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Composition dynamics and regeneration potential of preferred medicinal plants in the eastern arc mountains: case study of west Usambara mountains

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Abstract

The Lushoto district of Tanzania boasts a rich diversity of medicinal plants, cherished for their therapeutic properties by the local communities. However, utilisation preferences of medicinal plants have been linked to their threats due to overharvesting and poor management. This study aimed at assessing the diversity and regeneration of medicinal plants used by the local people in five selected villages (Kiluwai, Irente, Kwemakame, Viti and Mwangoi) of Lushoto District. Medicinal plants diversity was assessed through phytosociological survey while regeneration potential was determined based on the number and dimensions of seedlings, saplings and adults. Simpson's diversity index (D) was used to calculate the diversity of medicinal plants in each of the selected village. Quantitative data were analysed by using Statistical package for Social Sciences (SPSS) version 23. The study revealed low diversity of medicinal plants in all studied villages ranging from D = 0.361 in Kiluwai Village to D = 0.054 in Irente Village. Likewise, majority of the medicinal plants exhibited no regeneration (NR) across all study sites. The detected poor or no regeneration status of medicinal plants and low diversity serves as an indicator of the ecological extinction of medicinal plants at local level in the near future. Therefore, strong initiatives should be taken to ensure the sustainability of medicinal plants in the study area.

Keywords: *Eastern Arc Mountains; Regeneration potential; Saplings; Seedlings; Species diversity*

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Introduction

Medicinal plants have played an essential role in human health for thousands of years. Over eighty percent of world's population relies on traditional herbal medicine for primary health care especially in developing countries (World Health Organization (WHO), 2013). Medicinal plants are also crucial to the pharmaceutical industries, providing raw materials for many modern drugs. Medicinal plants have been used in traditional and modern medicines because of their healing effect on humans or animals (Motaleb, 2011). Because traditional medicines are easily accessible at an affordable price and proved to have no health problems, WHO has been promoting them to be included in the health care systems (Dar, Shahnawaz, and Qazi, 2017).

Tanzania is a developing country which for many years has been promoting the use of traditional medicine in health care provisions. For example,

80% of the people in the country rely primarily on medicinal plants to treat chronic diseases. West Usambara is among leading regions where the use of plants for medicinal purposes is steadily given a special attention due to presence of abundant medicinal plants and their effectiveness in combating challenging health problems. Schlage *et al.* (2000a) reported 328 different medicinal plant species in West Usambara being effectively used for treatment of various diseases. Among the diseases that faced the people of the West Usambara include gastro-intestinal diseases, pain and inflammation, skin diseases, respiratory diseases, children's diseases such as pneumonia, malaria and fever (Schlage *et al.,* 2000). The diseases were found to be treated using different medicinal plants, for example: gastrointestinal diseases were treated using *Senna didymobotrya*, *Deinbollia borbonica* and *Albizia anthelmintica*. Pain and inflammation were treated using *Myrica salicifolia*, *Todalia asiatica*, *Zehneria scabra*, *Clutia abyssinica*, skin diseases were treated using *Clutia abyssinica, Zehneria scabra*, *Dichrocephala integrifolia,* respiratory diseases were treated using *Myrica salicifolia, Zanhago lungensis*, *Clausena anisata*, *Ficuss exasperate*, pneumonia was treated using *Microglossa oblongifolia*, *Microglossa densiflora*, *Ocimum suave* and, fever and malaria were treated using *Artemicia afra, Plectranthus barbatus*, *Spilanthes mauritiana* and *Vernonia iodocalyx* (Schlage *et al.,* 2000).

Due to population increase and the eruption of different diseases, there is an increase in demand for medicinal plants in the market, thus resulting in overharvesting of medicinal plants for health purposes. Different ways of harvesting medicinal plants affect their abundance, distribution and evenness consequently the diversity (Augustino, Hall, Makonda, and Ishengoma, 2014). According to Augustino *et al.,* (2014), both digging out of roots and striping of the barks are highly used as harvesting methods. For example, in Tabora at Urumwa Forest Reserve roots and barks are the most preferred parts of the medicinal plants (Augustino *et al.,* 2014). Since plant roots and stems play a role of absorbing nutrients and water from the soil to the upper parts of plants, their removal mostly results in the weakening of the plants and even wilting which may contribute to reduction in the number of plant species and hence affecting diversity (Augustino *et al.,* 2014). The harvesting practices may interfere with medicinal plants' regeneration potential since the harvested parts (leaves, stem bark, root, fruits and flowers) are responsible for medicinal plants' regeneration. Plant regeneration which is the ability of the plant to repair the damaged parts or produce the new plant, is an important aspect that ensures the sustainability of the plant concerned (Ikeuchi, Ogawa, Iwase, and Sugimoto, 2016). Regeneration of different life forms particularly trees, saplings, coppices and seedlings, determine the populations of medicinal plants and their future health (Karamian and Ghasemlou, 2014).

Limited studies have been carried out to investigate the diversity and regeneration potential of the preferred medicinal plants in West Usambara Mountains. Hence this study aimed to investigate the diversity and regeneration potential of the preferred medicinal plants of the West Usambara Mountains.

Materials and Methods

Study area description

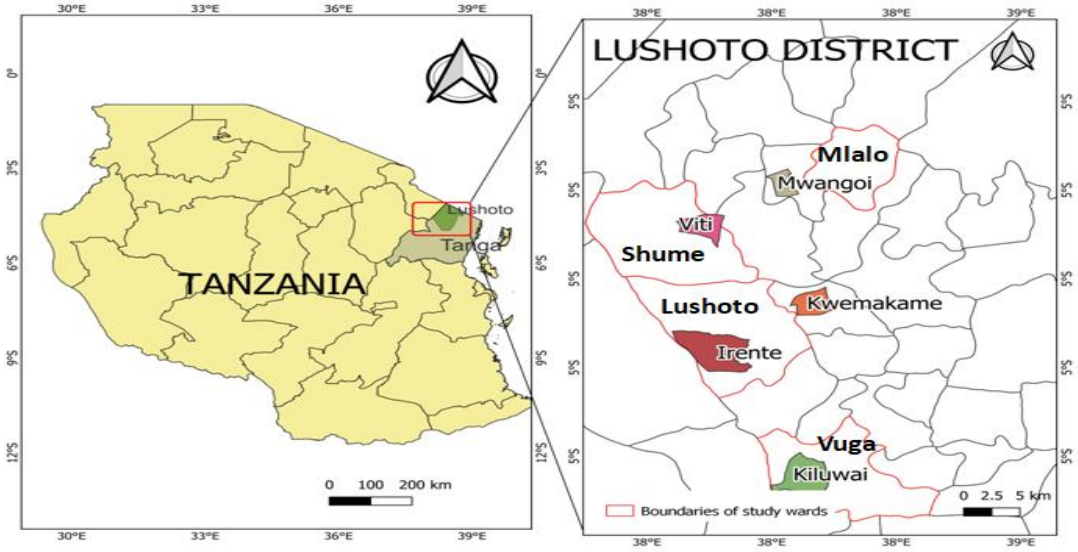
The West Usambara Mountains are situated in the north-east Tanzania (40 24' to 50 00'S and 380 10'to 380 36'E), bordered by the Great Rift Valley to the west and coastal plain to the east (Schlage *et al.,* 2000). The range consists of several individual mountains, with the highest peak being Loolmalasin (also known as Shengena) at around 2,674 metres (8,773 feet) above sea level (Meliyo *et al.,* 2018). These mountains are part of the Range of Eastern Arc Mountains, which is recognised globally for its exceptional biodiversity and conservation value. The West Usambara Mountains stand out as a unique and ecologically diverse area due to the fact that they are home to a remarkable array of plant species, including rare and ancient plant lineages. The montane rainforests, cloud forests, grasslands and heath lands that provide minerals, fuel and habitats for a number of plant species, some of which have evolved specific adaptations to their habitats (Meliyo *et al.,* 2018). Location and topography of the West Usambara Mountains favor it to be a very important region for several plants including Medicinal plants.

The indigenous people of Lushoto are Wasambaa and Wambugu, the dominant group being Wasambaa (78%). Ninety per cent (4500 km²) of the total area of the Lushoto District is covered by West Usambara Mountains (Msuya and Kideghesho, 2009). The area is approximately 90 km long and broader to the east with a width of 31 km and the east is narrow with a width of 19 km (Meliyo *et al.,* 2018). East and West Usambara are the two blocks separated by a 4 km wide Lwengera River Valley, which forms the Usambara Mountains (Meliyo *et al.,* 2018).

According to the 2022 Tanzania National Census, the population of Lushoto District was 492,441 people which is 24.7% of the Tanga Region, citizens who live in 44 Wards including Lushoto, Vuga, Mlalo and Shume where the present research was conducted (Augustino, 2014; United Republic of Tanzania, 2022). In particular, this study was conducted in five villages namely Mwangoi, Viti, Kwemakame, Irente and Kiluwai as shown in Figure 1. The study villages were purposively selected to cover all parts of Lushoto District.

Figure 1

A map of Lushoto District showing the location of study villages



Target population

The target population for this research was the household heads 18 years of age and older who had resided in the area for not less than one year. Also, traditional healers and people who sell and buy medicinal plants within the study area were involved.

Research design

The present study used an exploratory sequential mixed research design to assess preferred medicinal plants used by the people of the West Usambara Mountains (Bryman, 2008). Then, the data obtained on the preferred medicinal plants were mixed with those on diversity, and regeneration potential of the preferred medicinal plants.

This design helped to collect quantitative data required for obtaining preferred medicinal plants and qualitative data for determination of regeneration potential and diversity of medicinal plants in the study area.

Determination of preferred medicinal plants

The preferred medicinal plants were determined by using free listing method (Chatty, Baas, and Fleig, 2003). Pair wise ranking or preference ranking is a tool used to set priorities between different medicinal plants available. In pair wise ranking each medicinal plant was compared directly against others to emerge with the ranking from the highly preferred to least preferred medicinal plants (Chatty *et al.,* 2003).The respondents selected 10 most preferred

medicinal plants from the list obtained from focused group discussion, market survey and household questionnaire. The commonly used medicinal plants were compared with all others in pairs to obtain the rank from first to the last as recommended by Dery *et al.* (1999).

Determination of medicinal plant species diversity

Medicinal plant species diversity was determined in the field through the establishment of quadrats for determination of the abundance, evenness, richness and diversity of different medicinal plant species. The surveys were done from April to August 2022 to cover both seasons (dry and wet seasons). The survey started with taxonomic identification followed by determination of abundance (Iqbal, Pala, Bhat, and Negi, 2012).

Four randomly established plots of 1 h. Five quadrats (rectangular) of 20 m x 25 m within each established plots in each study village (Kuluwai, Kwemakame, Irente, Viti and Mwangoi) were employed, resulting in a total of 100 quadrats within the site of the study. These quadrats covered 20 ha out of 1000 ha that were established in all villages. In every quadrat, trees with diameter at breast height (DBH) ≥ 10 cm were identified to the level of species, medicinal plants demarcated, counted and their measurements (height and width) were taken. Two sub-quadrats of 2 x 5 m within bigger quadrat were designed to sample shrubs (Stohlgren, Falker, and Schell, 1995; Vesa, Malimbwi, Nsokko, Otieno, and Dlsgaard, 2010). On the other hand, determination of herbaceous species and grasses was done using 1 m^2 quadrats which were randomly made within the bigger quadrats of 20 x 25 m and in each species, plants were counted and their numbers were established regarding the size of the quadrats. Species that were difficult to immediately identify in the field were collected, pressed, and taken to the herbarium at Tanzania Forestry Research Institute (TAFORI) for proper determination of unknown identity.

Determination of regeneration potential

Regeneration potential of preferred medicinal plant species was assessed using rectangular quadrats where the number of saplings, seedlings and mature plants were enumerated. The established in 20 x 25 m quadrats were used to enumerate the number of mature plants for regeneration assessment. Within each 20 x 25 m rectangular quadrat, eight 5 x 5 m square quadrats for saplings enumeration and four (1 x1m) square quadrats in each 5x5m quadrats for seedlings enumeration were laid (Stohlgren *et al.*, 1995). Circumference at breast height (CBH), i.e. 1.37m from the soil was used for simplifying the categorisation of the forms of life of the plants into 3 classes i.e. seedlings, saplings, and mature plants(Mishra *et al.*, 2013). Samples were categorised as seedling ≤ 10 cm, saplings11-30 cm or mature plant ≥ 31 cm (Sharma, Mishra, Tiwari, Krishan, and Rana, 2018). Tallying of species in each site was done to quantify seedlings, saplings, and mature plants.

Data analysis

Preferred medicinal plant species diversity

Medicinal plant species diversity was determined using Shannon-Wiener's Diversity Index (H'). Shannon-Wiener's Diversity Index (H') is the most used measure for determination of plant species diversity (Hilonga *et al.*, 2019). Shannon-Wiener's diversity index assumes the sample is representative of the randomly selected species, Shannon-Wiener's diversity index considers both relative abundances (evenness) and the number of species (richness). H' ranges from 0 to 5, mostly ranging between 1.5 and 3.5; the greater the H' the more species diversity.

$$H' = -\sum_{i-l}^{s} Piln\ Pi$$

Where:

H' is Shannon and Wiener's diversity index; S is species number; Pi is individuals in the i^{th} species and their proportion and ln is $\log_e 10$

Species dominance was assessed using the Simpson's dominance index which highlights the dominance of specific within a community. This was done by using the following formula:

$$D = \sum \left({}^{ni}/_{N}\right)^2$$

This means:

D is Simpson's index

ni is sum of Individuals in a particular species

N is sum of individuals of all species involved (Kikoti and Mligo, 2021).

Species evenness was assessed using the Pielou Evenness Index, because it assesses relative abundance of medicinal plants. This was done by using the following formula:

$$E = \frac{H'}{lnS}$$

Where:
E is Pielous Evenness Index
H' is Shannon and Wiener's diversity index;

S is number of species in a community

Species richness was assessed using the Margalef Richness Index because it provides baseline for conservation by providing a reference point for monitoring changes in species richness over time. This was done by using the following formula:

$$DMg = \frac{S - 1}{\ln N}$$

Where:
DMg is Margalef Richness Index
S is the total number of species in a community
N is the total number of individuals in a community

Quantitative data were analyzed by using Statistical package for social science (SPSS) version 23. SPSS was used because it has high data management capability which is essential for preparing datasets for analysis and ensuring integrity of data

Preferred medicinal plants Regeneration potential
Determination of the regeneration of plant species was based on the size and numbers of the population of seedlings, saplings and adults (Sharma *et al.,* 2018), as per the following descriptions:
Regeneration was considered as *good* when the numbers of seedlings were greater than sapling and saplings were greater than adults.

Regeneration was considered as being *fair* when the numbers of the seedlings were greater than saplings and that of saplings were greater or equal to adults.

Regeneration was considered as *poor* when there were saplings without seedlings (irrespective of the relative numbers of saplings and adults).
There was *no regeneration* when there were only adults in the area with neither seedlings nor saplings
Regeneration was considered as *new* if there were no adults only saplings/and or seedlings were seen.

Results

Preferred medicinal plants
Among the 86 medicinal plants mentioned to treat different ailments, each village selected 10 most preferred medicinal plants which were determined using free listing technique. The most listed plants were considered the first by looking at the frequency of mentioning (Malik *et al.,* 2019). The obtained 10 plants were then compared to get the most preferred and the least preferred plants that is, ranking from the first to the last using pairwise ranking method. Free listing and pairwise ranking resulted into different ranks. According to free listing technique the 10 most preferred medicinal plants were obtained by considering their respective frequency. The obtained ten plants included *Vernonia iodocalyx, Grewia bicolor, Vengueria infausta*, *Senna didymobotrya*, *Ocimum suave*, *Cissus rotundifolia*, *Plectranthus barbatus, Warburgia ugandensis*, *Myrica salicifolia* and *Physalis peruviana*
as shown in Table 1

Table 1

Preferred medicinal plants in West Usambara Mountain

S/N	Scientific name	Local name (Kishambaa)	Family	Form	Frequency	Rank
1	*Vernonia iodocalyx* O. Hoffim.	Mhasha	Asteraceae	Herb	25	2
2	*Grewia bicolor* Juss	Mkole	Malvaceae	Tree	18	7
3	*Vengueria infausta* Burch	Mvilu	Rubiaceae	Tree	23	3
4	*Senna didymobotrya* Fresen	Mwinu	Leguminoceae	Shrub	26	1
5	*Ocimum suave* Willd	Mzumbasha	Labiatae	Shrub	20	5
6	*Cissus rotundifolia* Forssk	Ulenge	Vitaceae	Herb	17	8
7	*Plectranthus barbatus* Andr	Mzugwa	Labiaceae	Shrub	22	4
8	*Warburgia ugandensis* Sprague	Mlifu	Canellaceae	Shrub	14	10
9	*Myrica salicifolia* Hochst	Mshegheshe	Myricaceae	Shrub	19	6
10	*Physalis peruviana* L.	Msupu	Solanaceae	Shrub	16	9

High diversity was observed in Mwangoi Village (D = 0.188), followed by Kiluwai Village (D = 0.192), and Kwemakame Village appeared the least diverse (D = 0.416) as indicated in Table 2

Table 2

Species richness, evenness, and diversity of preferred medicinal plants in West Usambara Mountains

Village	Shannon's Diversity Index (H') $H' = -\sum_{i-l}^{s} Pi\ ln\ Pi$	Pielou Evenness Index $E = \frac{H'}{lnS}$	Margalef Richness Index $DMg = \frac{S-1}{\ln N}$	Simpson's Dominance Index (D) $D = \frac{\sum ni(ni-1)}{N(N-1)}$
Kiluwai	1.839	0.2546	1.246	0.192
Irente	1.467	0.2624	1.609	0.361
Kwemakame	1.320	0.2395	1.267	0.416
Viti	1,649	0.3403	1.239	0.221
Mwangoi	1.808	0.3429	1.328	0.188

Where *Pi* represents the number of individuals in a given species over the total number of individuals in a community, *S* denotes the total number of species in a community; *N* represents the total number of individuals in a community

Regeneration potential of preferred medicinal plants

The findings demonstrated that the majority of the therapeutic plants exhibited no regeneration (NR) across all study sites. Kiluwai Village ranked the first in regeneration as it contained all of the ten preferred medicinal plants where one plant (*Vangueria infausta*) had Good regeneration (GR) status, three plants namely *Vernonia iodocalyx, Warburgia ugandensis* and *Myrica salicifolia* had fair regeneration status; where one plant *Senna didymobotrya* had poor regeneration (PR) status while the remaining five preferred medicinal plants had no regeneration (NR) status. Viti Village ranked the second with two preferred medicinal plants (*Myrica salicifolia* and

Vangueria infausta) having fair regeneration (FR) status followed by Kwemakame and Mwangoi Villages where Kwemakame had two plants with fair regeneration (FR) and six plants with no regeneration (NR) status. The last Village was Irente which had two plants (*Plectranthus barbautus* and *Physalis peruviana* with fair regeneration (FR) status and seven plants with no regeneration status as indicated in Table 3.

Table 3

Regeneration potential of preferred medicinal plants in the study villages

	Kiluwai	Irente	Kwemakame	Mwangoi	Viti
V. iodocalyx	FR	NR	NR	NR	NR
W. ugandensis	FR	-	NR	NR	NR
O. suave	NR	NR	NR	NR	-
P. barbatus	NR	-	-	-	-
S. didymobotrya	PR	NR	NR	NR	NR
G. bicolor	NR	NR	NR	NR	NR
M. salicifolia	FR	FR	FR	FR	FR
V. infausta	GR	FR	FR	FR	FR
P. peruviana	NR	NR	-	-	-
C. rotundifolia	NR	NR	NR	NR	NR

Key: GR=Good regeneration, FR=Fair regeneration, PR=Poor regeneration, NR=No regeneration

Discussion

Low diversity of preferred medicinal plant species is caused by human activities particularly uncontrolled harvesting of plants for medicinal purposes. This is because the usual Shannon's plant species diversity range is from 0 to 5 though commonly ranging between 1.5 and 3.5; thus, the diversity values found in all Villages are quite low, indicating the need for additional effort to conserve the preferred medicinal plants. This suggests elimination several species from the habitat that consequently lower the diversity. This result is in line with the study done by Dara (2015) in Pakistan on ethno botany and biodiversity conservation which revealed that most of the preferred medicinal plant species are threatened by excessive usage as medicine. The majority of the chosen therapeutic herbs had no regeneration (NR) implying disappearance of certain plant forms with time. The result was probably caused by the method of harvesting medicinal plants where leaves were the mostly used plant part which implies interference with food manufacturing process (photosynthesis) and mobilization processes. This situation in turn leads into poor plant growth and reproduction. Leaves are important in enabling survival and perpetuation of plant's production of sugar from carbon dioxide (CO_2) fueled by sunlight to provide the plant with energy and organic substances (Roth-nebelsick and Krause, 2023). For example, *P. barbatus* which is found in only one study village (Kiluwai) had no regeneration, the roots and leaves are mostly used which is likely to affect plant anchorage, growth and uptake of minerals. The observed poor and no regeneration statuses of preferred medicinal plants in the study villages serve as indicators of ecological extinction of the plants at local level in the near future. According to Iqbal *et al.,* (2012b), areas characterised by the abundance of only adults of the species or the lack or presence of a very low population of seedlings and saplings are predicted to experience local extinction (Iqbal *et al.,* 2012). Multiple utilisation of the preferred medicinal plants also could be responsible for interfering with regeneration, for example *Ocimum suave* which had no regeneration plays the role of aromatic and medicinal plant (QLeary, 2016). Besides, some fruits for example *Physalis peruviana* have the tendency of lasting for long period of time regardless of the methods used in collecting them (natural or anthropogenic) (Singh *et al.,* 2019). These fruits are important source of nutrition apart from being used for medicinal purpose. The longer stay of the fruit is likely to

interfere with regeneration potential of the plant species.

Some preferred medicinal plants in the study area may have poor or no regeneration status due to a variety of reasons such as fire outbreak (Murthy, Murali, Hegde, Bhat, and Ravindranath, 2002), grazing, canopy density, soil moisture, soil nutrients, and anthropogenic pressure (Iqbal *et al.,* 2012). However, these factors were not covered in this study.

The study area demonstrated poor regeneration and no regeneration status mostly in high altitude villages compared to low altitude villages due to good soil moisture, presence of soil nutrients, and low anthropogenic pressure due to low population density. Moist habitat and stream banks promote regeneration of many tree species by providing adequate moisture for seed germination and seedling survival (Jagdish, Rawat, Rawat, and Jeet, 2010).

Conclusion

Most of the preferred medicinal plants used by the community of West Usambara Mountains are from the family Asteraceae which were mostly used for treating pain and inflammation. Also, the results of this study revealed that most of the preferred medicinal plants have low diversity which is an indication of the future extinction if immediate actions are not taken.

Furthermore, most of the preferred medicinal plants were not regenerating or had a fair regeneration. This also signifies future extinction if conservation measures are not taken. Literature shows that factors such as land clearing for agriculture, animal grazing, altitude and soil characteristics may collectively result in low diversity of plants (Murthy *et al.,* 2002). However, these factors were not covered in this study.

Recommendation

Sustainable harvesting, strengthening community-based conservation and proper selection of plant parts to be used for medicinal purposes is recommended since this will help to conserve the preferred medicinal plants in the study area. Education should be provided to the local community and traditional healers on sustainable use of medicinal plants especially during preparation, storage and the dosage. By consideration of the likelihood of the possible extinction of the preferred medicinal plants due to unsustainable harvesting and maximum utilisation, the study recommends on cultivating some of preferred medicinal plants preferably, *Plectranthus barbatus*, *Physalis peruviana, Wabugia ugandensis* and *Ocimum suave* around households to ensure maximum availability of the plants for future use.
Also, the study recommends on the investigation of the influence of other factors such as altitude, soil characteristics, clearing for agriculture and overgrazing on the diversity and regeneration potential of the preferred medicinal plants.

***Ethical approval*:** Ethical clearance for conducting this study was obtained from the University of Dodoma.

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