The influence of forest proximity to harvesting and use of provisioning ecosystem services from tree species in traditional agroforestry landscapes

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Abstract

Traditional agroforestry landscapes play a critical role in conserving biodiversity and sustaining rural livelihoods through multiple products and services. However, an unprecedented rise in the unsustainable utilisation and management of provisioning ecosystem services from these landscapes contributes to forest biodiversity loss and impacts livelihood efforts. The objective was to evaluate the link between distance and socio-ecological determinants and the provisioning ecosystem services consumption behaviour. This study tested whether "*rural people's preferences and extent of PESs harvesting decrease as the distance from the village to forest patches increase, regardless of the prevalent socio-ecological conditions'*. Using a structured questionnaire survey, data were collected in 882 households in four villages of Thulamela Municipality, Limpopo Province in South Africa. The data were analysed using Chi-square, Fidelity level, Use-value, Friedman test, and Generalised linear model. Consistent with the hypothesis, the results showed that local people harvest most of the provisioning ecosystem services at an immediate (1^{st}) level, followed by intermediate (2^{nd}) and far distance (3^{rd}) levels. This study further revealed the existence of 108 useful tree species in the study areas. This study also found that although socio-ecological determinants influence consumption behaviour, the influence of specific socio-ecological determinants was not consistent across the different regimes of distance from the forest resources. The fact that there is a preference to use and harvest provisioning ecosystem services from the distance regime closest to the household, shows a concerted effort to conserve and enhance the abundance of multipurpose tree species in homesteads and the immediate areas.

Keywords: Harvesting distance level; optimal foraging theory; provisioning ecosystem service; traditional agroforestry landscape; concentric-circle model; Use-value

Introduction

With the growing dominance of humanity in natural ecosystems, forests and woodlands are widely utilised by most rural communities around the world for provisioning ecosystem services (PESs) such as medicine, fuelwood, fodder, and wild food (Zhyla et al. 2018; Hong and Saizen 2019; Hussain et al. 2019; Mushi et al. 2020; Shackleton 2020). The world population depending on PESs for survival has proportionally increased in recent years by over 2 billion people (Sinthumule and Mashau 2020). However, the sources of PESs are currently subjected to intense collection pressure, resulting in the modification of natural landscapes and decline of life-supporting ecosystem services (Vitousek et al. 1997). Hence, we see evidence of the negative impact of over-harvesting and/or use, such as decreased biodiversity including loss of important tree species (Hong and Saizen 2019; Hovek et al. 2020; Sinthumule and Mashau 2020).

Globally, over 2 billion hectares of forest have been degraded, posing a serious threat to species biodiversity, thus reducing PESs and inadvertently impacting human well-being (Feng et al. 2021). This has stimulated research aimed at understanding the socio-ecological determinants (SEDs) of PESs harvesting and use (Augustynczik et al. 2020; Hovek et al. 2020; Musakwa et al. 2020), specifically to investigate factors that influence the harvesting of PESs (Kutal et al. 2021). Some of these studies have shown, for example, that elevation, accessibility, socio-economic status, availability, culture, and distance are major socio-economic ecological determinants that influence the extent of harvesting of PESs (Araia and Chirwa 2019; Ofoegbu and Chirwa 2019; Araia et al. 2020; Gomes et al. 2020; Musakwa et al. 2020; Kutal et al. 2021). However, there is a paucity of information on which factors pre-dominate to inform sustainable forest conservation and management strategies and policies. Recently, many studies have applied the Optimal Foraging Theory (OFT) to disentangle the contribution of different socio-ecological determinants on user behaviour. The OFT suggests that human beings will maximise their gains, whether economic or energy demanding, when extracting PESs (Soldati et al. 2017; Feitosa et al. 2018). The theory is applied to understand the fundamental choices of foragers, such as where to forage, what to forage, and how long to spend foraging (Kefa et al. 2018).

The foragers require time and energy to search for PESs, and the availability of resources influences the choice of the foraging site. This leads foragers to choose foraging sites that combine availability and quantity with minimal distance (Feitosa et al. 2018). If foragers choose their foraging site based on the distance to the forest, perhaps to minimise the collecting energy and travelling time, distance becomes endogenous to PESs harvesting and use. The study by Suleiman et al. (2017) confirmed that the greater the distance from the household to the forest, the less likely the forest will be targeted for collection by the household. However, to our knowledge, there have not been any local studies that investigated how other SEDs influence the harvesting and use-behaviour of households within a specific distance regime of forest resources in human-modified landscapes.

Furthermore, studies show that foragers do not select foraging sites randomly, but rather that foraging distance may be an indicator of availability (Scales and Fries 2019; Luswaga and Nuppenau 2020), scarcity (Kegode et al. 2017) and use-value (Etongo et al. 2017) of the PES in a given foraging site. Availability and use-value of species may compel foragers to travel a long distance to the forest (Luswaga and Nuppenau 2020). Depleting PESs in the forest adjacent to the communities compels foragers to travel a relatively long distance to collect PESs (Makhado et al. 2009). Foragers may have to bridge some distance in space and time to collect PESs necessary for survival. For instance, women and youth foragers may prefer to travel a short distance. Such preference for short-distance areas for harvesting saves energy and time for other productive activities (Uhunamure et al. 2017). Araia and Chirwa (2019) further argued that there is a weak correlation between the specific category utility and use-value of tree species and their ecological abundance. Collection and use of tree species do not imply equal knowledge of the different uses of the trees. Local people do not value and use all the tree species equally because not all species used are known and valuable to everyone in a given area (Camou-Guerrero et al. 2008; Etongo et al. 2017). Hence, understanding the knowledge of forest resources in general and tree species in particular used for a specific utility category, is a socio-ecologically complex issue that may not be fully explained by household distance from the forest resources (Makhado et al. 2012).

The unprecedented rise in the unsustainable utilisation and management of PESs in the Traditional Agroforestry Landscape (TAL) of South Africa has contributed to forest degradation and consequently impacts on livelihoods efforts (Ofoegbu and Chirwa 2019). A detailed understanding of foragers' behaviour will likely be the key to successful forest utilization planning and management in traditional agroforestry landscapes. The main objective of this study was to evaluate the influence of distance and other socio-ecological determinants on PES consumption behaviour in the TAL. Thus, this study tested the hypothesis that '*The extent of rural people's preferences and extent of PES harvesting decrease as the distance from the village to forest patches increases, regardless of the prevalent socio-ecological conditions'*. The following associated research questions were developed to answer the objective: (a) At which distance do local people harvest PESs in TALs? (b) Which tree species are important for different PESs in TALs? (c) What factors determine the extent of PES harvesting at different distance levels?

Research methods

Study area

Limpopo Province is classified as one of the underdeveloped provinces in South Africa (Statistics South Africa 2016), characterised by a persistently high unemployment rate and extreme poverty (Makhubele et al. 2022). The majority of the 5.7 million people in the province live below the poverty line (Statistics South Africa 2016) and heavily depend on PESs (Makhubele et al. 2021), agriculture and social grants (Shackleton 2020). The population growth in the province subsequently increases the demand for PESs and land for agriculture and settlements (Makhubele et al. 2021). This study was conducted in four villages, Damani (22°.50' 45S, 30°.31′38 E), Thenzheni (22°.49' 54S, 30°.28' 57 E), Tshiombo (22°.48' 30S, 30°.30' 53 E) and Tshipako (22°.51' 14S, 30°.28' 59 E) situated in the Vhembe District of the Limpopo Province (Figure 1). The tree cover of Tshipako was approximately 249 hectares, Damani 188 hectares, Tshiombo 515 hectares and Thenzheni 170 hectares.

The annual rainfall of this area is above the threshold of both agriculture and forestry (500 mm-1000 mm per annum). As a result, this rainfall trend offers conducive climatic conditions for agriculture and forestry (Maponya et al. 2019). Thus, the slopes of the south-eastern part of the mountain range are dominated by various farming activities such as agriculture, forestry, and tea plantations (Kori et al. 2018). Native tree species are retained in and outside homesteads. At the same time, people plant diverse exotic species on their homesteads for different utilities. In Vhembe Biosphere Reserve (VBR), tree species diversity in the TAL provides a wide range of uses and PESs, which include fuelwood, medicine, wild fruits, fodder, wild food, timber, soil improvement, fencing, and building materials.

Data collection

Mixed Methods Research (MMR) was used to collect the data using a combination of quantitative and qualitative research techniques (Edmonds and Kennedy 2017; Kimmons 2022). The MMR approach provided a sufficient and in-depth understanding of the influence of distance and socio-economic factors on PES use (Migiro and Magangi 2011; Alavi and Habek 2016), thereby strengthening the study validity and reliability of findings (Hesse-Biber 2010). The purposive samplings were premised on the fact that the study communities are located in the TAL and are in close proximity to the VBR hotspot of forest biodiversity, the Soutpansberg Mountain (Leavy 2017; Lune and Berg 2017). Due to the unprecedented rise in unsustainable harvesting and management of PESs in the TAL, the purposive approach sought to address these challenges (Leavy 2017). The selected communities were Damani, Thenzheni, Tshipako and Tshiombo. Ethical clearance was obtained from the University of Pretoria ethics committee (NAS317/2020). The list of the households in each community was sourced from the communities' leadership for sampling. The sample size was determined at a 95% confidence level and 5% margin of error. The following sample size calculation formula (Alavi and Habek 2016) was used:

$$S = \frac{X^2 N p(1-p)}{d^2(N-1) + X^2 p(1-p)} \tag{1}$$

Where S is the sample size required, X is the confidence interval, N is the population size (N-1), d is the degree of accuracy (0.05) or a margin of error, p is the estimated level (1-p, given as p = 0.5). The calculated sample sizes were 172 for Damani, Tshipako (177), Thenzheni (198) and Tshiombo (335). The household respondents were selected using a random sampling computerised program (random number generator) (Krosnick 2018). For Focus Group Discussion (FGD), quota sampling was adopted to select the participants for FGD (Lune and Berg 2017), and age attributes such as young and older groups were considered to understand their experience and knowledge of harvesting PESs.

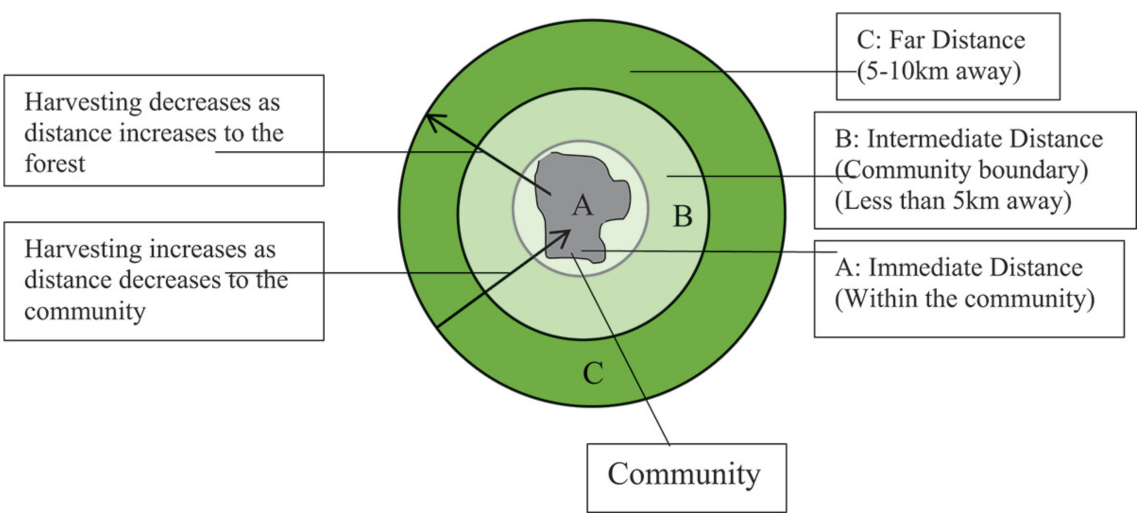

Figure 2. Concentric-circles model of distance levels.

Concentric-circles model for distances classification

The concentric-circles model (CCM) was used to describe the harvesting distances approach that characterises the local people's use of PESs (Hall and Farrell 2001; Gorresen and Willig 2004). This model describes the distances as a set of concentric circles. As shown in Figure 2, set A represents the community and immediate distance, set B denotes the community boundary and intermediate distance (less than 5 km away from the community centre) and set C denotes the far distance measured at 5–10 km. The assumption is that PES harvesting decreases as the distance to the forest increases or vice versa, as indicated by the arrows in the CCM.

Household interviews

A structured questionnaire was used to conduct household surveys (Krosnick 2018; Balza et al. 2021). The questionnaire explored the respondents' harvesting behaviour, knowledge, and experience in relation to PES use, harvesting distance levels, and tree biodiversity in the TAL. In parallel, FGDs were conducted using semi-structured questions to ensure that there was flexibility in questioning and to allow follow-up questions. This approach helped to check the reliability of responses and to validate the data (Lune and Berg 2017; Balza et al. 2021). The FGDs in each community were conducted with a group of young and old participants, including the communities' leadership. The FGD size ranged from 15 to 35 participants and the sessions lasted about 2 hours. A digital audio recorder was used to capture the data during FGD sessions and responses were later transcribed (Balza et al. 2021). The following questions were asked in order to lead the discussions: Where do local people harvest the PESs such as fuelwood, fodder, medicinal plants, and wild fruits/food? Which tree species are mainly used for food, medicine, fuelwood, and livestock fodder? What are the SEDs influencing the use of certain tree species?

Data analysis

The quantitative data were analysed using the Statistical Package for Social Science (SPSS) software, version 23.0. Firstly, the Kolmogorov-Smirnov normality test was performed to check the normal distribution of the data (Mishra et al. 2019; Khatun 2021). The results of the test of the variables were significant ($p < 0.05$). Therefore, the null hypothesis of normal distribution was rejected. Since the results showed no normal data distribution, the non-parametric analysis was applied. Next, demographic variables were analysed using cross-tabulation in percentiles and means.

The homogeneity of the harvesting distance level of provisioning ecosystem services

The homogeneity of the harvesting distance level of PESs among the communities was analysed using the Friedman test of whether there are differences in harvesting distances of PESs among study communities. The results were considered significant at $p < 0.05$. When the significant difference in harvesting distances of PESs was detected in the Friedman test, it was critical to determine which distance level was mostly preferred by the local people. Therefore, the Friedman test was also used to determine the most preferred distances.

Association of the extent of harvesting distance levels and their socio-ecological determinants

A Generalised Linear Model (GLM) with an ordinal logistic distribution (Schmettow 2021) was used to examine the association between the PES harvesting distance levels and their SEDs. SEDs were used as independent variables and the extent of harvesting distance levels as the dependent variables. The following GLM formula was used:

$$Link_{(\Upsilon ij)} = \theta j - (\beta_1 X_{i1} + \beta_2 X_{i2} \ldots + \beta_p X_{ip} \beta \text{ p}) \quad (2)$$

Where *Link* (γ_{ij}) is the link function, γ_{ij} is the cumulative probability of the j^{th} category for the i^{th} case, θj is the threshold for the jth category, p is the number of regression coefficients, X_{i1}, X_{i2}, X_{ip} are the values of the predictors (age, gender, household income, education, cultural value, use-value, elevation, accessibility and availability) for the i^{th} case, β1….βp are regression coefficients.

Importance of tree species based on use-value

To assess tree species use-value, the fidelity level (FL) technique was adopted (da Silva et al. 2014; Araia and Chirwa 2019). The following FL formula was used to calculate the tree species use-value:

$$FL\ (\%) = (I_p / I_u\ ) \times 100\% \quad (3)$$

Where *FL (%)* is the fidelity level or use-value in percentile, I_p is the mention of tree species for a particular use, I_u is the total number of respondents. The fidelity level (use-value) was calculated by dividing the number of mentioned tree species by the total number of respondents in percentiles. The total use-value of tree species was the summation of the use-value of all categories of utility. An Overall Use-Value (OUV) was calculated as the summation of all use-values of four categories. Based on the high use-value score, the top 30 tree species were selected for utility and community comparison categories. The following formula was used to calculate the OUV:

$$OUV = \sum (Food_{uv} + Fuel_{uv} + Medicine_{uv} + Fodder_{uv}) \quad (4)$$

Where OUV is the overall use-value, $Food_{uv}$ is the total food category use-value, $Fuelwood_{uv}$ is the fuelwood category use-value, $Medicine_{uv}$ is the medicine category use-value and $Fodder_{uv}$ is the fodder category use-value.

Results

Demographics

Table 1 shows that the dominating age group of the respondents ranged from 36 to 60 years, representing 58% in Tshipako, 51% in Damani, 38% in Thenzheni and 43% in Tshiombo. Overall, the majority of the respondents were elderly people in all the communities. The study areas were predominated by females, with 74% in Tshipako, 59% in Damani, 55% in Thenzheni and 73% in Tshiombo. Except for Thenzheni where the majority (46%) are self-employed, the main source of income in the study area was a social grant, with 52% in

Tshipako, 31% in Damani, and 47% in Tshiombo dependent on an old-age grant, child support, disability or foster grants. The dominant level of education was secondary education with 63% of people in Tshipako, 48% in Damani, 46% in Thenzheni and 43% in Tshiombo, who attended secondary school.

Table 1. Socio-economic and demographic profile of the study area.

	Proportions of respondents (%)			
Socio-economic	Tshipako (n = 177)	Damani (n = 172)	Thenzheni (n = 198)	Tshiombo (n = 335)
Age of respondent				
18–25	4.52	8.14	7.07	7.76
26–35	17.51	20.35	30.30	16.72
36–60	58.19	50.58	37.88	42.99
>61	19.77	20.93	24.75	32.54
Gender				
Male	25.99	40.70	44.95	26.87
Female	74.01	59.30	55.05	73.13
Household source of income				
No formal income	14.69	27.91	7.58	15.82
Employed	12.99	18.02	14.14	10.45
Self-employed	19.21	20.93	45.45	24.48
Pensioner	1.13	2.33	7.58	2.09
Social grant	51.98	30.81	25.25	47.16
Level of education				
No schooling	4.52	10.47	12.12	15.22
Primary	19.77	21.51	12.12	18.51
Secondary	62.71	48.26	45.45	43.28
Tertiary	12.99	19.77	30.30	22.99

The homogeneity of the harvesting distance level of provisioning ecosystem services

As depicted in Table 2, the results show that there was a statistically significant difference (x^2 = 109.9, $p < 0.05$) in harvesting distance of wild food and fruits across the study areas. The wild food and fruits are harvested at an intermediate distance by 92% in Tshipako and 91% in Thenzheni communities, while 94% in Damani and 85% in Tshiombo harvest wild food and fruits at an immediate distance. The harvesting distance of fuelwood was significantly different (x^2 = 123.4, $p < 0.05$) across the study areas. About 90% of people in Tshipako and 91% in Thenzheni harvested the fuelwood at an intermediate distance, while 90% in Damani and 86% in Tshiombo harvested fuelwood at an immediate distance. There was a significant difference (x^2 = 150.9, $p < 0.05$) in harvesting distance of traditional medicine across the study areas. Traditional medicine was harvested at an intermediate distance by 89% of people in Tshipako and 87% in Thenzheni, while 89% in Damani and 69% in Tshiombo harvested traditional medicine at an immediate distance. The collection of fodder and grazing distance was statistically significantly different (x^2 = 121.9, $p < 0.05$) across the study areas. About 83% in Damani and 73% in Tshiombo collected fodder and grazed their livestock at an immediate distance, while 88% in Thenzheni grazed and collected fodder at a far distance, and 87% in Tshipako harvested at an intermediate distance.

Table 3 shows the Friedman test of significant differences in harvesting distances of PESs. The Chi-square results revealed a significant difference in harvesting distance across the communities. There were significant differences in the distance levels for wild food and fruits (x^2 = 363.8, $p < 0.05$), fuel wood (x^2=300.9, $p < 0.05$), traditional medicine (x^2 = 185.7, $p < 0.05$) and fodder (x^2 = 29.1, $p < 0.05$) (). The Friedman results showed that overall the local people mostly harvest PESs at an immediate distance. The immediate distance was highest ranked (1),

Table 2. Proportion of communities' provisioning ecosystem services harvesting from distance regimes.

		Proportion of respondents (%)				Chi-square	
Provisioning ecosystem services	Distance levels	Damani (n = 172)	Thenzheni (n = 198)	Tshiombo (n = 335)	Tshipako (n = 177)	x^2	*p*-value
Food & Fruits	Immediate	94.20	88.40	85.20	90.80	109.85	0.01
	Intermediate	69.20	90.90	47.80	92.00		
	Far	45.30	86.40	39.80	79.90		
Fuelwood	Immediate	90.10	86.40	86.10	86.20	123.40	0.00
	Intermediate	71.50	91.40	45.40	90.20		
	Far	41.90	85.40	36.50	85.00		
Traditional medicine	Immediate	89.00	82.80	68.80	82.90	150.94	0.00
	Intermediate	62.20	87.40	39.50	89.10		
	Far	44.80	86.40	28.20	81.70		
Fodder	Immediate	83.10	66.20	73.30	66.30	121.96	0.00
	Intermediate	62.20	84.80	43.60	87.40		
	Far	44.80	87.90	36.20	85.70		

Table 3. Friedman's means ranking of the PES harvesting distance levels.

	All communities (n = 882)			
	Food & fruits	Fuelwood	Traditional medicine	Fodder
Distance levels	Mean Rank	Mean Rank	Mean Rank	Mean Rank
Immediate distance	2.38^1	2.37^1	2.27^1	1.88^3
Intermediate distance	1.87^2	1.88^2	1.91^2	2.07^1
Far distance	1.74^3	1.76^3	1.82^3	2.05^2
Chi-Square	363.80	300.78	185.65	29.08
Df	2	2	2	2
Asymp. Sig.	0.00*	0.00*	0.00*	0.00*

*$^{1, 2, 3}$Ranking ranging from highest (1) to (3), *$p < 0.05$*

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followed by an intermediate distance (2) and far distance (3) in three of the PES categories, but not in the grazing and fodder collection category (Table 3).

Importance of tree species based on use-value

Local people used 108 tree species for the selected four categories (food, fuel, medicine, and fodder) of use (Table 4). The leading category of use was medicine. An average of 55 tree species was reported as trees that are used for medicine, comprising 29% of all useful tree species. The second category was fuelwood with an average of 52 tree species (27%), followed by 44 tree species (23%) used for fodder and 40 tree species (21%) for edible trees.

Table 4. Average number of tree species per category of use.

Category of use	The average number of species[a]	Percentage (%)
Food & fruits	40.20	21.02
Fuelwood	52.00	27.15
Traditional medicine	55.25	28.85
Fodder	44.00	22.98

[a]Includes all tree species mentioned (n = 108 species)

Table 5 shows the use-value of selected species of tree for specific and overall use. This study recorded 108 tree species that are useful to local people. The use-value for the selected species showed that the most important species in the four categories in Thenzheni were as follows: food (UV = 0.858, *Englerophytum magalismontanum*), fuel (UV = 0.515, *Xylopia odoratissima*), medicine (UV = 0.510, *Combretum molle*) and fodder (UV = 0.267, *Bridelia micrantha*). Based on the total use-value in the community, *E. magalismontanum* spp. has multiple uses in Thenzheni (UV = 1.005). The most important tree species of the four categories in Tshipako: food (UV = 0.734, *E. magalismontanum*), fuel (UV = 0.672, *Parinari curatellifolia*), medicine (UV = 0.451, *Clematis brachiata*) and fodder (UV = 0.282, *Persea americana*). Based on the total use-value in the community, *E. magalismontanum* spp. has multiple uses in Tshipako (UV = 1.056). The most important tree species of the four categories in Damani: food (UV = 0.430, *E. magalismontanum*), fuel (UV = 0.412, *Albizia adianthifolia*), medicine (UV = 0.267, *Zanthoxylum capense*) and fodder (UV = 0.232, *Dichrostachys cinerea*). Based on the total use-value in the community, *Sclerocarya birrea* spp. has multiple uses in Damani (UV = 0.903). The most important tree species for the four categories in Tshiombo: food (UV = 0.450, *E. magalismontanum*), fuel (UV = 0.179, *Dichrostachys cinerea*), medicine (UV = 0.200, *C. molle*) and fodder (UV = 0.149, *Mangifera indica*). Based on the total use-value in the community, *M. indica* spp. has multiple uses in Tshiombo (UV = 0.582).

Based on the OUV results (Table 5), the top 10 species were selected and considered to be the most important multiple-use tree species within and across the four categories. In descending order (OUV = 3.089–1.290), Munombelo (*E. magalismontanum)*, Muvhungo (*Landolphia kirkii*), Mufula (*S. birrea*), Muvhula (*P. curatellifolia*), Mugwiti (*C. molle*), Muungo (*M. indica*), Muelela (*A. adianthifolia*), Muvhulavhusiku (*X. odoratissima*), Muzwilu (*Vangueria esculenta*) and Muafukhada (*P. Americana*).

Table 5. Use-value of tree species.

Tree species (Top 30 of 108 tree species)	Thenzheni (n = 198)					Tshipako (n = 177)					Damani (n = 172)					Tshiombo (n = 335)					Overall Use Value
	Food	Fuel	Medicine	Fodder	Use V	Food	Fuel	Medicine	Fodder	Use V	Food	Fuel	Medicine	Fodder	Use V	Food	Fuel	Medicine	Fodder	Use V	
Annona senegalensis	0.101	0	0	0.005	**0.106**	0.028	0.005	0.045	0.022	**0.101**	0.081	0.034	0.186	0	**0.302**	0.011	0.056	0.068	0.032	**0.170**	**0.680**
Tabernaemontana elegans	0.030	0.015	0.025	0	**0.070**	0.005	0.033	0.141	0	**0.180**	0.023	0.238	0.104	0	**0.366**	0.002	0.071	0.089	0	**0.164**	**0.781**
Englerophytum magalismontanum	0.858	0.075	0.010	0.060	**1.005**	0.734	0.271	0.039	0.011	**1.056**	0.430	0.063	0	0.017	**0.511**	0.450	0.059	0.005	0	**0.516**	**3.089**
Landolphia kirkii	0.778	0.045	0	0.015	**0.838**	0.728	0.011	0	0.028	**0.768**	0.325	0.005	0.005	0	**0.337**	0.358	0.032	0.005	0.005	**0.402**	**2.346**
Hexalobus monopetalus	0.252	0	0	0	**0.252**	0.248	0.005	0	0	**0.254**	0.186	0	0	0	**0.186**	0.149	0.005	0	0.002	**0.158**	**0.851**
Vangueria esculenta	0.373	0.015	0.005	0	**0.393**	0.293	0.011	0.005	0.016	**0.327**	0.284	0.029	0.011	0	**0.325**	0.250	0.008	0	0	**0.259**	**1.306**
Psidium guajava	0.121	0.015	0	0.055	**0.191**	0.197	0	0.084	0.011	**0.293**	0.139	0.005	0.023	0.046	**0.215**	0.110	0.002	0	0.017	**0.131**	**0.832**
Pterocarpus angolensis	0.156	0.010	0.045	0.005	**0.217**	0.067	0.248	0.056	0.011	**0.384**	0	0.104	0.075	0	**0.180**	0.077	0.083	0.044	0	**0.205**	**0.987**
Mangifera indica	0.056	0.025	0	0.237	**0.318**	0.237	0.039	0	0.248	**0.525**	0.273	0.058	0	0.104	**0.436**	0.367	0.065	0	0.149	**0.582**	**1.861**
Persea americana	0.025	0.025	0	0.257	**0.308**	0.096	0	0.005	0.282	**0.384**	0.127	0.029	0	0.145	**0.302**	0.167	0.008	0	0.119	**0.295**	**1.290**
Grewia microthyrsa	0.040	0.005	0	0.040	**0.085**	0.124	0.062	0	0.045	**0.231**	0.220	0.052	0	0	**0.273**	0.277	0.152	0.005	0	**0.435**	**1.026**
Citrus sinensis	0.030	0	0	0.045	**0.075**	0.107	0.005	0	0.084	**0.197**	0.255	0	0	0.034	**0.290**	0.214	0.008	0	0.008	**0.232**	**0.797**
Sclerocarya birrea	0.030	0.101	0.111	0.141	**0.383**	0.045	0.112	0.372	0.090	**0.621**	0.215	0.366	0.174	0.145	**0.901**	0.008	0.089	0.137	0.056	**0.292**	**2.199**
Bridelia micrantha	0.085	0.181	0	0.267	**0.535**	0.016	0.056	0.005	0.084	**0.163**	0	0.075	0	0	**0.075**	0	0.026	0.023	0.011	**0.062**	**0.837**
Albizia adianthifolia	0	0.232	0.015	0.065	**0.313**	0	0.214	0	0.163	**0.378**	0	0.412	0.046	0.151	**0.610**	0	0.047	0.005	0	**0.053**	**1.355**
Parinari curatellifolia	0	0.363	0.020	0.101	**0.484**	0.084	0.672	0.079	0.062	**0.898**	0.104	0.319	0.075	0.011	**0.511**	0.038	0.170	0.026	0.002	**0.238**	**2.133**
Acacia ataxacantha	0	0.207	0.015	0.075	**0.297**	0	0.067	0	0.067	**0.135**	0	0.058	0.005	0	**0.063**	0	0.032	0	0	**0.032**	**0.530**
Dichrostachys cinerea	0	0.050	0.025	0.090	**0.166**	0	0.011	0.016	0.197	**0.225**	0	0.180	0.038	0.232	**0.447**	0	0.179	0.011	0	**0.191**	**1.031**
Xylopia odoratissima	0	0.515	0.015	0.005	**0.535**	0	0.423	0.016	0.028	**0.468**	0	0.104	0.127	0.011	**0.244**	0	0.083	0	0	**0.083**	**1.332**
Heteropyxis natalensis	0	0.191	0.075	0.015	**0.282**	0	0.107	0.005	0.101	**0.214**	0	0.063	0	0	**0.063**	0	0.023	0	0.002	**0.026**	**0.588**
Peltophorum africanum	0	0.050	0.030	0.035	**0.116**	0	0.022	0.220	0.101	**0.344**	0	0.209	0.052	0.034	**0.296**	0	0.119	0.086	0.017	**0.223**	**0.981**
Combretum molle	0	0.106	0.510	0.030	**0.646**	0	0.305	0.446	0.056	**0.807**	0	0.087	0.110	0	**0.197**	0	0.083	0.200	0	**0.283**	**1.935**
Pteleopsis myrtifolia	0	0.005	0	0	**0.005**	0	0.237	0	0.186	**0.423**	0	0.273	0.017	0.040	**0.331**	0	0.158	0	0.017	**0.176**	**0.936**
Faurea saligna	0	0.156	0	0	**0.156**	0	0.282	0	0.005	**0.288**	0	0.011	0	0	**0.011**	0	0	0	0	**0**	**0.456**
Zanthoxylum capense	0	0.005	0.085	0	**0.090**	0	0.005	0.367	0	**0.372**	0	0	0.267	0.005	**0.273**	0	0	0.143	0.005	**0.149**	**0.886**
Securidaca longepedunculata	0	0	0.500	0	**0.500**	0	0	0.225	0	**0.225**	0	0.017	0.081	0	**0.098**	0	0	0	0	**0**	**0.824**
Wrightia natalensis	0	0	0.368	0	**0.368**	0	0	0.005	0	**0.005**	0	0	0	0	**0**	0	0	0.014	0	**0.014**	**0.389**
Clematis brachiata	0	0	0.060	0.015	**0.075**	0	0.005	0.451	0	**0.457**	0.005	0	0.098	0	**0.104**	0	0	0.083	0	**0.083**	**0.721**
Erythrina lysistemon	0	0	0.010	0.232	**0.242**	0	0	0	0.022	**0.022**	0	0.034	0.040	0	**0.075**	0	0	0.017	0	**0.017**	**0.358**
Melia azedarach	0	0	0	0.126	**0.126**	0	0	0.028	0.265	**0.293**	0	0	0.011	0.186	**0.197**	0	0.029	0.011	0.044	**0.086**	**0.704**
Totals	**2.939**	**2.398**	**1.929**	**1.924**	**9.191**	**3.169**	**3.220**	**2.621**	**2.197**	**11.056**	**2.674**	**2.837**	**1.552**	**1.168**	**8.232**	**2.486**	**1.602**	**0.985**	**0.498**	**5.573**	**34.054**

Use V = Use-value

Table 6. The influence of socio-ecological determinants on the extent of harvesting of wild food and fruits at different distance levels.

Wild food & fruits harvesting			95% Confidence Interval			
Distance level	Socio-ecological determinants	B	Lower	Upper	Wald	Sig.
Immediate	Age	.041	−.135	.217	.204	0.651
	Gender	.217	−.060	.495	2.353	0.125
	HH Income	−.112	−.206	−.017	5.348	0.021*
	Education	−.035	−.198	.128	.177	0.674
	No.HM	−.013	−.070	.043	.215	0.643
	Culture value	.056	.006	.106	4.883	0.027*
	Use-value	.100	.053	.146	17.848	0.000*
	Elevation	.032	−.009	.079	2.299	0.129
	Accessibility	.047	−.001	.096	3.687	0.005*
	Availability	.056	.007	.105	4.972	0.026*
Intermediate	Age	−.041	−.216	.135	.205	0.651
	Gender	−.230	−.508	.048	2.621	0.105
	HH Income	−.035	−.130	.061	.507	0.476
	Education	−.039	−.201	.123	.223	0.637
	No.HM	.032	−.024	.088	1.225	0.268
	Culture value	.039	−.033	.111	1.139	0.286
	Use-value	.034	−.034	.101	.952	0.329
	Elevation	−.024	−.084	.037	0.590	0.442
	Accessibility	5.569	−.070	.070	0.000	0.999
	Availability	.063	−.008	.134	2.989	0.084
Far distance	Age	−.090	−.257	.078	1.100	0.294
	Gender	−.133	−.396	.130	.985	0.321
	HH Income	−.037	−.126	.053	.640	0.424
	Education	−.083	−.235	.069	1.152	0.283
	No.HM	.001	−.053	.055	.002	0.961
	Culture value	.038	−.039	.116	.940	0.332
	Use-value	.021	−.051	.094	.328	0.567
	Elevation	−.016	−.081	.049	.243	0.622
	Accessibility	.006	−.069	.081	.024	0.876
	Availability	−.032	−.109	.045	.667	0.414

Sig. = Significance at p value < 0.05, HH Income = Household income, No.HM = Number of Household Members

Association of harvesting distance levels and their socio-ecological determinants

Wild food and fruits harvesting distance level

Table 6 presents the GLM odds ratios and their 95% confidence intervals for each harvesting distance level and the associated SEDs. The results showed that the harvesting of wild fruits and food at immediate distance was significantly more likely to be influenced by the cultural value (Wald = 4.883, $p < 0.05$), use-value (Wald = 17.848, $p < 0.05$), accessibility (Wald = 3.687, $p < 0.05$) and availability (Wald = 4.972, $p < 0.05$) of the wild fruits and food. On the other hand, household income was significantly less likely to influence (Wald = 5.348, $p < 0.005$) the harvesting of wild fruits and food at the immediate distance. During FGD, Tshiombo participants indicated that they survive by collecting wild fruits in the forest close to their community and selling them along the streets. The 95% confidence interval depicts no significant ($p > 0.05$) difference in the association of age, gender, education, and number of household members of harvesting wild food and fruits at an immediate distance. The model analysis at a 95% confidence interval showed that age, gender, household income, education, number of household members, cultural value, use-value, accessibility and availability are not statistically significant determinants of harvesting wild food and fruits at intermediate and far distance levels.

Fuelwood harvesting distance level

Based on the GLM model results in Table 7, harvesting of fuelwood at an immediate distance was significantly less likely to be influenced by education (Wald = 4.508, $p < 0.005$). However, the harvesting of fuelwood was more likely to be influenced by the use-value (Wald = 6.209, $p < 0.005$) and elevation (Wald = 4.755, $p < 0.005$). On the other hand, age, gender, household income, number of household members, cultural value, accessibility and availability were not statistically significant ($p > 0.05$) determinants of harvesting fuelwood at an immediate distance. The model showed that age, gender, household income, education, number of household members, cultural value, use-value, accessibility and availability are not statistically significant determinants ($p > 0.005$) of harvesting fuelwood at an intermediate level. However, the likelihood of harvesting fuelwood at far distance was significantly more likely to be influenced by household income (Wald = 4.034, $p < 0.005$) and use-value (Wald = 4.493, $p < 0.005$). On the other hand, gender was significantly less likely (Wald = 5.603, $p < 0.005$) to influence the harvesting of fuelwood at far distance. Furthermore, the results showed that age, education, number of household members, cultural value, accessibility and availability are not statistically significant determinants ($p > 0.005$) of harvesting fuelwood at far distance.

Traditional medicine harvesting distance level

Table 8 presents the GLM odds ratios and their 95% confidence intervals for each harvesting distance level and the interactions of SEDs. The GLM results showed that the harvesting of traditional medicine at an immediate distance was significantly less likely to be influenced by education (Wald = 8.744, $p < 0.005$), cultural value (Wald = 8.117, $p < 0.005$), use-value (Wald = 10.700, $p < 0.005$) accessibility (Wald = 9.180, $p < 0.005$) and availability (Wald = 8.424, $p < 0.005$). The age, gender, household income, number of household members and elevation are not statistically significant ($p > 0.05$) determinants of harvesting traditional medicine at an immediate distance in the communities. The model analysis at a 95% confidence interval showed that age, gender, household income, education, number of household members, cultural value, use-value, accessibility and availability are not statistically significant

Table 7. The influence of socio-ecological determinants on the extent of harvesting of fuelwood at different distance levels.

Fuelwood harvesting		95% Confidence Interval				
Distance level	Socio-ecological determinants	B	Lower	Upper	Wald	Sig.
Immediate	Age	−.141	−.316	.034	2.491	0.114
	Gender	.009	−.266	.283	.004	0.951
	HH Income	−.006	−.101	.089	.015	0.901
	Education	−.173	−.334	−.013	4.508	0.034*
	No.HM	−.026	−.082	.030	.810	0.368
	Culture value	.046	−.008	.099	2.831	0.092
	Use-value	.063	.013	.113	6.209	0.013*
	Elevation	.049	.005	.094	4.755	0.029*
	Accessibility	.029	−.022	.081	1.249	0.264
	Availability	.026	−.027	.078	.929	0.335
Intermediate	Age	−.087	−.252	.079	1.051	0.305
	Gender	−.084	−.347	.179	.390	0.532
	HH Income	.073	−.019	.164	2.444	0.118
	Education	−.037	−.191	.116	.225	0.636
	No.HM	.013	−.040	.066	.223	0.637
	Culture value	.063	−.010	.135	2.895	0.089
	Use-value	.028	−.040	.096	.663	0.416
	Elevation	.003	−.057	.064	.011	0.917
	Accessibility	.028	−.043	.098	.598	0.439
	Availability	.022	−.050	.094	.367	0.545
Far distance	Age	−.043	−.205	.120	.264	0.607
	Gender	−.313	−.571	−.054	5.603	0.018*
	HH Income	.091	.002	.179	4.034	0.045*
	Education	.024	−.126	.173	.095	0.757
	No.HM	.038	−.014	.091	2.097	0.148
	Culture value	.036	−.042	.114	.824	0.364
	Use-value	.079	.006	.151	4.493	0.034*
	Elevation	−.023	−.088	.043	.458	0.498
	Accessibility	−.004	−.079	.072	.008	0.928
	Availability	−.003	−.080	.074	.006	0.939

**Sig. = Significance at p value < 0.05, HH Income = Household income, No.HM = Number of Household Members*

Table 8. The influence of socio-ecological determinants on the extent of harvesting of traditional medicine at different distance levels.

Traditional medicine harvesting		95% Confidence Interval				
Distance level	Socio-ecological determinants	B	Lower	Upper	Wald	Sig.
Immediate	Age	−.030	−.198	.138	.123	0.726
	Gender	.027	−.239	.293	.039	0.843
	HH Income	−.023	−.116	.069	.246	0.620
	Education	−.236	−.392	−.079	8.744	0.003*
	No.HM	−.033	−.088	.022	1.419	0.234
	Culture value	−.526	−.887	−.164	8.117	0.004*
	Use-value	−.571	−.913	−.229	10.700	0.001*
	Elevation	−.229	−.553	.095	1.924	0.165
	Accessibility	−.545	−.898	−.193	9.180	0.002*
	Availability	−.530	−.888	−.172	8.424	0.004*
Intermediate	Age	−.096	−.263	.071	1.276	0.259
	Gender	−.138	−.400	.125	1.056	0.304
	HH Income	.077	−.012	.167	2.885	0.089
	Education	−.046	−.197	.106	.354	0.552
	No.HM	−.024	−.076	.029	.778	0.378
	Culture value	.018	−.313	.348	.011	0.917
	Use-value	−.252	−.556	.053	2.626	0.105
	Elevation	.193	−.083	.470	1.886	0.170
	Accessibility	−.063	−.382	.257	.147	0.701
	Availability	.033	−.294	.360	.039	0.843
Far distance	Age	−.116	−.278	.046	1.961	0.161
	Gender	−.074	−.332	.184	.319	0.572
	HH Income	.076	−.012	.165	2.894	0.089
	Education	.003	−.146	.151	.001	0.970
	No.HM	−.007	−.059	.045	.073	0.787
	Culture value	.062	−.256	.380	.144	0.704
	Use-value	.032	−.265	.329	.045	0.832
	Elevation	.154	−.112	.420	1.290	0.256
	Accessibility	.149	−.161	.459	.885	0.347
	Availability	.170	−.146	.485	1.112	0.292

* Sig. = Significance at p value < 0.05, HH Income = Household income, No.HM = Number of Household Members

determinants ($p > 0.005$) of harvesting traditional medicine at an intermediate and far distance level.

Discussion

Provisioning ecosystem services and the harvesting distance

This study provides valuable information regarding patterns of PES utilisation in relation to harvesting distance level. Rural communities demonstrated optimal choices that maximise utility when deciding whether or not to harvest PESs from forest sources, and the distance (proximity) to the forest resources influenced these choices. The findings reveal that the PESs such as wild food and fruits, fuelwood and traditional medicine are widely utilised by rural people from immediate distances followed by intermediate and far distances, respectively. However, rural people rely more highly on intermediate and far distances for livestock fodder (grazing) than immediate distance. Overall, this study found that rural people rely on 108 tree species for various PESs that are crucial to maintaining their livelihood demands. These include a number of useful tree species for traditional medicine, fuelwood, livestock fodder (grazing) and wild food in descending order.

Though several studies demonstrate that PES harvesting behaviour is influenced by different SEDs, such as (i) availability (Hora et al. 2021), (ii) socio-economic factors, (iii) culture (Hora et al. 2021), and (iv) species-level (Leaver and Cherry 2020), this study also found that the influence of a given socio-ecological factor was not consistent across the different distance regimes from the forest resources. Our finding implies that distance regimes may highly influence human behaviour in forest resource harvesting consistent with the Optimal Foraging Theory (Soldati et al. 2017; Feitosa et al. 2018). Our finding is consistent with Mohammed and Inoue (2017) who reported that as the distance from communities to the forest resources increases, there is less likelihood that communities will harvest the PESs at far distance depending on the prevalent socio-ecological factors that differ from one community to other.

For instance, while the PESs such as wild food and fruits, fuelwood and traditional medicine were harvested at the immediate harvesting distance level at Damani and Tshiombo, in the other communities (Tshipako and Thenzheni), these were harvested at a far distance level. This may be attributed to the fact that Damani and Tshiombo communities had more forest trees at their immediate distance compared to the other communities. Furthermore, the FGD with communities at Tshipako and Thenzheni revealed that overharvesting of wild fruits and fuelwood at an immediate distance caused a decline in the availability of forest trees. Thus, forest degradation becomes severe in the near distance. Hence, the residents are compelled to travel relatively long distances in search of PESs. As resources become scarce, people may infringe on the relatively intact forests in distant areas. To avoid this, forest conservation and tree planting in the near distance become crucial. Though, ecological assessment results showed that Tshiombo community harvest fuelwood at an immediate distance, evidence of high fuelwood harvesting at a far distance was observed in Tshiombo (Figure 3, right photo).

Figure 3. Left photo: *Parinari curatellifolia* tree species fuelwood left to dry in the forest (Thenzheni). Right photo: stacks of fuelwood (mixed species, including *X. odoratissima, Pteleopsis myrtifolia, Parinari curatellifolia*, etc.) left to dry in the forest (Tshiombo) .

In the context of tree species, scarcity and community leadership (traditional authorities) restrictions on harvesting fuelwood directly influence the choice of harvesting distance level and the quantity of harvested fuelwood. As depicted in Figure 3, large stacks of fuelwood were harvested illegally and hidden in the forest in Thenzheni and Tshiombo. Similarly, Kyaw et al. (2020) reported that an increase in distance from the human residents to the forests increased the quantity of the fuelwood harvested in the forest. Evidently, due to an increase in harvesting distance, the traditional medicine harvesters in some parts of Limpopo Province harvest large quantities (Semenya et al. 2013).

On the contrary, several studies indicated that an increase in harvesting distance decreases the amount of PESs harvested (Singh et al. 2021). These harvesting behaviours may lead to a high incidence of forest degradation in the proximate forest, and degraded forests would impede the rural people's livelihood. The rate of fuelwood extraction in southern Africa is unsustainable (Rasimphi and Tinarwo 2020). The findings of this study demonstrate that, although OFT may be used as a guide, the local level SEDs need to be integrated with conservation strategies and the sustainable harvesting practice in the TAL. Sustainable utilisation of PESs is pivotal to ensuring sustainable forest production of goods and services for current and future generations (Mohammed and Inoue 2017; Amadu et al. 2021).

Importance of tree species based on the use-value

The local people within the study sites were found utilising various tree species for various use categories. The highest percentage of the cited tree species were being used for traditional medicine. Unsurprisingly, the studies conducted by Ramarumo and Maroyi (2020), and Ndhlovu et al. (2019) reaffirmed that most of the tree species in VBR are utilized for medicinal purposes. This shows the knowledge and great dependence of rural people on traditional medicine for health care. This high number of tree species used for traditional medicine is greatly influenced by the direct contact of local people with PESs and the rural communities' closeness to the forest (Gomes et al. 2020).

This study found that the second use category of the number of important tree species as cited was fuelwood. In contrast, a study conducted in Himalayan traditional agroforestry systems reported that the leading use category for most tree species was fuelwood (Pangging et al.

2017). This implies that fuelwood harvesting in traditional agroforestry is equally critical to people's livelihood. During FGD in Damani, Tshipako and Thenzheni, the participants indicated that they harvest fuelwood for both household consumption and commercial purposes. Female participants at Tshipako said, '*We survive by selling fuelwood and sometimes wild fruits because we are not employed, people come with bakkies (pick-ups) from far places every week to buy our fuelwood*'. In addition, during the survey, large stacks of fuelwood for sale were observed along the streets within the communities, and fuelwood stacks selling in Damani as per Figure 4. According to the respondents at Damani and Tshipako, one stack of fuelwood normally sells from 350ZAR (24.9USD) to 600ZAR (42.8USD); the prices depend on the quality of the wood, while in Thenzheni, processed fuelwood is sold and priced using a small scale of three sections (Figure 4). One stack of the processed fuelwood costs 400 ZAR (28.54USD).

Figure 4. Right photo: on-market fuelwood stack (Damani). Left photo: Fuelwood sales measuring scale at Thenzheni.

An unprecedented increase in the harvesting of fuelwood and traditional medicine poses a serious threat to tree species diversity in the TAL, which could lead to forest degradation (Specht et al. 2015). In South Africa, commercial exploitation of traditional medicine and fuelwood caused a decline in tree species in some parts of the country (Leaver and Cherry 2020). Though several studies reported that availability, socio-economic factors, distance and cultural factors (Araia and Chirwa 2019) influence tree species utilisation, human behaviour and harvesting decision-making based on distance also play a role (Lenfers et al. 2018).

The most important tree species used by the local people in the study communities differ considerably, despite living in the same cultural landscape. However, the *E. magalismontanum* species is a predominantly used wild fruit tree species within the study sites. This might be an indication of the high value, abundance and extent of knowledge of the tree species in VBR. Araia and Chirwa (2019) reported that the user preference of *E. magalismontanum* species in VBR is more due to the traditional ecological knowledge that exists, rather than the abundance of the species. Tree species used for fuelwood, traditional medicine and fodder were differently valued in the study sites. The results illustrate that despite living in the cultural landscape, the user preference for tree species differs. This may indicate that the local abundance of species differs from site to site (Kunwar et al. 2020), and this may override the predominance of culture over ecological abundance in use decision-making. This study revealed that the multipurpose tree species, *E. magalismontanum* (Figure 5) has several different uses, such as fuelwood, fruits, medicine and fodder in Thenzheni and Tshipako.

Figure 5. *Englerophytum magalismontanum* tree species.

However, the multiple uses of a single tree species have a negative impact on the tree species abundance due to high demand and harvesting intensity, thereby posing a threat to the tree species (Rasethe et al. 2013; Sinthumule and Mzamani 2019). Tshipako respondents reported a decline of *E. magalismontanum* species in the forest adjacent to the community. Surprisingly, the multiple-use tree species in the Damani community is *S. birrea*, which is one of the protected tree species in terms of the National Forests Act of 1998 (Act 84 of 1998) in South Africa. A recent study by Sinthumule and Mzamani (2019) reported the multiple uses of *S. birrea* in rural communities. According to the Forest Act, *Sclerocarya birrea* is not supposed to be cut, damaged, removed or disturbed unless a license has been granted by the forestry department. The multiple-use tree species in the Tshiombo community is interestingly a domesticated tree species, *M. indica* species. The *M. indica* species is one of the dominant fruit species in homesteads of VBR TALs (Ayisi et al. 2018). In rural communities, *M. indica* is used for multiple purposes such as fuelwood, shade and fruits. The multiple uses of domesticated or cultivated trees could perhaps ease the pressure on PESs as they could serve as an alternative. However, from the top 10 multiple-use tree species found in this study, *E. magalismontanum, Landolphia kirkii, S. birrea, P. curatellifolia, C. molle, M. indica, A. adianthifolia, X.odoratissima, Vangueria esculenta* and *P. Americana*, only two domesticated species were found, the *M. indica* and the *P. Americana*. It is clear from the fact that a protected tree species (*Sclerocarya birrea*) is within the top 10 multiple-use tree species, that there is a need for effective policy enforcement and for communities to plant more multipurpose indigenous trees, including protected trees such as *S.birrea*.

Correlation of socio-ecological determinants and extent of harvesting of provisioning ecosystem services

Similar to Rasethe et al. (2013), the results of this study showed that although distance influences the PES user behaviour, the extent of resource harvesting at each distance is also influenced by different SEDs. In particular, our study found that the extent of PES harvesting was influenced by a larger number of SEDs (gender, household income, education, cultural value, use-value, elevation, accessibility and availability) in almost all use categories, depending on the distance level.

The results showed that people with low income are more likely to harvest wild food or fruits at an immediate distance compared with high-income people. Similarly, low-literacy people are more likely to harvest fuelwood at an immediate distance compared with educated people. Unsurprisingly, females are less likely to harvest fuelwood at a far distance compared to their male counterparts. Harvesting of fuelwood at an immediate distance by females reduces the hardship in fuelwood collection, by minimising the travelling distance, time and possible encounter with wild animals. Thus perhaps the majority of females may prefer to harvest in the forest adjacent to the communities.

Fuelwood is the affordable, accessible and available source of energy in rural communities (Semenya and Machete 2019). Therefore, the rural poor people would harvest at an immediate distance, avoiding attaching the cost of travelling, time and transport to collecting fuelwood. It is a common strategy of the poorer communities to utilise forest resources adjacent to their communities to make savings for other needs (Temudo et al. 2020), while higher-income people are more likely to harvest fuelwood at a far distance. The FGD participants at Tshiombo indicated that harvesting fuelwood at a far distance is a challenge if you do not have transport or money to pay for transport; therefore, they harvest from the forest around or within their community. Also, harvesting fuelwood at a close distance reduces the burden of walking a long distance with a heavy fuelwood load (Uhunamure et al. 2017).

The results showed that the educated local people are less likely to harvest traditional medicine at an immediate distance compared to low-literacy people. Mostly, educated people are working class, and can therefore afford health care centres, while the low-literacy classes are compelled to use traditional medicine found at their homestead or in adjacent forests for their primary health care (Kunwar et al. 2020). During an interview, participants indicated that they use Tshiumbeumbe (*Clematis brachiata*) to treat flu and COVID-19 (SARS-CoV-2) related symptoms, harvested in their homestead and forests adjacent to their community. Regardless of households' SEDs, this study's results show that local people's harvest of PESs decreases as the distance to the forests increases. Similar findings were reported by Singh et al. (2021) regardless of socio-economic status.

Conclusion

PESs form the pillar of livelihood strategies of local people, with a huge part of the population highly depending on PESs for survival in most developing countries. This study was an attempt to understand the human harvesting behaviour in obtaining PESs in TALs in relation to distance. This study found that distance determines harvesting behaviour. However, the extent of harvesting at each distance is also influenced by prevailing local socio-ecological conditions. The results showed that when the distance from the communities to the forest increases, the harvesting decreases as projected by the results ranking in this sequence: immediate, intermediate and far distance. The results are consonant with the assumption and advance support to the applicability of optimal foraging theory to human PESs harvesting behaviour. Despite local people living in the same cultural landscape with different socio-ecological conditions, their livelihood strategies and harvesting patterns of PESs are similar.

From ethnobotanical analysis, there are many tree species used multi-purposely such as for fuelwood, traditional medicine, fodder and wild food or fruits. However, there is a scarcity of indigenous species used for multiple-purpose. Perhaps, for the conservation of tree species biodiversity, planting indigenous tree species for multiple uses could ease the demand and pressure in the natural forest adjacent to TALs. There is a need for speedy research on the multi-use of *E. magalismontanum* species and the associated importance of taking necessary measures for the conservation of this species. Furthermore, research on protected tree species in the TAL is very important, as *S. birrea* species was found in multi-use categories such as fuelwood, while according to forest policy, the tree species is protected for such use. This study underscores the importance of harvesting distance and the extent of the use of PESs in conservation strategies in TALs. The fact that there is a preference to use and harvest provision ecosystem services from the nearest distance to the household, means that a concerted effort to conserve and enhance the abundance of multi-purpose tree species in homesteads and the immediate areas is crucial. This may alleviate use pressure on the relatively intact forest patches in the intermediate and far distance. At the same time, any conservation intervention should consider the local socio-ecological conditions that do have an influence on the extent of PESs at different distance regimes in TALs.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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