

The linkages between local Ecological knowledge and land-use allocation among rural communities in South Africa

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Abstract: Land-use allocation is a management framework for sharing land resources among different uses for diverse purposes. This study investigated household local knowledge and land-use allocation using two local municipalities in South Africa. The study aimed to understand the interactions among household knowledge systems, environmental parameters, and how these influence land use allocation decisions. A quantitative research design was employed, involving a questionnaire covering household ecological knowledge. The field observations and questionnaire data were coded and analyzed using Microsoft Excel to yield valuable statistics. Spearman's correlation (two-tailed), multiple regression, and two-way ANOVA analyses were applied in hypothesis testing. The findings inferred a strong linkage between land-use allocation and ecological knowledge. The community's land allocation for different purposes depends on their education level, occupational status, resource access, and residence time. Local ecological knowledge about rainfall, the onset of seasons, temperature range, and soil type influences cropping and land utilization. The local ecological knowledge acquired from formal or informal sources significantly influences land use, planning, and management of land resources. Therefore, incorporating indigenous knowledge during land-use allocation is essential for the resilience of rural economies and livelihoods. This paper provides attention to the central contribution of local ecological knowledge to the information of sustainable land-use planning and rural development policy guidance.

1. Introduction

Livelihood is a cumulative outcome of a complex system that depends on ecological, environmental, economic, and institutional arrangements. It depicts the relationships between individuals and their environment (Lan et al., 2021). A robust livelihood mechanism maintains its balance despite socio-economic and ecological changes (Mubbin et al., 2022). It empowers humans to cope with shocks and stresses without disturbance (Gwiriri et al., 2021). Therefore, it should be flexible in dealing with high-risk combinations. Thus, it depends on various capital/ assets and activities, i.e., livelihood strategies driven by critical decisions such as land-use allocation. Local Ecological Knowledge (LEK) characteristically influences cardinal decisions that decide livelihoods (Li et al., 2024).

Local ecological knowledge is the cumulative body of knowledge, practices, and beliefs that evolve through adaptive processes (Lam et al., 2020; Bernard et al., 2024). Therefore, it reflects perceptions and practices based on human interactions with the environment (Mosissa et al., 2017; Vortkamp and Hilker, 2023). The formal and/or informal systems for acquiring knowledge, values, skills, and social attitudes define this knowledge framework (Wu et al., 2020). It trickles down among generations through cultural diffusions and demographic interactions. Ecological knowledge succinctly describes an individual's ability to identify the symbols, concepts, and inclinations for ecological integrity (Debrah et al., 2021; Durar et al., 2023). Thus, LEK stimulates people's interest, awareness, and proclivities toward ecological resilience (Peattie, 2010; Scott and Vigar-Ellis, 2014). At the same time, the community's well-being depends on the efficiency of the land allocation mechanism (Warden et al., 2024). Hence, dexterous decision-making through LEK is required to improve land productivity and human well-being (Tang et al., 2013; Mohammadi et al., 2021).

Therefore, empirical information from the grassroots level is vital. They infer the perceptions and orientations regarding LEK. According to Cook et al. (2014), local ecological knowledge includes people's life experiences that reflect their dialectical interactions with the natural environment (Kupika et al., 2019). Environmental and ecological knowledge contribute to the resilience of the natural and human environment (Dewulf et al., 2020) that is incumbent for social, economic, and environmental stability (Shi et al., 2023). It plays a decisive role in situations where the patterns of change and growth are dynamic and interwoven. Thus, LEK is critical for ensuring integrated ecosystem management and community-based adaptation strategies (Kupika et al., 2019). United Nations Convention to Combat Desertification (UNCCD) recognizes LEK's significance for ensuring sustainable development (Edsand and Broich, 2020). It offers crucial inputs for public and private decision-making.

South African land use is shaped by the interacting dynamics between environmental knowledge and ecological knowledge (LEK) that shape environmentally sustainable peri-urban and rural resource management (Bird et al., 2024). LEK influences the agriculture, water harvesting, and wildfire avoidance of the local and indigenous population, promoting the resilience of the ecosystem (Bird et al., 2024). Environmental awareness, including biodiversity conservation and climate change adaptation, contributes more authority to land-use choice, particularly soil erosion and drought (Ziervogel et al., 2024). Industrialization, agriculture, urbanization, and the absence of policy integration are, however, endangering long-term sustainability of such knowledge systems (Shackleton et al., 2024). Gender and age differences affect knowledge exchange, and critical comment by women and old people is known to be excluded from planning (Agarwal, 2024). Joining LEK with scientific land-use models improves growth and environmental concord (Reyers et al., 2025). Pastoral grazing has recovered lost land in the Eastern Cape (Cundill et al., 2024). Land security of tenure and policy mainstreaming of LEK are significant to increase sustainability (Ostrom et al., 2025), assisting in offering resilience and culture conservation in South Africa.

Contrary to that, the decision-makers have less acknowledgment of LEK and its usefulness. Thus, it entails a better understanding of the decision-making processes regarding environmental and land resources (Dewulf et al., 2020; Christensen and Eetvelde, 2024). Land allocation is a tricky process that weighs the options for equitable distribution of limited land resources for alternative uses. Shuqair and Abdel-Aziz (2015) observed that the mechanism provides a blueprint for ensuring economic development, ecological sustainability, and social equity.

Realizing these objectives is obligatory for the resilience of natural and social systems. It is also required to harmonize the societal demands for integrated local, regional, and national development (Chakir and Le Gallo, 2013). Therefore, the present study focused on two objectives: (i) to examine the relationship between land use allocation decisions and knowledge systems, and (ii) to compare variations in household

ecological knowledge. For this purpose, the data was retrieved from two rural local municipalities in South Africa.

2. Materials and Methods

2.1 The study area

The study area is located in South Africa, focusing on two local municipalities (LM) chosen from two municipalities in the Free State and Limpopo Provinces of South Africa (Figure 1). These are Maluti-a-Phofung LM in Thabo Mofutsanyana District Municipality (Free State province) situated on Latitude $28^{\circ}33'04''\text{S}$ and Longitude $29^{\circ}4'48''\text{E}$. Maluti-a-Phofung LM is a Category B municipality established in 2001. Almost 27% of the population lives in traditional residences. In Maluti-a-Phofung LM, four wards were selected for the research: Monontsha, Phahameng, Mafikeng, and Lejwaneng.

While Thulamela LM in Vhembe District municipality (Limpopo province) is situated at Latitude $22^{\circ}57'\text{S}$ and Longitude $30^{\circ}29'\text{E}$. Thulamela Local Municipality is a Category B municipality established in 1998. More than 85% of the people in this municipality live in tribal areas. In Thulamela LM, four wards were selected for the research: Makumeke, Machele, Bulwini, and Makovha.

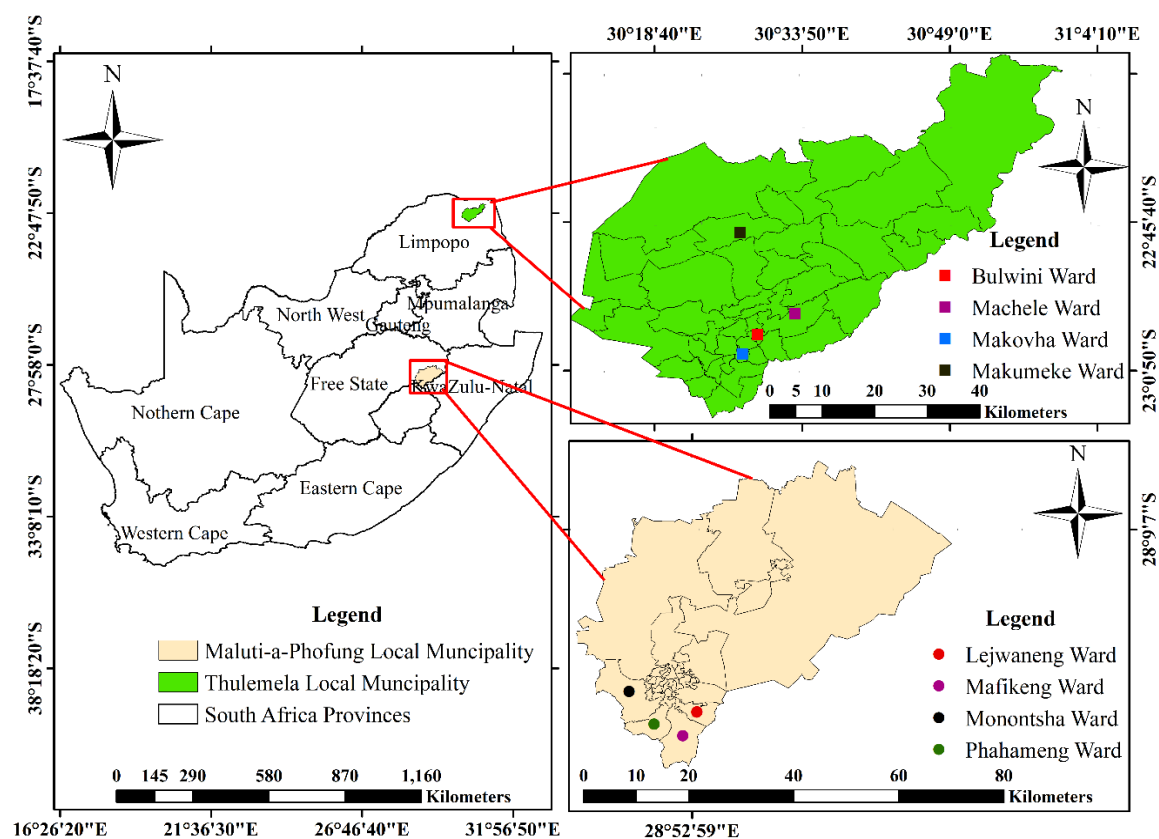


Figure 1. South African Provinces and the two study sites.

Maluti-a-Phofung LM reflects a diversified land use pattern. It ranges from agriculture, forestry, mining, open spaces, protected buffer zone, residential, transport, and wetland to wildlife and tourism attractions. Thulamela LM's land-use classes range from agricultural land, forest cover, and mining areas. Besides, the open spaces, protected buffer zone, residential transport, and wetland for wildlife & tourism attractions are also prominent classes.

2.2 Research Design

This study assesses the respondents' LEK and evaluates land allocation mechanisms based on selected environmental and climatic parameters, i.e., rainfall and temperature. Besides this, the linked ecological variables, such as soil, were also focused on. The yield relies on the soil's physical, chemical, and biological characteristics (Mubbin et al., 2022). However, indigenous knowledge about the soil productively contributes to soil resilience and agroecosystem management (Huynh et al., 2020). Thus, local knowledge about soil characteristics is obligatory for informed decision-making concerning environmental stability. This study utilized a quantitative research design based on observations, measurements, and management of household interviews. The primary data was captured on the ratio and interval scales for the objective statistical analysis.

2.3 Data Sources and Collection

The study relies on primary data and secondary data sources. The population and household characteristics were retrieved from Statistics South Africa (StatsSA, 2016). The data about climate was obtained from South African Weather Services. While the land use data were sieved from the Department of Agriculture and Land Affairs reports. These data sources empowered for critical analysis of the research problem according to the study's objectives. In addition, the secondary data was used to verify and supplement the Information collected from the interviews.

The main focus of this investigation was to collect present data on the status and role of the knowledge system of households in local municipalities. It was not obtainable from the above-mentioned secondary data sources. Therefore, the primary data were collected through field observations followed by face-to-face interviews using questionnaires from the study areas, i.e., Thulamela LM and Maluti-a-Phofung LM. Three types of data were collected from primary sources: (i) perception about environmental parameters; (ii) the orientation towards land use was noticed through field observations (iii) household data regarding environmental knowledge were collected through a structured interview. A household questionnaire was designed for this purpose. A set of observable socio-economic indicators were incorporated into the tool for data collection. Questionnaires were administered to 187 inhabitants from Maluti-a-Phofung LM and 198 residents from Thulamela LM to collect data on household environmental knowledge. The process was conducted during January and February, 2020.

2.4 Sampling procedures

The number of households per ward as of the end of 2020 was obtained from the records of Statistics South Africa (StatSA, 2020) and the Municipal Demarcation Board, using a stratified random sampling technique. Stratified random sampling involves dividing a population into smaller groups—called strata—and randomly selecting samples from each stratum. Potential respondents were identified based on specific selection criteria.

The selection procedure followed four interrelated phases:

Phase 1: Population estimates for December 2020 were sourced from StatSA, according to each local municipality (LM).

Phase 2: Household numbers for each LM and its respective wards were established from StatSA (2020).

Phase 3: Ecological zones (EZs) were defined using climatic, soil, vegetation, landform, and drainage data.

Phase 4: EZ boundaries were overlaid on ward maps to produce an ecological zone map for each of the two study areas.

The sample size of 385 households was used for the study. Proportional percentages (32% of Thulamela and 24% of Maluti-a-Phofung) were used in determining the household representation in each ward. This approach ensured representative, precise,

and well-balanced data gathering from the different socio-economic and geographic locations within the municipalities (Table 1).

Table 1. Sample size distribution

Research Site (1)	Wards (2)	Households (3)	Stratum I Population* (4)	% of households** (5)	Stratum II households*** (6)	Sample size (7)
Thulamela LM		130320	497237			
Makumeke	15	172	664	32%	55	49
Machele	16	128	557	32%	41	38
Bulwini	17	207	931	32%	66	57
Makovha	18	195	787	32%	62	54
						Total=198
Maluti-a-Phofung		110725	353452			
Monontsha	11	325	1164	24%	78	65
Phahameng	15	340	1113	24%	82	68
Lejwaneng	20	90	302	24%	22	21
Mafikeng	21	150	505	24%	36	33
						Total=187

Source: Census 2020; *=stratum I population; **= % of households engaged in selected land-based activities; ***=stratum II population expressed as a percentage based on field enumeration

2.5 Data processing and analysis

The data was used to compare household ecological knowledge between the two selected study sites. Socio-economic characteristics and ecological knowledge data were analyzed using Microsoft Excel (TM) by calculating descriptive statistics and transferred into Statistical Package for Social Scientists (SPSS) software version 25.0 for further analysis. Cross-tabulations helped to determine the association between socio-economic variables (education, length of residence, and occupational status) and ecological knowledge. Therefore, inferential statistics techniques like two-tailed Spearman's correlation coefficient, multiple regression, and two-way analysis of variance were consulted.

3. Results

The element of weather and climate (rainfall and temperature) suggestively influence the composition and structure of ecological infrastructure. The meteorological record of 25 years (1994-2018) formulates that Bloemfontein lies in a moist (466mm) environmental zone (Haddad et al., 2019). At the same time, Thulamela municipality is in the sub-tropical climatic zone. The mean annual rainfall ranges from 300mm to 1000mm in this area. Temperature is a critical element of weather and climate. It has significant bearings on the other cardinal aspects of weather and atmosphere, such as precipitation, air pressure, and winds. The findings formulate an average monthly maximum temperature of 23.5°C in the study area. However, the mean monthly minimum temperature in the winter season observed was 2.5°C, and in summer, it was 26.4°C in Maluti-a-Phofung LM. In Thulamela LM, observations formulate about a summer maximum of 29.2°C and winter minimum temperature of 9.7°C. An escarpment, highlands, and mountainous types of land surfaces characterize the physiography of Maluti-a-Phofung LM. In comparison, Thulamela LM is composed of floodplains and mountain areas.

The study areas' topography, climate, and geology govern the drainage systems. Whereas, Maluti-a-Phofung combines seasonal streams, permanent streams, and water

reservoirs. In contrast, the drainage system in Thulamela LM is characterized by a flood plain associated with the prevalence of seasonal streams and water reservoirs.

Indigenous soil information is essential for long-lasting soil administration and agroecosystems (Huynh et al., 2020). The soil of Maluti-a-Phofung LM is divided into the following distinctive classes: Yellow and red (Ac), none red (Bb), Clay Soil (Ca), Dark blocky and clay (Ea), Shallow and rocky (Fa), much shallow and/or rocky (Ib) and mainly rock with little soil (Ic). However, in Maluti-a-Phofung LM is characterized by red and yellow (Ab), Red soil (Ba), Non-red (Bb), Dark blocky and clay (Ea), Shallow, and/or rocky (Fb), and much shallow and/or rocky (Ib) soil types. The most dominant type of soil in Thulamela LM municipality is rich red loam soil, though it repeatedly experiences excessive overspill. This soil category has a greater and longer water-retaining ability (Musyoki et al., 2016).

The land uses range from agriculture, forestry, mining, open spaces, protected buffer zone, residential, transport, and wetland to wildlife & tourism attractions. Thulamela LM's land-use classes range from agricultural land, forest cover, and mining areas. Besides, the open spaces, protected buffer zone, residential transport, and wetland for wildlife & tourism attractions are also prominent classes.

Environmental education acquired through formal education could form the basis of indigenous knowledge, understanding, and standards and determine training outcomes. This study assessed respondents' local knowledge and land-use allocation to perform a comparative analysis of household environmental knowledge. (Figure 2-4) succinctly portray the socio-economic and demographic characteristics of the respondents from the two study sites. The findings (Figure 2) indicate that most of the respondents (56%) in Maluti-a-Phofung LM and (44%) in Thulamela LM are well-educated. However, a smaller proportion, 1% of the total respondents in the case of Maluti-a-Phofung LM and 2% from Thulamela LM, were uneducated. At the same time, a smaller proportion of the surveyed population (23%) in Maluti-a-Phofung LM and 11% in Thulamela LM also affirmed that they obtained primary education. However, 50% of respondents from Thulamela LM and 25% from Maluti-a-Phofung LM have attained education at the Matric level (Grades 8–12). The study shows that Maluti-a-Phofung LM exhibits higher levels of education, likely due to better access to schools, facilities, and support, while Thulamela LM may face more educational challenges and fewer resources.

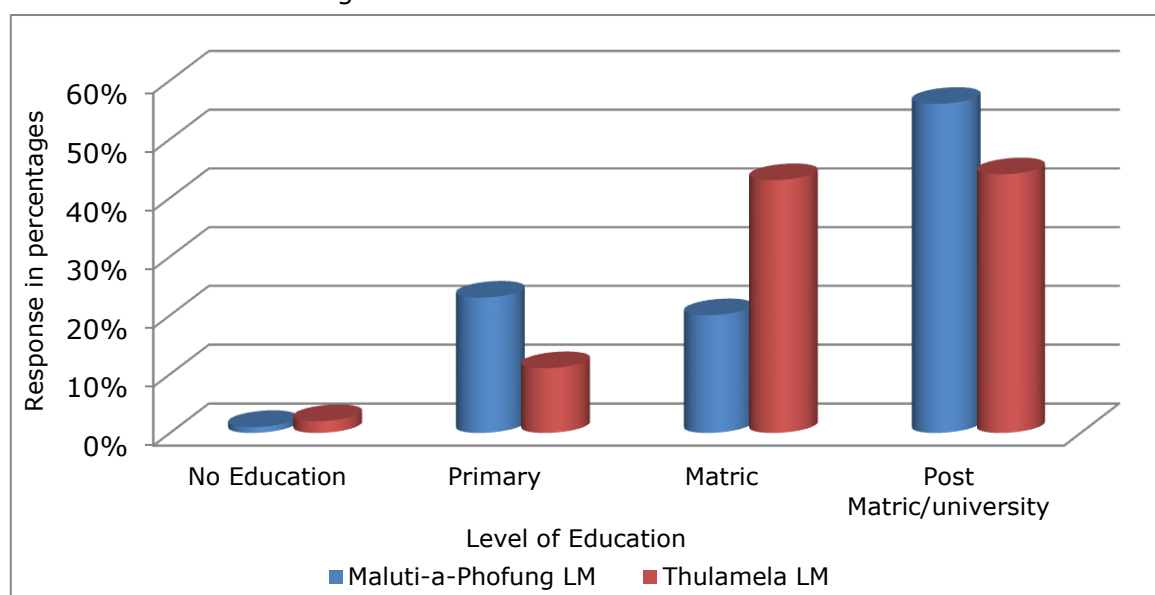


Figure 2. Distribution of respondents by the level of education.

Figure 3 infers that most of the respondents (49%) in Maluti-a-Phofung LM and (70%) from Thulamela LM residing in these areas for between 31 and 50 years. Most respondents in both study areas started to live there between 31 to 70 years ago. These

results indicate that the inhabitants are acquainted and satisfied with the environmental settings of their contextual surroundings.

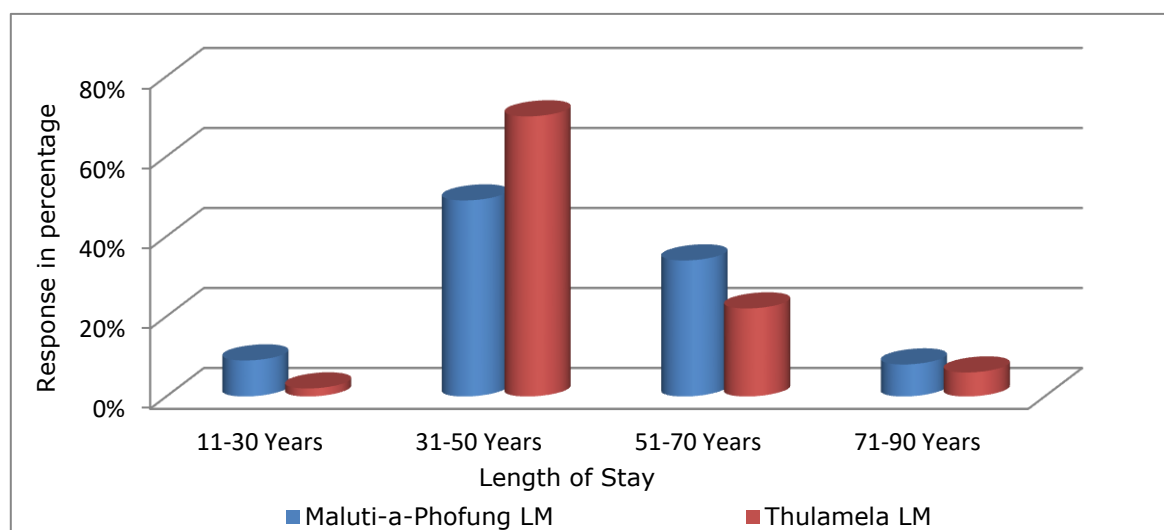


Figure 3. Distribution of respondents by the length of stay.

The results (Figure 4) indicate that most residents directly or indirectly depend on primary economic activities such as agriculture, forestry, mining, etc. A substantial proportion of respondents from Maluti-a-Phofung LM (30%) and 25% from Thulamela LM stated that they are engaged in farming. At the same time, a sizeable share of respondents from Maluti-a-Phofung LM (17%) and Thulamela LM (22%) are involved in the livestock sector. The other occupational groups, such as mining, industrial activities, and transportation, constitute smaller percentages. However, 10% of the respondents from Maluti-a-Phofung LM and 5% from Thulamela LM were linked with construction activities.

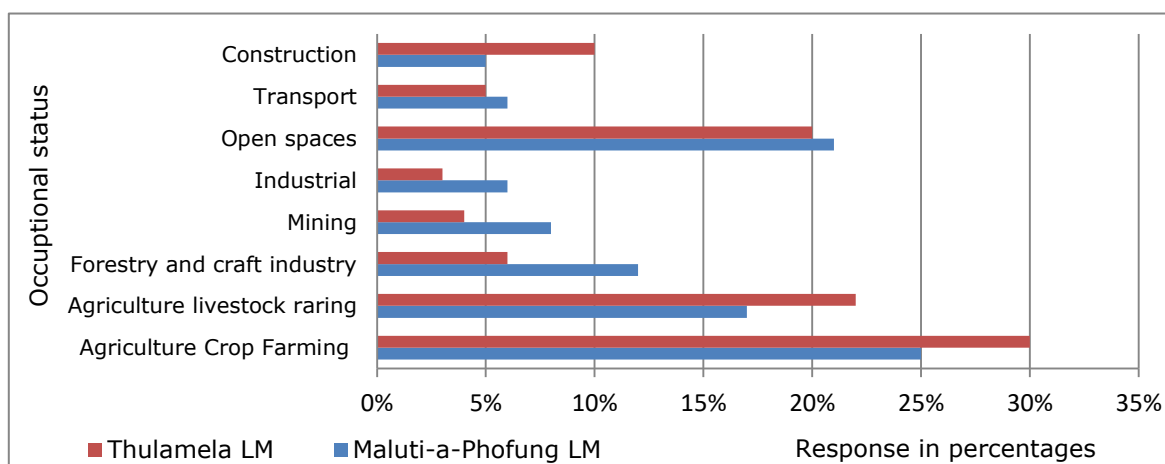


Figure 4. Distribution of respondents based on occupational status. Household local knowledge

A study by Adisa et al. (2018) showed that climatic factors such as sunlight, moisture in the air, rainfall, temperature, and humidity frequently decide the global distribution and productivity of crops and livestock within a specific setting. This study estimated respondents' local knowledge and land use distribution based on climate (precipitation and temperature) and environmental variables (soil). Response percentages were relied upon to assess the proportion of respondents who possess a particular local knowledge.

3.1 Climatic Variables

Climate entails the statistical characteristics of weather conditions in a given area. Climate zones are characterized by different combinations of climate variables, such as rainfall, temperature, humidity, and wind (Mubbin et al., 2022). The household's local knowledge and assessments regarding climatic variables are relied upon for inferences and estimations.

3.1.1 Rainfall

The quantity and distribution of precipitation determine the suitability of crop diversity and associated agronomic management (Muthoni et al., 2019). The respondents were invited to share their local knowledge about the rainfall pattern in their vicinity. Several indicators were used to deduce the local environmental knowledge concerning rainfall, its temporal distribution, and reliability. The assessments indicate that the local knowledge of the reliability of rain among the respondents from Maluti-a-Phofung LM and Thulamela LM is identical; in both municipalities, 14% of the respondents know about reliable rainfall. However, noticeable differences in knowledge about the length of the wettest season and the amount of precipitation were noted. At the same time, the inconsistencies were negligible in the evaluation of other parameters.

3.1.2 Temperature

The variations in local temperature influence humans and the environment through air quality and energy utilization and impacts people's health (Tran et al., 2017). The respondents were requested to share their knowledge of the temperature fluctuations in their locality regarding the hottest and coldest months and average temperature. The results revealed differences in responses, as 18% of respondents in Maluti-a-Phofung LM and 26% in Thulamela LM know the average summer season temperature. However, the respondents were less divided regarding the coldest month and about the average winter temperature.

3.2 Household local knowledge and soil quality

The evaluations regarding soil and related aspects were made (Figure 5). About 50% of the respondents in Maluti-a-Phofung LM and 46% in Thulamela LM viewed the soil in their locality as generally fertile. However, rural household farmers have unique indigenous or local environmental knowledge about farming operations and soil management (Bajgai and Sangchyoswat, 2018). However, the respondents' local knowledge about soil acidity is slightly lower, as only 12% of the respondents in Thulamela LM and 11% in Maluti-a-Phofung LM knew about this concept. The lack of knowledge about the soil characteristics in both municipalities could negatively influence farming operations and soil management.

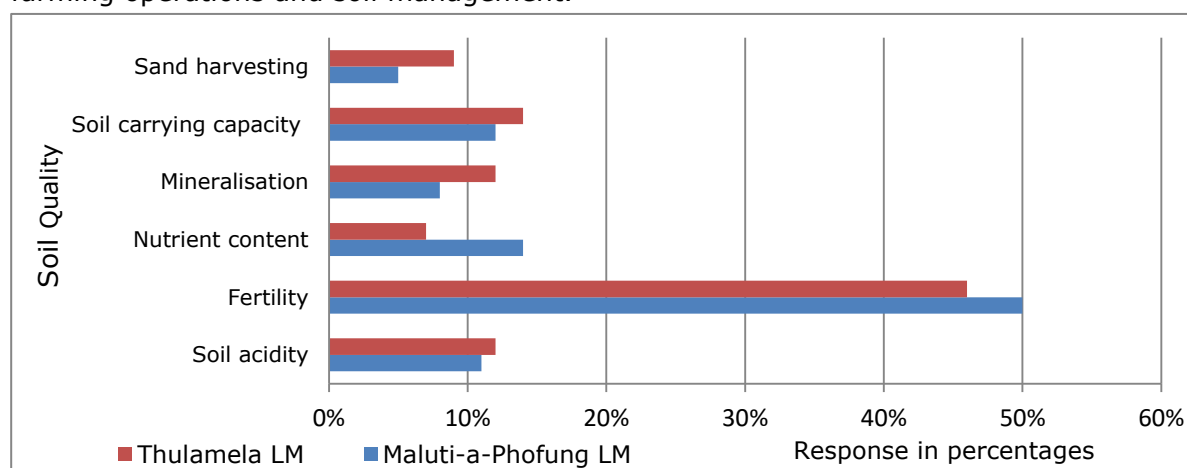


Figure 5. Distribution of respondents based on knowledge about soil quality.

Figure 6 indicates that 14% of the respondents in Maluti-a-Phofung LM and 7% in Thulamela LM affirmed that they know the soil's nutrient composition in their locality. The findings infer that 14% of the respondents in Thulamela LM and 12% in Maluti-a-Phofung LM know about soil carrying capacity. Local knowledge about soil richness and carrying capacity is critical because it symptomatically influences soil fertility and management (Bajgai and Sangchyoswat, 2018).

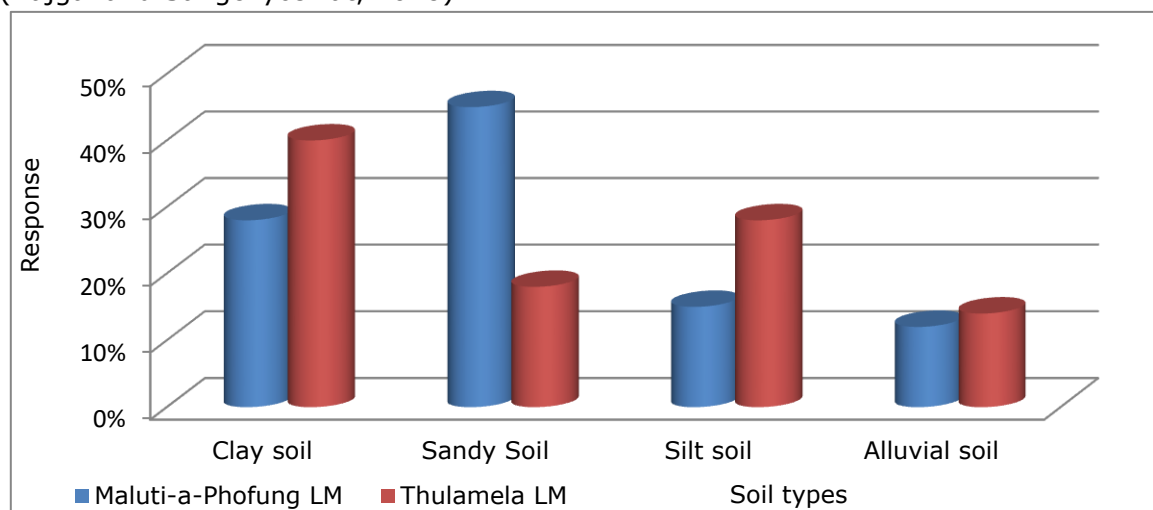


Figure 6. Distribution of respondents based on knowledge about soil types.

Most of the respondents in Maluti-a-Phofung LM have local knowledge about soil fertility and nutrient content, and they perceive that the soils are sandy. Diverse soil types, including sandy, clay, and sandy-loam soils, typify the Thulamela LM. As such, respondents mentioned that the clayey and mud soils are fit for growing cereals like wheat. Clayey soil's water retaining capacity helps grow crops like paddy, which needs extra moisture. In contrast, silt soil and alluvial soils are dominant in Maluti-a-Phofung LM. According to the respondents' knowledge, wind erosion is a powerful element in Thulamela LM.

3.3 Drivers of local ecological knowledge

The strength and direction of associations between drivers of local environmental and ecological knowledge were ascertained by deploying a two-tailed Spearman's Correlation coefficient test. The findings (Table 1) reveal that in Maluti-a-Phofung LM, there is a positive association between the level of education and ecological knowledge ($r = .136$; $P = .063$). However, a significant negative association was observed in the case of Thulamela LM regarding education and ecological knowledge ($r = -.176$; $P = .013$).

Assessments were also made to determine the relationship between the length of stay and ecological knowledge. Table 1 reveals that Maluti-a-Phofung LM has a negative correlation between the two variables ($r = -.083$; $P = .258$) while Thulamela LM has a positive association between residence and ecological knowledge ($r = .003$; $P = .967$).

Table 1 reveals that in Maluti-a-Phofung and Thulamela LM, there is a positive association between occupational status and ecological knowledge: $r = .134$; $P = .067$ and $r = .023$; $P = .750$, respectively.

Furthermore, the multiple regression modeling about Maluti-a-Phofung LM and Thulamela LM was carried out to assess the weights of the selected variables in the case of these settlements. Equation 1 shows results for Maluti-a-Phofung LM.

$$\text{Ecological Knowledge} = 38.891 + 1.047 (\text{Education}) - 0.124 (\text{Residence}) + 1.870 (\text{Occupational status}) \quad (1)$$

Results for the regression model revealed that education ($t = 3.04$, $p < .001$, $\beta = .242$) and occupational status ($t = 2.311$, $p < .022$, $\beta = .163$) were statistically significant and residence ($t = -1.610$, $p > .109$, $\beta = .113$) was an insignificant negative variable to

ecological knowledge. The results agree with Spearman's correlation, whereby negative associations were computed between residence and ecological knowledge in Maluti-a-Phofung. From the model summary, the three predictor variables register an adjusted R-squared value of .102, translating to 10.2% of the explained variation in Y (ecological Knowledge).

Table 1. Spearman correlation

		Ecological Knowledge	
Education	Correlation Coefficient	1.000	.136
		-	.063
		1.000	-.176*
	Sig. (2-tailed)	.000	.013
Residence	Correlation Coefficient	1.000	-.083
		-	.258
		1.000	.003
	Sig. (2-tailed)	.000	.967
Occupation status	Correlation Coefficient	1.000	.134
		-	.067
		1.000	.023
	Sig. (2-tailed)	.000	.750

*. Correlation is significant at the 0.05 level (2-tailed).

The positive slope for education (1.047), as a predictor of ecological knowledge, indicated that there was about a 1.047% increase in ecological knowledge for each reported improvement in education. In other words, ecological knowledge tends to increase as education increases. The squared semi-partial coefficient (sr^2) that estimated how much variance in ecological knowledge was uniquely predictable from education was (.244), indicating that 24% of the variance in the ecological knowledge is uniquely accounted for education and occupational status. Thus, the residual of 76% could be explained by other variables such as ecological knowledge about the environmental factors, i.e., rainfall, temperature, humidity, sunshine, soil vegetation, topography, and drainage.

$$\text{Ecological Knowledge } Y = 47.828 - 0.600 (\text{Education}) - 0.002 (\text{Residence}) + 0.19 (\text{Occupational status}) \quad (2)$$

The positive slope for occupational status (0.19) as a predictor of ecological knowledge indicated a 0.019% increase for each 1-point increase in the occupational group. In other words, ecological knowledge tends to increase with respondents' occupational statuses. The squared semi-partial coefficient (sr^2) estimated how much variance in ecological knowledge was uniquely predictable from occupational status (.002), indicating that 0.2% of the variance in ecological knowledge is uniquely accounted for occupational status. However, education and residence results were reported as insignificant. These results verify the computed Spearman's correlation, whereby there is a weak association between residence and ecological knowledge ($r=.003$) and a significant negative relationship between education and ecological learning ($-.176$).

4. Discussion

The context-based knowledge about ecological resources helps to interpret the relationship between human and their surroundings (Durar et al., 2023). Therefore, the present study evaluated the feedback from the grass root levels. The data for assessing the inclinations about local ecological knowledge was collected from Maluti-a-Phofung LM and Thulamela LM. The study mainly assessed the imprints of socio-economic determinants on the orientations toward LEK. The study's findings confirm that socio-economic factors like education, residence, and occupational status

symptomatically influence household ecological knowledge and awareness (Mubbin et al., 2022). Besides, involvement in decision-making and resource access also contribute to knowledge acquisition (Mosissa et al., 2017).

Therefore, households' knowledge regarding the local environment was assessed. It systematically evaluates the linkages between local knowledge about meteorological data. The spatial and temporal climatic considerably affect ecological diversity. The scorching, damp summers and chilly winters are the hallmarks Maluti-a-Phofung LM climate (Myeni et al., 2019). During the winter weather, the area experience snowfalls, particularly in high mountains (Myeni et al., 2019). Heavy precipitation in this area occurs during summer due to powerful downpours (ARC, 2016). These factors are evident from the respondents' local knowledge of rainfall in Maluti-a-Phofung LM. Based on the local climatic knowledge, the eastern parts of the LM are very appropriate for dry land farming production compared to the wet areas in the western and southern regions of the LM (Moeletsi and Walker, 2013). Dry land-grown crops may include winter wheat, corn, beans, sunflowers, or watermelons. The selection of produce is affected by the timing of main rains as regards the seasons—for instance, winter wheat suits regions with more significant winter rain.

In comparison, areas with summer wet seasons may be more appropriate to summer growing crops such as sorghum, sunflower, cotton, etc. (ARC, 2016). Moreover, dearth and prolonged waterless periods frequently occur in summer (December to February). Such periods are the main agro-climatological risks influencing agricultural systems and land-use allocation in Maluti-a-Phofung LM (Mbiriri et al., 2018).

The respondents' local knowledge about rainfall was outstanding regarding the dry and wet seasons in Thulamela LM compared to Maluti-a-Phofung. The LM mainly undergoes long, bright days and dry, cool evenings (Tshiala et al., 2011). The LM is characterized by a dry spell from March to September (Musyoki et al., 2016), with the onset of rainfall in October. The mean yearly rain in Thulamela LM is 820 mm. Therefore, flooding is expected from January to February. During winter, from May to August, the weather is hot during the day, with cool, dry air in the evenings (Musyoki et al., 2016). Temperature can plummet rapidly at night. At some point in winter months, Thulamela LM characteristically obtains less than 20 mm of rainfall each month, with almost 8 mm of rain in August (Mpandeli and Maponya, 2013). In Thulamela LM, poor rainfall results in livestock losses, a scarcity of drinking water, reduced crop production, and a shortage of seed (Wilk et al., 2017). In this study, most farmers pointed out that peanuts and peas grow well in dry land areas because these crops need less water than other crops, such as avocados and bananas. Peanuts and cowpeas also retain moisture by spreading over the soil surface. Nonetheless, maize occupies the largest area of all other field crops, followed by sorghum, beans, and groundnuts. Fruits, vegetables, tea, and sugar are also commonly grown. Based on the local knowledge associated with fewer rainfall conditions, farmers opt to grow food crops that are drought resistant and can mature fast (Phokele and Sylvester, 2015).

The prevailing temperature conditions of Thulamela LM and Maluti-a-Phofung LM were recorded and compared. The respondents' local knowledge portrayed that the contextual surroundings of Thulamela LM have hotter months than Maluti-a-Phofung LM. For Thulamela LM, the typical maximum temperature is 35°C and 18°C in summer and winter, respectively (Musyoki et al., 2016). In Limpopo, during the summer months, hot days are regularly interrupted by brief heavy showers (LDARD, 2019). However, Maluti-a-Phofung LM respondents' knowledge of the coldest month and average summer and winter temperatures was more pronounced than Thulamela LM. In the Free State province, temperatures often plunge to below zero in winter. Summers are wet and hot; winters are dry with regular frost. Snowfalls happen at least once a year between July and September, but low-lying areas get infrequent snow events. The area experience frostiness, which is conducive to the abundance of grassland vegetation and prevents the growth of trees (Rankoana, 2016). Grasslands are significant landscapes and afford the natural resources and ecological infrastructure that assists most of South Africa's vital

economic activities and millions of pastoral livelihoods. The conditions in grasslands make them highly apt for human occupancy and land uses upon which food production and other economic activities depend. Therefore, some 40% of South Africans, including the residents of Thulamela LM, tend to sustain their livelihoods from these grasslands (SANBI, 2013).

The statistical findings of Thulamela LM indicated the negative associations between the level of education and ecological knowledge. However, Maluti-a-Phofung LM showed a positive association between the level of education and ecological knowledge. Besides, the findings also indicate that both groups of education and environmental learning have noticeable imprints on the residence and occupational status of the respondents. It deduces that the level of education directly (in the case of Maluti-a-Phofung LM) and indirectly (in the case of Thulamela LM) shapes and tailors the respondents' socio-economic conditions and their inclinations on environmental resources. Thus, the findings of this study substantiate the reported postulations that focus on human capacity building through informed decision-making, which produces dividends for ecological and environmental infrastructure (Li et al., 2024).

Besides, most of the respondents in both of these study areas have lived there for decades. It follows that the inhabitants are acquainted with the ecological/environmental settings of their contextual surroundings. Most of them depend on primary economic activities whereby the knowledge about ecological resources significantly determines their social and economic activities. Based on the results described here, one observes that the sample of Maluti-a-Phofung LM was dominated by people who have lived in this area for over thirty years. As far as Thulamela LM is concerned, no respondent had lived in the area for less than 11-20 years. In both LMs, most inhabitants have stayed in their locations for 31 to 60 years. There is an assumption that as the duration of stay prolongs, the residents' knowledge about natural resources enhances. However, the findings in this study noted a negative association between residence and ecological knowledge in Maluti-a-Phofung ($r = -.083$) and a weak association in Thulamela LM ($r = .003$). These results suggest that other factors besides residence would determine local ecological knowledge. For example, there is a positive association between occupational status and ecological knowledge in Maluti-a-Phofung LM ($r = .134$) and $r = .023$ in Thulamela LM. Thus, the prudent utilization of available ecological/environmental resources depends on the residents' awareness and knowledge base. However, the findings suggest that ecological resources are vulnerable due to looming threats from possible unsustainable resource consumption, global warming, and climate change (Vicente-Serrano et al., 2020). Ultimately, the consequent degradation in the natural environment could translate to human suffering. However, it is incumbent upon the residents of these localities to protect the natural resources because they derive livelihoods from the same.

5. Conclusions

Ecological knowledge, for this study, was assessed in terms of education, residence, and occupational status from Maluti-a-Phofung and Thulamela local municipalities. Knowledge of climatic factors and soil was acquired through observation and experiences. This acquired knowledge manifests itself in decision-making and guides land use practices. Thus, indigenous knowledge symptomatically influences the orientation of human-environment interactions. Knowledge of the quantity and timings of rainfall, the onset of seasons, temperature ranges, and soil characteristics is acquired through contextual setting experiences. It tailors cropping and land utilization. The findings infer that socio-economic determinants such as education, occupational status, and residence time significantly influence the knowledge and awareness of rural communities about critical decisions such as what crops to grow and where these crops can be grown.

Besides local knowledge, this study recommends public participation in decision-making processes and resource access to motivate communities to acquire

formal education and training. The study also stresses the need to adopt innovative measures to tackle challenges such as climate change and resilient socio-economic development. To advance local knowledge, a pragmatic and comprehensive policy response is critical to land-use allocation and environmental sustainability. Therefore, increased public involvement in land-use planning and management is necessary for capacity building and informed land-use allocation decision-making. This study is needed as it explores how socio-economic factors like education, occupation, and residence impact local ecological knowledge and land use decisions. It provides new insights into sustainable land management and emphasizes the importance of public participation, formal education, and innovative solutions to address climate change and socio-economic development challenges.

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