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Spatial distribution and anthropogenic threats facing medicinal plant *Zanthoxylum chalybeum* in Simanjiro Area, Northern Tanzania.

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ABSTRACT

Knob wood (*Zanthoxylum chalybeum* - Rutaceae) is a medicinal plant species subject to heavy exploitation throughout its areas of occurrence in Sub-Saharan Africa. Despite that the tree has different values as a traditional herb, there is a gap in understanding its current distribution and anthropogenic threats in its range areas. This study aimed at mapping the distribution and anthropogenic threats facing *Z. chalybeum* tree in different land uses of Simanjiro area, northern Tanzania. The rates of threats such as debarking, branch cutting, uprooting and harvesting were observed to be high in grazing lands (GL) and farmlands (FL) (73% and 62% respectively) while least threats were observed in game controlled areas (GCA) and game open areas (OA) (39% and 40% respectively). Majority of trees observed had signs of debarking (51%) followed by debarking and branch cutting (20.6%), debarking and uprooting, (15.8%), debarking, branch cutting and uprooting (4.76%), whole tree cutting (4.76%) and branch cutting (3.17%). Conservation areas (i.e. hunting blocks within game controlled areas and game open areas) were found to have higher abundance of *Z. chalybeum* with detectable distribution pattern than other locations in Simanjiro area. The current observation in this study also shows that the rates of harvesting are increasing and harvesting methods used by community members are unsustainable. Regulatory approaches that promote sustainable harvesting of the species should be developed and implemented to reduce the impacts of over harvesting of the species on its population persistence. Promotion of cultivation and conservation of the species in farmland would help reduce the harvesting pressures in protected areas while providing access by the local community in their farms.

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1.0. Introduction

Medicinal plants are plants that contain compounds beneficial for both human and animal health [41]. Savanna ecosystems have been reported to be rich in biodiversity whereby 71% of vegetation within these ecosystems is the sourcing of medicinal products [11]. One of the important medicinal plants in Tanzania includes *Zanthoxylum chalybeum* commonly known as 'Oloisuki' and 'Mkunungu' in Maasai and Swahili respectively. *Zanthoxylum chalybeum* (Rutaceae) is a deciduous spiny shrub or tree in Eastern Africa which can grow up to 12 m long. The tree is native to Burundi, Congo, Tanzania, Democratic Republic of Congo, Uganda, Zambia, Zimbabwe, Malawi, Kenya, Ethiopia, Namibia and South Africa [14].

Zanthoxylum chalybeum has been reported as an important medicinal plant for malaria treatment, fever, cough, headaches, chest pain, digestive illnesses (e.g. ulcers), diabetes and toothache [2,17,23]. The effectiveness of *Z. chalybeum* as an herbal medicine has been associated with the presence of bioactive compounds alkaloids (tembetarine; nitidine and skimmianine) which have been known as Anti-malaria secondary metabolites [40]. Benzophenanthridine alkaloids; chelerythrine and nitidine within root barks of *Z. chalybeum* have been effectively used as anti-inflammatory activities [19]. Other bioactive compounds reported to be found in *Z. chalybeum* are flavonoids, terpenoids, saponins, tannins, phenols and glycosides [4].

Distribution of *Z. chalybeum* as most woody medicinal plant species has been reported to be influenced not only by anthropogenic factors [35] but also by resource availability (water, nutrients) and disturbance regimes (fire, herbivory). Recently, *Z. chalybeum* has been reported in Tanzania as one of the medicinal plants that are under threat of local extinction due to excessive exploitation [22] and thus needs immediate conservation efforts [23]. Within the IUCN Red List of Threatened Species, *Z. chalybeum* is categorized as the least concerned species and with a stable population [13]. However, in Simanjiro area, the species is in the risks of local extinction mainly due to over exploitation and climate and land use changes. Apart from their general uses as forage, timber, poles, and fuelwood, *Z. chalybeum* is also harvested for local uses and export to Europe, the United States of America, Asia and the Middle East [23]. In addition to this, there are increasing threats from increased population pressures and climate change which potentially impede the survival and persistence of such highly demanded species. Furthermore, literature has pointed that the important vegetative organ such as seeds, have shown delay and has difficulties in germination, thus different treatments are recommended to ensure germination and reduction of germination time [25,28,30]. Difficulties in seed germination have been associated with hard seed coats, oily and loss of viability within a short time [28]. The regeneration pattern of this tree as according to the study conducted by Galabuzi *et al*. [8], showed a low number of saplings of the tree and suggesting that recruitment is genuinely impaired in the forest. Besides seeds, *Zanthoxylum* species can also be multiplied through air layering [28] and biotechnological methods [5,29].

Even though Z. *chalybeum* has many uses as traditional medicine, there is a gap in understanding its current distribution and anthropogenic threats consequential from plant exploitation, such information is crucial for conservation purposes. In Simanjiro areas, large quantities of plants are being harvested from the wild, raising a concern of whether this harvesting is sustainable. This study, therefore, focused on studying the distribution of *Z. chalybeum* by mapping its presence-absence in different land uses. It further searched to determine anthropogenic threats facing the tree due to exploitation among communities in the study area. Meetings with key informants and discussions with community leaders were used to collect data related to local people perceptions and information on the species' uses in Simanjiro area.

2.0. Materials and Methods

2.1. Description of the Study area

Simanjiro district of Manyara Region in Northern Tanzania lies between 3°52' and 4°24' South and 36°05'and 36°39' East [24]. The district borders Tarangire National Park to the Eastern side, it has an annual rainfall of 650 mm per annum while its temperature varies between 18-30°C. Simanjiro district covers about 19,928 km^2 and most of its area is covered by open woodland, bushy forests and grassland vegetation [24]. The area lies within the Maasai Steppe with an area of 20,591 km^2 of which 600 km^2 of the entire steppe is a fertile land for agriculture while 12,682 km^2 is covered by game controlled areas and game open areas and the rest is a hilly area [24]. The main vegetation types are grassland (51%) composing of short *Digitaria macroblephara* and *Panicum coloratum* species. Twenty-six (26%) of the vegetation is covered by wood vegetation mainly *Acacia stuhlmannii* and *Acacia drepanolobium*. Bushlands occupy 13% and the remaining 10% is covered by bushed grasslands [15]. Simanjiro is also heavily utilized by grazing ungulates where by Maasai zebu cattle (*Boss Taurus* Linn) constitute about 54% while 40% consists of migratory zebras (*Equus burchellii* Gray) and wildebeest (*Connochaetes taurinus* Burchell) [15]. Other wild herbivores include eland, gazelle, giraffes, and impalas. The ethnic groups' main economic activities in the area include livestock keeping, farming, and hunting.

2.2. Sampling design and data collection

A preliminary survey was conducted from June to July 2019 to identify the land use types present at Simanjiro area for data collection. Using a topographic map of the study area in combination with some local knowledge of the site about the occurrence and distribution of *Z. chalybeum* in different localities, the study employed a stratified random sampling technique in which the area was stratified into two main land use types (strata) i.e. game controlled area (GCA) and game open area (OA). For a given stratum, villages were randomly selected for setting up the survey plots in different land units (i.e. farmlands, grazing lands, settlement areas), and based on the background hypothesis for this study, it was assumed that each stratum (and the respective village selected) is uniform in terms of *Z. chalybeum* distribution. The most available roads were used as survey routes to observe *Z. chalybeum* distribution in the area. The use of roads as survey routes was done to permit access and reaching out to the different village survey sites as recommended by Buckland *et al*. [3]. A buffer off road walk distance of about 50m from the transect (road) to the interior was established to reduce edge effect and bias in observation. Systematic random sampling technique was employed in the study to observe presence-absence of *Zanthoxylum chalybeum* tree in each land use encountered in the study site along each established survey route and location. The presence and status of *Z. chalybeum* was recorded using roadside surveys similar to those conducted by Rejmánek *et al*. [33]. Such surveys are a cost-effective way of gaining a rapid and broad understanding of widespread distributions which can then guide more detailed mapping later [37]. In each survey location, a sampling plot of 20m radius was established with at least 1km apart for data collection [3]. A total of 501 sampling plots were established during the study (89, 119, 113, 71 and 109 plots for farmland, game controlled area, grazing lands, game open areas and Settlement areas, respectively) on which coverage of plots depend on the size of the land use type. Assessment of signs of anthropogenic threats (debarking, root digging, branch cutting and whole tree cutting), number of *Z. chalybeum* trees and record coordinates of sampling plots where *Z. chalybeum* was present and absent to attain distribution data was conducted during field study. Scaling of damage per tree was scaled from 0-3 where; (0)-no damage, (1)-slight damage-few scars, (2)-severe damage-scarred deeply, and (3)-tree completely damaged-dead [39]. A handheld Global Position System (GPS) Garmin 64S device was used to locate coordinates of the sites for tree present- absence data while a self-made data collection sheet was used to record the observed anthropogenic threat signs.

To explore traditional uses of the plant by the local communities, checklist and interview were employed by purposively selecting the key informants and participants from five selected villages (Terrat, Loiborsoit A, Londrekess, Naberera, and Namalulu) and with experience of indigenous uses and practices of medicinal plants from the surveyed area. A total of 103 respondents were involved in the interview of which 45.6 % being male and 54.4 % female. Participants were particularly selected based on the knowledge of the *Z. chalybeum* tree and are residents of the area for more than ten years. Respondents were asked to give information on the most potential uses of the plant in their community. Each respondent received information about the purpose of the research prior to the interview survey and each respondent was asked to respond to the interview upon his/her consent. The researcher stated clearly to respondents that the information collected was for research purposes and will not be disclosed or used for any other purposes. All procedures performed in this study and involving human participants were in accordance with the ethical standards of the Nelson Mandela-African Institution of Science and Technology (NM-AIST) committee which is part of the ethical clearance committee of Northern Tanzania.

2.3. Data analysis

Spatial distribution data of *Z. chalybeum* in the study area were analyzed using Arc GIS (Arc Map version 10.6) to produce a distribution map. The *Z. chalybeum* spatial distribution GPS coordinates recorded during data collection and the patterns across the entire study area were compiled then converted to shapefile (*.SHP*) format. Kernel density tool in the ArcMap version 10.6 with a search radius of 1km^2 area was used to calculate the density and extent of *Z. chalybeum* distribution across the entire landscape. Kernel tool creates a continuous surface with a specified radius distance in which only georeferenced coordinates points of the species that fall within the neighborhood of the search radius were considered in calculating density. Kernel tool calculated density units based on the linear unit of the projection of the output spatial reference. Given that our sampling strategy located coordinates by the GPS in a random way and given the variations in the study area biogeographically, our study assumed that the distribution of *Z. chalybeum* tree in the study area was not normally distributed within a particular sampling point. Based on this assumption, our kernel density linear estimator assumed a non-parametric data following García *et al*. [10] approach. Larger values of the search radius parameter produce a smoother density map while smaller values produce a raster that shows a more detailed map (see fig. 2&3). The different (range) categories of distribution and threats and analyzed patterns of change across the entire study area were also compared. Chi-square test was performed using STATISTICA Version 8 at a 5% level of significance to compare frequencies of anthropogenic threats in different land uses and also to compare the statistical difference in sampled plots with *Z. chalybeum* and those without *Z. chalybeum* in different surveyed land uses. Contest analysis (conceptual analysis) was used to analyze information obtained from the checklist and interview study. The data were summarized in key statements and presented in a table for interpretation and discussion.

3.0. Results

3.1. Distribution of Z. chalybeum *trees across surveyed land use types*

Simanjiro area as a whole has two major land use categories which are game controlled areas and game open areas (Fig. 2 and 3). Within these two major land use categories, there are other lands uses interwoven within the two mainland use types which were: settlements, grazing land and farmlands (Fig. 2). A total of 501 sampling plots were observed in this

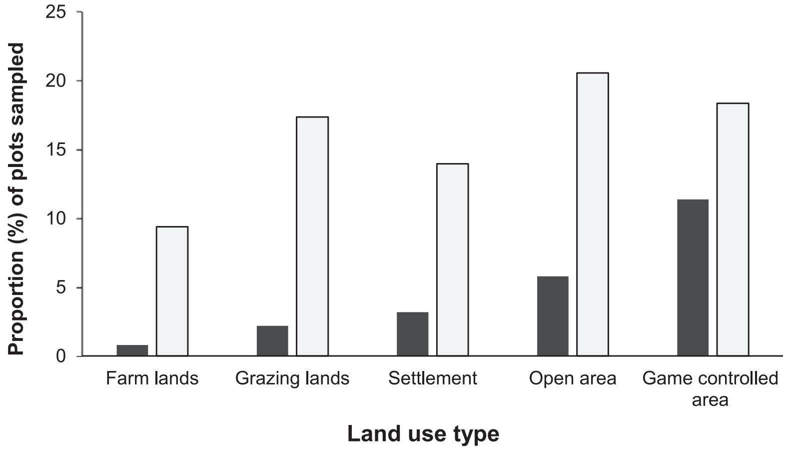

Figure 1. Shows the proportion (%) difference in the sampled plots with trees and plots without trees whereby; black shaded bars represents plots with *Z. chalybeum* while pale white shaded bars represent plots without *Z. chalybeum*.

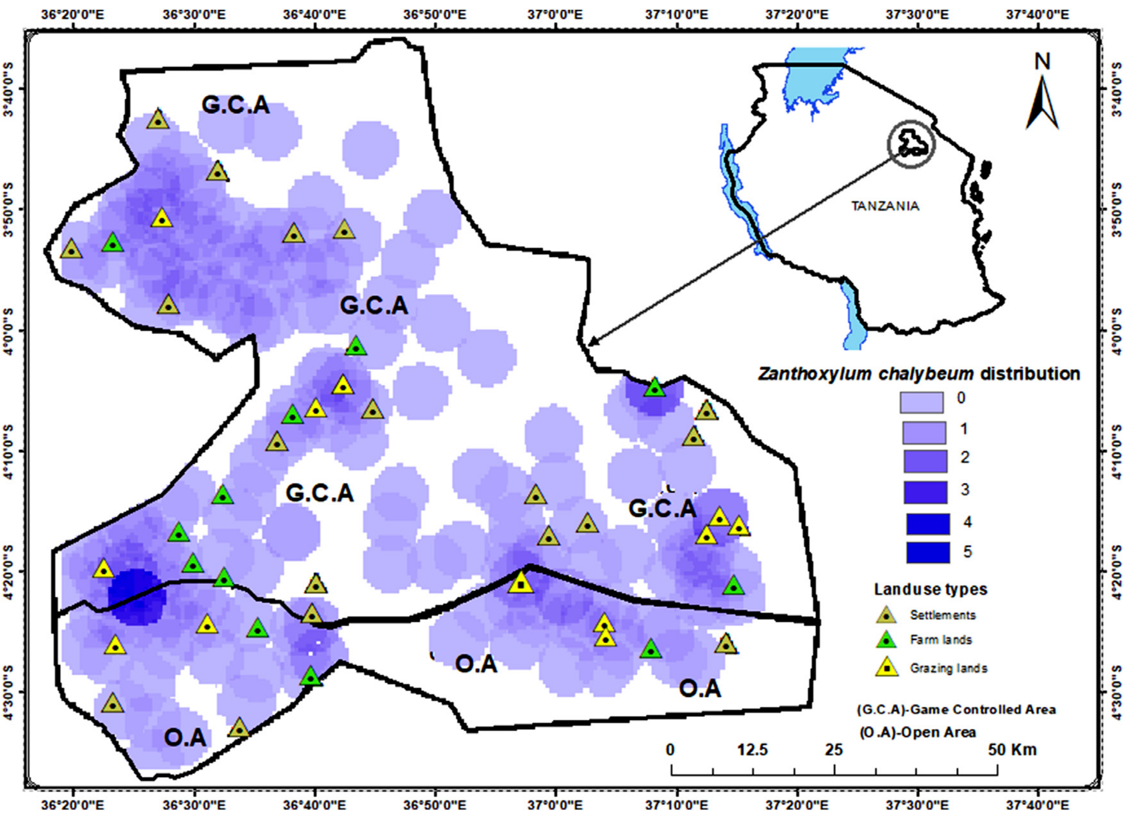

Figure 2. A Map showing distribution (presence- absence) of *Z. chalybeum* trees in Simanjiro area under different land uses categories.

study. There was a significant difference in the plots with *Z. chalybeum* versus those which did not have the tree in different land uses (χ^2 =16.427, $df = 4$, $p= 0.002$). The game controlled area had more plots with trees present compared to other land uses (Fig. 1). Each encountered tree in the sampling plot was counted individually, a high number in the total count of individual trees was observed in game controlled areas (49) and game open areas (40) while a lower number of trees within settlement (17), grazing lands (15), and farmlands (13).

Distribution (present-absent) of *Z. chalybeum* per sampling plots established was also different across land-use types encountered. The majority of *Z. chalybeum* trees were observed in-game controlled areas and game open areas (situated within hunting blocks) compared with other land use types (Fig. 2).

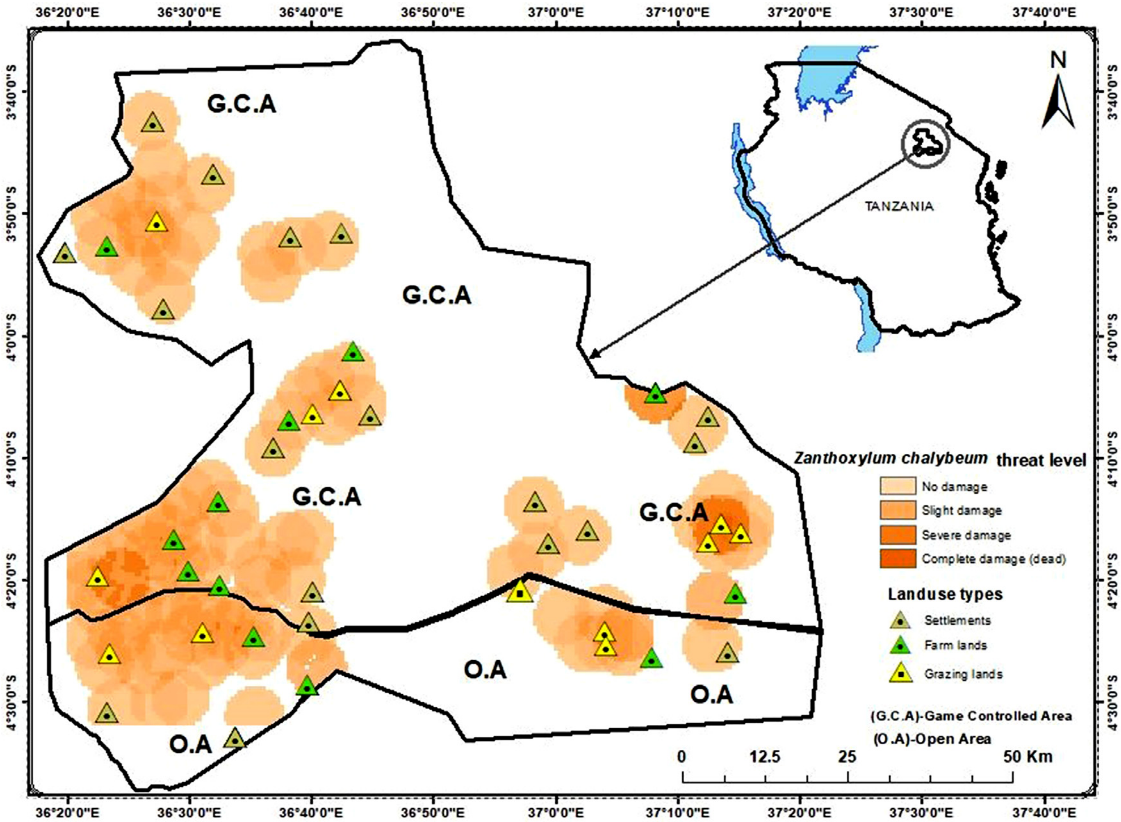

Figure 3. Map showing anthropogenic threats occurrence related to damage scale of *Z. chalybeum* trees in Simanjiro area under different land uses.

Areas along and close to the main road had no trees while a fewer number of *Z. chalybeum* trees were distributed on farming lands. High distribution of damaged trees and damage level (scaling) was observed in grazing lands and farmlands while partial damages were observed in settlement areas (Fig. 3).

3.2. Observed anthropogenic threats signs, frequency of the threat and threat damage scaling level

A total number of 134 trees were observed in the survey whereby (52.98%) and (47.01%) of the observed trees were unaffected and affected respectively. Generally, there was no significant difference between the overall count of affected and unaffected trees (χ^2 =7.63, $df = 4$, p= 0.10) but there was a significant difference between counts of affected and unaffected trees within land-use types such as in grazing lands trees (χ^2 =6.05, $df = 1$, p= 0.014), farmlands (χ^2 =8.05, $df = 1$, p= 0.004), settlements (χ^2 =4.05, $df = 1$, p= 0.04),game open areas (χ^2 =31.04, $df = 1$, p= 0.0000) and game controlled areas (χ^2 =40.604, $df = 1$, p= 0.00000) (Fig. 4). Several anthropogenic threat signs with a high percentage on debarking signs (61%) were observed while the least signs on root digging (21%) branch cutting (13%) and whole tree cutting (5%) were observed in the study sites.

Massive threats were observed in grazing lands and farmlands (73% and 62% respectively) while the least threats were observed in game controlled areas and game open areas (39% and 40% respectively). Majority of trees were debarked (51%) while other trees had a combination of threat signs such as debarking and branch cut (20.6%), debarking and uprooting (15.8%), debarking, branch cut and uproot (4.76%), whole tree cut (4.76%) and branch cut (3.17%). Tree damages differed significantly ($\chi^2 = 25.05$, $df = 12$, $p = 0.01$), whereby 30%, 13% and 4% under scale damage of (1)-slight damage-few scars, (2)-severe damage-scarred deeply, and (3)-tree completely damaged-dead respectively was observed while 53% of trees where having scale 0- no damage (Fig. 5).

3.3. Uses of Z. chalybeum *tree by the community*

All respondents (100%) mentioned the main use of the plant *Z. chalybeum* being for herbal medicine while 82.5% mentioned using the plant as a spice in drinks (e.g. porridge, tea, milk and soup) and is taken daily as a normal beverage. Furthermore, the plant seeds have also been mentioned as a source of fodder during grazing whereby herders cut down

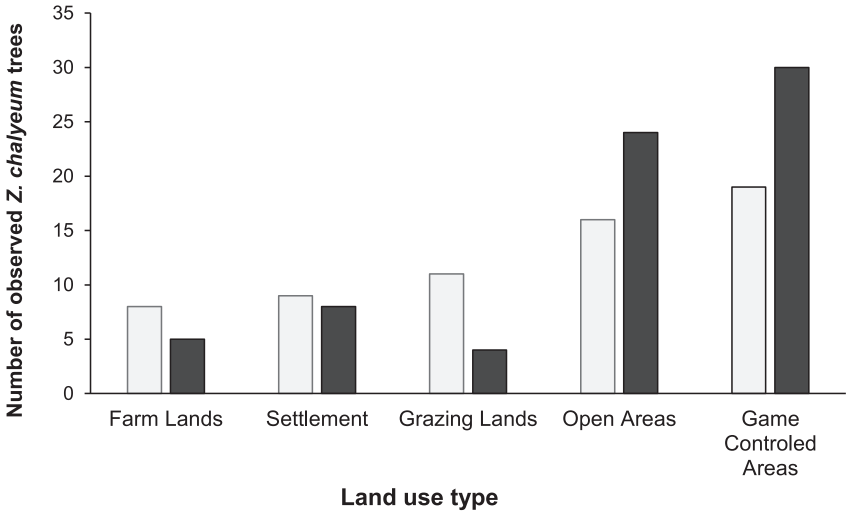

Figure 4. Total number of affected and unaffected *Z. chalybeum* tree encountered within each sampling plots in different land uses. The black shaded bars present number of undamaged trees while the white shaded bars present damaged trees.

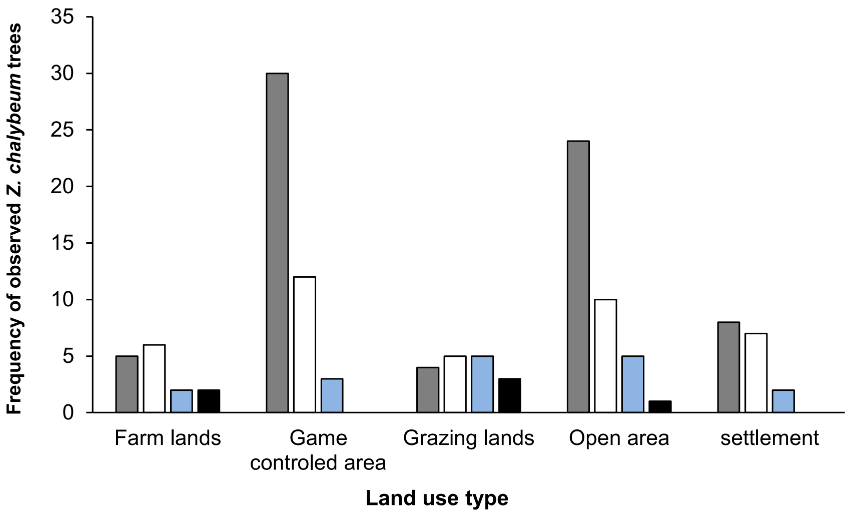

Figure 5. Scale of damage per tree and its frequency encountered in each land use The lighter black filled bars stands for 0-scale, white filled bars = 1-scale, light blue filled bars = 2- scale and deep black filled bars = 3- scale. Whereby; (0-no damage), (1-slight damage-few scars), (2-severe damage-scarred deeply), and (3-tree completely damaged-dead).

branches with seeds to feed goats (58.3%). Others (30.1%) said that the plant being used for cowshed fencing to protect their young ruminants from dangerous animals and also as a source of firewood (11.6%) as per table 1 below.

4.0. Discussion

4.1. Distribution of Z. chalybeum *tree in Simanjiro area*

The presence of hunting blocks within game-controlled areas and game open areas that are managed by several hunting companies that perform periodic patrol could have positively influenced the vast distribution of *Z. chalybeum* within these areas compared with other land use types (Personal Observation). The presence of protected areas, therefore, ensures the effective exploitation of natural resources compared with unprotected areas [6,12,16]. Few numbers of trees observed in farmlands and settlements can be due to land clearing for crop cultivations (Personal Observation). According to McGeoch *et al.* [21], land clearing for agriculture contribute significantly to the loss of native trees. The small number of trees observed in farmland and settlement areas suggests that the tree is mostly affected by excessive exploitation by humans for different uses. Our results conform with a study by Okigbo *et al.* [26] and Saqib *et al.* [36] whose findings suggested that there will be a decrease in the distribution of *Z. chalybeum* if settlement expansion and low conservation awareness was among local

Table 1
The summary of demographic characteristic of the interviewed informants and the responses on the uses of *Z. chalybeum* tree in their community.

Factor	Level	Frequency	Percentage (%)
Demographic characteristics			
Gender	Male	47	45.6
	Female	56	54.4
Age	18-30	24	23.3
	30-60	63	61.2
	> 60	16	15.5
Uses of *Z. chalybeum* tree			
Uses of the plant	Herbal medicine	103	100
	Spice	85	82.5
	Ruminant fodder	60	58.3
	Fencing	31	30.1
	Firewood	12	11.7

communities. This may also be the case with Simanjiro area because not all members of the communities understand the consequences of excessive exploitation on the species survival and persistence.

Interestingly, the majority of trees that were found in settlement areas were reported to be planted, this highlights the potential for engaging local people on conservation of *Z. chalybeum* through domestication as such efforts have been reported as a successful conservation strategy for most medicinal plants [18]. Domestication of *Z. chalybeum* will not only ensure its accessibility but also will secure the tree during the times of needs [1] and hence ensure its conservation [26]. We observed the lowest number of trees in grazing lands as a consequence of livestock grazing. Grazing has been reported to negatively influence species composition, distribution of biodiversity and biomass [9,38]. According to Sher *et al.* [38] the impacts of grazing on medicinal plant vegetation can be influenced by three factors; the type of herbivores grazing, the number of animals utilizing the area and distribution of use in time and space. In Simanjiro area, the tree has been cut down as a source of fodder to ruminants (goats). Members of the community graze a large number of animals (as a culture to Maasai) in one area which directly impacts the specie distribution. Branches and whole tree cutting have been practiced by grazers to harvest seeds and leaves which are then being fed to ruminants during grazing time (personal observation). Generally, the overall distribution of the tree in all surveyed land uses types was very low mainly because the tree is highly favored by the community as a remedy for different diseases [17,18,20]. Therefore, there is a possibility for a continuous decrease in the distribution of *Z. chalybeum* in the future if no effective conservation strategies will be initiated.

4.2. Anthropogenic threats facing Z. Chalybeum *in Simanjiro area*

A relationship between the harvesting method and the plant part being harvested, and its impacts on the natural wild plants have been observed in many cases [31,32]. It has been documented that, the effects of unsustainable harvesting methods on plants include wilting, stagnant growth and sometimes may result to plant death [31]. In this study, debarking was observed in many cases compared with other threats and this could be due to the presence of most active compounds in *Z. chalybeum* barks [2,40] compared with other parts. Debarking of plant stem has been reported to cause negative effects on the plant such as blocking of translocation of materials, which is necessary for healthy growth and survival of the plant, increased insect attack, limits survival rate of the tree and can eventually lead to plant death [7,27].

The highest frequency of anthropogenic threats was observed in grazing and farming lands compared with other land use types due to easy accessibility [6,38]. On the contrary, the observed low number of threats in trees grown in settlement areas can be due to the owner's protection of the trees from massive harvesting (Personal Observation). Although there were few observations of *Z. chalybeum* root digging signs, *Z. chalybeum* tree roots have been harvested for treatment purposes [17,18]. Observation of *Z. chalybeum* uprooting signs in the field was few and this could be related to the fact that people tend to cover uprooting signs [21]. The damage scales (Fig. 5) indicate that people are aware of the effects of unsustainable harvesting methods (Personal Observation) therefore if well informed will contribute much to the conservation of *Z. chalybeum*. It seems that local demand influenced by increased population and population pressures has fueled the unsustainable harvesting for both commercial and household use.

According to respondents, Oloisuki (*Z. chalybeum*) is not just any other tree as the plant has been utilized for medicinal purposes from centuries old. The preference in the use of *Z. chalybeum* as a medicinal plant has also been reported by Laltaika, [17], Makule, [18] and Roulette *et al.* [34] in their studies conducted on Maasai communities in Northern Tanzania. The high demand and methods of harvesting used by the community are not suitable looking on the fact that the most harvested parts are those of roots and stem bark, and thus leave scars and damages that are easily observed of which can also cause serious effects on the plant as discussed in part 4.2 above. The high dependence and harvesting of this plant by the community members and the effects of change in land use has led to the fading and declining of the tree population in their natural areas of occurrence. From the mentioned, it thus shows how important plant conservation is needed referring to the fact that, the demand increase and land-use changes will face the community.

5.0. Conclusions and recommendations

The study has highlighted the distribution and anthropogenic threats on the existence of medicinal plant *Z. chalybeum* in the Simanjiro area. The study also indicates the role of protected areas in the conservation of natural resources. It was observed that conservation areas (i.e. hunting blocks within game controlled areas and open areas) have higher abundance of *Z. chalybeum* with detectable distribution pattern than other locations in Simanjiro area. The current observation in this study also shows that the rates of harvesting are increasing and harvesting methods used by community members are unsustainable. The observed damages from debarking, uprooting, tree cutting, and branch cutting signify *Z. chalybeum* local extinction risk if no urgent conservation measures are taken and if effective regulatory measure on the harvesting and use practices are not appropriately effected. This evidence allows us to say that less observed distribution does not enable the species to sustain its population, hence, making it to the break of local extinction. Local and other authorities should use results generated from this study as a baseline to promote conservation strategies of medicinal plant *Z. chalybeum* at Simanjiro area.

This study recommends more conservation efforts to be implemented in Simanjiro areas with particular focus on enforcing regulations in game controlled areas and open areas as they were found to harbor high abundance of the species in the study area. Sustainable harvesting of the species should be practiced to reduce the impacts of overharvesting of the species on its population persistence. Promotion of cultivation and conservation of the species in farmland would help reduce the harvesting pressures in protected areas while providing access by the local community in their farms. More efforts should be directed on improving multiplication (both conventional & biotechnological means) and raising plant nurseries, implementing afforestation programs, involving the local community and linking with economic benefits as part of conservation measures. Adoption of *in vitro* propagation protocol (e.g. those developed by [29]) and application of this to *Z. chalybeum* may be effectively utilized for generating sufficient planting material that can be utilized in promoting domestication and conservation programs for the species The government should set regulations that will guide the use and exploitation of *Z. chalybeum* especially as it is being excessively exploited in the wild. Additionally, strategies that positively promote recruitment and establishment of *Z. chalybeum* need to be improved to ensure that a higher proportion of young trees survive. Our study further recommends the propagation of *Z. chalybeum* seedlings in their natural areas of occurrence to maintain viable distribution.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] B.J. Amujoyegbe, J.M. Agbedahunsi, O.O. Amujoyegbe, Cultivation of medicinal plants in developing nations: means of conservation and poverty alleviation, International Journal of Medicinal and Aromatic Plants 2 (2) (2012) 345–353.
[2] G.S. Bbosa, N. Mwebaza, A. Lubega, N. Musisi, D.B. Kyegombe, M. Ntale, Antiplasmodial Activity of Leaf Extracts of *Zanthoxylum chalybeum* Engl, British Journal of Pharmaceutical Research 4 (6) (2014) 705.
[3] S.T. Buckland, D.R. Anderson, K.P. Burnham, J.L. Laake, Encyclopedia of Biostatistics, 2nd Edition, Distance Sampling. John Wiley & Sons. Published Online (2005).
[4] M. Chrian, P. Erasto, N.J. Otieno, Antimycobacterial activity and cytotoxicity effect of extracts of *Hallea rubrostipulata* and *Zanthoxylum chalybeum*, Spatula DD-Peer Reviewed Journal on Complementary Medicine and Drug Discovery 1 (3) (2011) 147–152.
[5] N. Coelho, S. Gonçalves, A. Romano, Endemic Plant Species Conservation: Biotechnological Approaches, Plants 9 (3) (2020) 345.
[6] A.B. Cunningham, Applied ethnobotany: People, wild plant use and conservation. London: Earthscan. Ersity and sustaining local livelihood, Annual Review of Environment and Resources 30 (2001) 219–252.
[7] C. Delvaux, B. Sinsin, F. Darchambeau, P. Van Damme, Recovery from bark harvesting of 12 medicinal tree species in Benin, West Africa, Journal of Applied Ecology 46 (3) (2009) 703–712.
[8] C. Galabuzi, G.N. Nabanoga, P. Ssegawa, J. Obua, G. Eilu, Double jeopardy: bark harvest for malaria treatment and poor regeneration threaten tree population in a tropical forest of Uganda, African Journal of Ecology 53 (2) (2015) 214–222.
[9] A.H. Ganie, B.A. Tali, A.A. Khuroo, Z.A. Reshi, I.A. Nawchoo, Impact assessment of anthropogenic threats to high-valued medicinal plants of Kashmir Himalaya, India, Journal for Nature Conservation (2019) 125715.
[10] E. García-Portugués, R.M. Crujeiras, W. González-Manteiga, Kernel density estimation for directional–linear data, Journal of Multivariate Analysis 121 (2013) 152–175.

[11] A. Göhre, Á.B. Toto-Nienguesse, M. Futuro, C. Neinhuis, T. Lautenschläger, Plants from disturbed savannah vegetation and their usage by Bakongo tribes in Uíge, Northern Angola, Journal of Ethnobiology and Ethnomedicine 12 (1) (2016) 42.
[12] A.C. Hamilton, Medicinal plants, conservation and livelihoods, Biodiversity and Conservation 13 (8) (2004) 1477–1517 10.1023/B:BIOC.0000021333.23413.42.
[13] IUCN, (2020). The IUCN Red List of Threatened Species. Version 2020-1. https://www.iucnredlist.org. Downloaded on 19 March 2020.
[14] M. June, C.N. Kimani, J.M. Mbaria, M. Suleiman, D. Gakuya, S.G. Kiama, Antihyperglycemic activity of *Zanthoxylum chalybeum* stem bark extract in diabetic rats, The Journal of Phytopharmacology 4 (3) (2015) 183–189.
[15] J. Kahurananga, The vegetation of the Simanjiro Plains, Northern Tanzania, African Journal of Ecology 17 (2) (1979) 65–83.
[16] E. Kaky, F. Gilbert, Using species distribution models to assess the importance of Egypt's protected areas for the conservation of medicinal plants, Journal of Arid Environments 135 (2016) 140–146.
[17] E. Laltaika, Oloisuki–A tale of biopiracy in the Maasai Steppe, Tanzania (2011) Retrieved from https://scholar.google.com/.
[18] E. Makule, Ethnopharmacological survey and phytochemical investigation of Maasai traditional medicinal plants from north-eastern Tanzania, (Doctoral dissertation, University of Regensburg) (2018).
[19] E.N. Matu, J. Staden, Antibacterial and anti-inflammatory activities of some plants used for medicinal purposes in Kenya, Journal of Ethnopharmacology 87 (1) (2003) 35–41.
[20] S.D. Mbinile, L.K. Munishi, I.B. Ngondya, P.A. Ndakidemi, Conservation and Management Challenges Facing a Medicinal Plant *Zanthoxylum chalybeum* in Simanjiro Area, Northern Tanzania, Sustainability 12 (10) (2020) 4140.
[21] L. McGeoch, I. Gordon, J. Schmitt, Impacts of land use, anthropogenic disturbance, and harvesting on an African medicinal liana, Biological Conservation 141 (9) (2008) 2218–2229.
[22] H. McMillen, Ethnobotanical Knowledge Transmission and Evolution: The Case of Medicinal Markets in Tanga, Tanzania1, Economic Botany 66 (2) (2012) 121–131, doi:10.1007/s12231-012-9201-8.
[23] M. Nahashon, Conservation of Wild-harvested Medicinal Plant Species in Tanzania: Chain and consequence of commercial trade on medicinal plant species (Masters thesis, Uppsala University, Sweden, 2013 Retrieved from https://scholar.google.com/.
[24] C.N.M. Nyaruhucha, J.M. Msuya, P.S. Mamiro, A.J. Kerengi, Nutritional status and fedding of under-fives in Simanjiro District Tanzania, Tanzania Health Research Bulletin 8 (3) (2006) 162–167.
[25] M.M. Okeyo, J.O. Ochoudho, R.M. Muasya, W.O. Omondi, in: Investigation on the germination of *Zanthoxylum gilletii* (african satinwood) seed. In *Innovations as Key to the Green Revolution in Africa*, Springer, Dordrecht, 2011, pp. 683–691.
[26] R.N. Okigbo, U.E. Eme, S. Ogbogu, Biodiversity and conservation of medicinal and aromatic plants in Africa, Biotechnology and Molecular Biology Reviews 3 (December) (2008) 127–134.
[27] A. Purohit, R.K. Maikhuri, K.S. Rao, S. Nautiyal, Impact of bark removal on survival of *Taxus baccata* L.(Himalayan yew) in Nanda Devi biosphere reserve, Garhwal Himalaya, India, Current Science (2001) 586–590.
[28] S. Purohit, A. Bhatt, I.D. Bhatt, S.K. Nandi, Propagation through air layering in *Zanthoxylum armatum* DC: An endangered medicinal plant in the Himalayan region, Proceedings of the National Academy of Sciences, India Section B: Biological Sciences 86 (3) (2015) 607–610.
[29] S. Purohit, K. Joshi, V. Rawat, I.D. Bhatt, S.K. Nandi, Efficient plant regeneration through callus in *Zanthoxylum armatum* DC: An endangered medicinal plant of the Indian Himalayan region, Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology 154 (3) (2019) 288–294.
[30] S. Purohit, S.K. Nandi, L.M.S. Palni, L. Giri, A. Bhatt, Effect of Sulfuric Acid Treatment on Breaking of Seed Dormancy and Subsequent Seedling Establishment in *Zanthoxylum armatum* DC: An Endangered Medicinal Plant of the Himalayan Region, National Academy Science Letters 38 (4) (2015) 301–304.
[31] H. Rahman, M. Rahman, M. Islam, S. Reza, The importance of forests to protect medicinal plants: a case study of Khadimnagar National Park, Bangladesh, International Journal of Biodiversity Science, Ecosystem Services & Management 7 (4) (2011) 283–294.
[32] L.K. Rai, P. Prasad, E. Sharma, Conservation threats to some important medicinal plants of the Sikkim Himalaya, Biological Conservation 93 (1) (2000) 27–33.
[33] M. Rejmánek, B.J. Huntley, J.J. Le Roux, D.M. Richardson, A rapid survey of the invasive plant species in western Angola, African Journal of Ecology 55 (1) (2017) 56–69.
[34] C.J. Roulette, E.F.A. Njau, M.B. Quinlan, R.J. Quinlan, D.R. Call, Medicinal foods and beverages among Maasai agro-pastoralists in northern Tanzania, Journal of Ethnopharmacology 216 (2018) 191–202.
[35] ... & M. Sankaran, N.P. Hanan, R.J. Scholes, J. Ratnam, D.J. Augustine, B.S. Cade, J. Ardo, Determinants of woody cover in African savannas, Nature 438 (7069) (2005) 846.
[36] Z. Saqib, R.N. Malik, M.I. Shinwari, Z.K. Shinwari, Species richness, ethnobotanical species richness and human settlements along a Himalayan altitudinal gradient: Prioritizing Plant Conservation in Palas Valley, Pakistan, Pakistan Journal of Botany 43 (2011) 129–133.
[37] R.T. Shackleton, A.B. Witt, W. Nunda, D.M. Richardson, *Chromolaena odorata* (Siam weed) in eastern Africa: Distribution and socio-ecological impacts, Biological Invasions 19 (4) (2017) 1285–1298.
[38] H. Sher, A. Ahmad, M. Eleyemeni, S. Fazl-i-Hadi, H. Sher, Impact of nomadic grazing on medicinal plants diversity in Miandam, Swat-Pakistan (Preliminary results), International Journal of Biodiversity and Conservation 2 (6) (2010) 146–154.
[39] H. Sukopp, Human-caused impact on preserved vegetation, Landscape and Urban Planning 68 (4) (2004) 347–355.
[40] T. Wunganai, Synthesis, characterisation of silver nanoparticles from *Zanthoxylum chalybeum* root bark extract, evaluation of its anti-microbial and anti-proteolytic activity on bitis arietans venom (Doctoral dissertation), Bindura University of Science Education, Zimbabwe, 2016.
[41] S. Xego, L. Kambizi, F. Nchu, Threatened medicinal plants of South Africa: case of the family Hyacinthaceae, African Journal of traditional, complementary and alternative medicines 13 (3) (2016) 169–180, doi:10.4314/ajtcam.v3i3.20.