Yimberber; writing – original draft preparation, Yihew B. Woldegiorgis; writing – review and editing, Yihew B. Woldegiorgis, Mekbib M. Yimberber, and Zelalem T. Assaye; and visualization, Yihew B. Woldegiorgis. All authors have read and agreed to the published version of the manuscript.

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