Acta Botanica Hungarica 68(1–2), pp. 49–86, 2026
DOI: 10.1556/034.2025.00573

AWARENESS OF LICHENS AND THE NECESSITY OF THEIR CONSERVATION AMONG CITIZENS IN DIFFERENT REGIONS OF KENYA

C. N. Kanyungulu[1]* and E. É. Farkas[2]

[1]*Doctoral School of Biological Sciences, Hungarian University of Agriculture and Life Sciences, H-2100 Gödöllő, Páter K. u. 1, Hungary; E-mail: colnyiva@gmail.com (*corresponding author)*
[2]*HUN-REN Centre for Ecological Research, Institute of Ecology and Botany, H-2163 Vácrátót, Alkotmány u. 2–4, Hungary; farkas.edit@ecolres.hu*

(Received: 10 February 2025; Accepted: 24 February 2025)

Kenya is regarded as a biodiversity hotspot. However, biodiversity conservation has been coupled with a few challenges including economic constraints, habitat degradation, climate change, industrialization, and lack of environmental awareness. The current research aimed to reveal the existing knowledge of lichens from Kenyan citizens, literate and illiterate, old and young, and urban and rural, and show the role of including local knowledge in their utilization. This interdisciplinary study combining lichenology and cultural anthropology was conducted in four counties in Kenya (Kakamega, Narok, Nairobi, and Makueni) through semi-structured interviews between July and September 2023.

The results show a gap of knowledge on lichens (morphological, ecological aspects) between youths and aged people especially in the urban areas. Awareness of nature conservation depends on traditional or educational knowledge considering that illiterate individuals have substantial conservation know-how. Conservation activities have multidisciplinary aspects. All stakeholders must play their role inclusive of the local conservationists. Traditional knowledge has been underestimated generally, though it is important in awareness of conservation matters.

Key words: conservation, cultural and environmental threats, diversity, socio-cultural environment, traditional knowledge

INTRODUCTION

Tropical ecosystems, particularly their forests, are characterized by high levels of biodiversity ranging from animals to plants (Mittermeier *et al.* 2003, 2004, 2011). The East African region has a unique biodiversity hosted by the Great Rift Valley that runs from Mozambique through Tanzania and Kenya and ends in Ethiopia. Van Breugel *et al.* (2015) adopted a recently developed high-resolution potential natural vegetation map for East Africa to support the identification of the conservation priorities and studied how these are represented in the protected area network of the area. This may contribute to a more direct representation of global priorities in regional or national implementations. Kenya hosts a wide range of terrestrial tropical habitats, including mangrove

and coastal forests, cloud forests and alpine vegetation found at high altitudes. Kenya has experienced a roughly 1 °C increase in mean annual temperature since the 1970s, while a total of 76,346 km^2 area of the country was shifted from a cooler to a warmer zone, and the hottest zone increased 0.59 °C (Lawrence *et al.* 2023). Furthermore, a total of 136,129 km^2 was shifted from a wetter to a drier zone, and the average precipitation in the most arid zone decreased 2.57 mm, resulting that all arid regions expanded from 72% over all of Kenya's area in 1980 to 81% in 2020 (Habel *et al*. 2023, Lawrence *et al.* 2023). Therefore, the biodiversity is decreasing enormously over time due to environmental changes (Mittermeier *et al.* 2003, 2004, 2011, van Breugel *et al.* 2015). This fact needs special attention, since the mountains especially in East Africa, such as the ancient Eastern Arc Mountains spanning from southern Tanzania to Kenya are encompassed by extensive arid woodlands and savannas still representing a considerable diversity in plants and animals (Mittermeier *et al.* 2011). Thus, the country is one of the most intensely investigated East African areas particularly for its abundant lichen vegetation (Farkas and Muhoro 2022, Farkas *et al.* 2023, Kaasalainen *et al.* 2021, 2022, 2023, Swinscow and Krog 1988) with an estimation of 1,400 species by Tassilo Feuerer in 2011 (Kirika *et al.* 2012).

Lichens are symbiotic organisms of a primary fungus (mycobiont), a primary photosynthetic partner (photobiont), and an indeterminate number of further microorganisms (Hawksworth and Grube 2020). Lichens are known to live on various substrates (soil, rock, tree bark, leaves of evergreen trees), morphologically are grouped as crustose (closely covering a surface), foliose (leaf-like), and fruticose (shrubby) (Nash 2008). There are more than a thousand lichen secondary metabolites produced almost exclusively by lichens with antibacterial, antifungal, analgesic, antipyretic, and anti-inflammatory activities making them valuable for the pharmaceutical industry (Molnár and Farkas 2010).

The other side of the problem (i.e., the decrease of biodiversity) is that the destruction of natural forest ecosystems reduces the quality of livelihoods of local people. This also means a transformation of the socio-cultural environment and system; thus, the loss is multiple. It has also become clearer and more and more necessary, therefore, to re-align the natural and cultural environment, to identify and create the "survival" and "revival" that are well known in cultural anthropology and sociology (associated with the names of Tylor and Durkheim, respectively) (Eller 2020). Consequently, there is a need for intergenerational communication and better communication of scientific knowledge to policy makers and society. A consistent example from southern Kenya is that researchers and governmental organizations are taking the initiative to prevent ecosystem degradation by involving the local community, with local traditional knowledge and intergenerational communication as the cornerstone (Habel *et al*. 2023). The protection of biological and ecological diversity has been a pol-

icy and sustainability issue for some time, but cultural protection lags behind, even though they share many common factors that, when addressed together, point to a much better outcome. These include culturally relevant education and revitalisation programmes (Pretty and Pilgrim 2008). This paper, in broad agreement with this, argues that in order to gather appropriate knowledge, an interdisciplinary study is necessary, the natural science, ecological-botanical approach alone is not sufficient, but that a social science, social and cognitive anthropology approach is also needed, i.e., an approach that involves meeting and communicating with people. The current research will do this in relation to a specific question, in specific places, combining and consistently applying together the interface between lichen-biology/ecology and cultural anthropology. This yields, for example, information about how members of a given community relate to changes in their environment and what factual or abstract knowledge they have about particular elements of it (in this case, lichens). This is all the more justified because of the following factors.

There are a few ethnobotanical studies in Kenya (Muthee *et al.* 2011), where traditionally applied medicinal plants (for example with anthelmintic effect) are revealed. Nankaya *et al.* (2020) based on data from 289 plant species found that gastrointestinal and respiratory system disorders were most often treated by them. In the field of ethnolichenology, researchers try to find indigenous knowledge on the traditional applications of lichens by humans (Devkota *et al.* 2017, Vinayaka and Kekuda 2023, Yang *et al.* 2021). Indigenous and traditional knowledge refers to the specific information passed down through generations among indigenous and local communities, exclusive to a particular culture or community. Higher plants (herbs) and lichens have several such traditional applications (alleviating respiratory or gastrointestinal disorders), especially in medicine (Gakuya *et al.* 2020). Therefore, lichens can be utilized in pharmaceutical products as raw materials (Pereira *et al.* 2020). Collection and preservation of ethnomycological and ethnolichenological data is supported by the initiative "Ethnomycological knowledge in Africa" by the database application EthnoMycAfrica launched in 2021. Its aim was to create a repository for published data from recent peer-reviewed publications and books (Kinge *et al.* 2023).

Currently, most children are no longer interested in learning the practices of their ancestors, as often hypothesize that traditional knowledge may not help them later in life, and thus traditions (less useful or even useful ones) are being lost at a fast rate (Bellino 2018, Gómez-Baggethun 2022). A significant part of this knowledge loss is due to cultural modernization. Globalization has put pressure on people to integrate and adapt to the ways of other cultures. This is also true for many smaller societies or indigenous people. The youth of the society, not seeing much value in their traditional ways due to schooling and digital tools introduction, have dropped many traditions and

absorbed the new culture (Fernández-Llamazares *et al.* 2021). This has led to a gap in the knowledge of the traditional culture and a loss of valuable cultural assets. The transmission of indigenous knowledge is vital to the survival of the knowledge itself, as without it, the knowledge cannot be passed down to new generations of community members. Additionally, knowledge transmission is a key to maintaining the culture and identity of a given community, which is characterized by its way of life and its heritage (Huntington 2018). Joining the elders and youth in participatory research related to their knowledge is an important step in reversing this trend, as it validates the knowledge of the youth and encourages them to assume the role of knowledge reservoirs (Bellino 2018). Although there is substantial research on lichen diversity and threats caused by environmental changes in East Africa including Kenya, there is a gap between limited traditional knowledge on lichens and its passage to newer generations, especially their use and conservation measures compared to other regions. Most studies primarily focus on lichen diversity, taxonomy, habitat (Farkas and Muhoro 2022, Farkas *et al.* 2023, Kaasalainen *et al.* 2021, 2022, 2023, Suija *et al.* 2018, Swinscow and Krog 1988), and composition (Kirika *et al.* 2018), while some citizens are rich in knowledge mostly acquired through direct contact with their environment.

Based on the above facts and tendencies, the current research aimed to reveal the existing knowledge of lichens among Kenyan citizens, literate and illiterate, old and young, and urban and rural, and show the role of including local knowledge in their utilization, especially in lichen conservation.

MATERIALS AND METHODS

Study area

The study was conducted in four major counties in Kenya out of the 47 counties of the country. The study areas are named after the counties Kakamega, Narok, Nairobi, and Makueni (1–4 respectively) as shown in Figure 1. The map was constructed by a computer program for geographical information systems QGIS 3.36 'Maidenhead', released in 2024. More or less the entire county (in the case of Nairobi and Makueni) or a considerable part of the county (in the case of Kakamega and Narok) was visited and investigated. The northern and eastern part due to geography, relief, climate and vegetation is regarded less rich in lichens, furthermore these areas have a lower population density. Therefore, the choice of the study areas was determined by these facts (see also further explanations below under characterization of climate).

According to Kenya National Bureau of Statistics (KNBS) 2019 (KNBS 2019*a*), the country's population was 47,564,296.

Kakamega County (1) is situated in the former Western Province of Kenya. The population of the county is 1,867,579 (KNBS 2019*b*) and its area is 3,033.8 km^2. The elevation of Kakamega County ranges from 1,240 m to 2,000 m above sea level and includes the only existing tropical rainforest (Kakamega Forest) in Kenya (Andole *et al.* 2020). This region is home to the Luhya people, Kenya's third largest ethnic group after the Kikuyu and Luo. The area is densely populated, which affects land utilisation and livelihoods. Agriculture is practised on small plots of land, which are becoming smaller for the next generation. At the same time, they have a strong connection with nature, and the tension between local and western knowledge and customs, as described

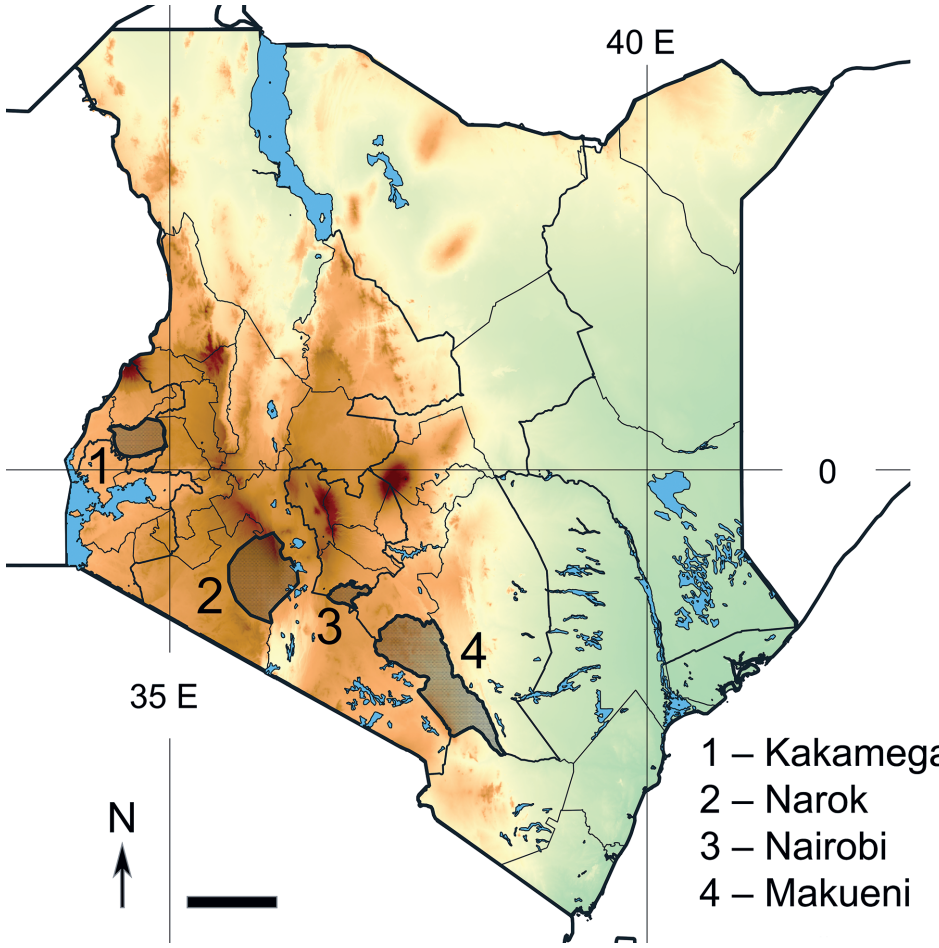

Fig. 1. The geographical map of Kenya presenting the study areas within county boundaries (QGIS 3.36 'Maidenhead' 2024). Scale 100 km

by some authors, is particularly evident here (Tomory 2019). The Luhya community will not give up the struggle for nature and traditional knowledge without a fight (Khasandi-Telewa 2016).

Narok County (2) is situated in the southern part of the Great Rift Valley. The county is positioned between the latitudes 0° 50′ and 1° 50′ S, and the longitudes 35° 28′ and 36° 25′ E (CoG 2022). The 2019 census estimates the population at 1,157,873, with the Maa community being the dominant ethnic group (KNBS 2019*b*). They are better known as Maasai and are well known for their cultural and conservation activities and advocacy in the area. In 2023, Narok leaders called for the preservation of Kenyan cultures to preserve the country's heritage and pointed out that Maasai culture and sustainability are intertwined and play a role in the diversity of the country's tourism offerings. They see education as an intermediary bundle and argue for sustainable living and traditional knowledge (Kirui 2024).

Nairobi County (3) involves the capital city of Kenya and acts as the Central Business District for the surrounding areas, situated between coordinates 1° 09′ S 36° 39′ E and 1° 27′ S 37° 06′ E (Ren *et al.* 2020). It covers an area of 696 km^2. The Ngong Hills, situated west of the city, and the Karura Forest in the north, are the predominant topographical features of the Nairobi region which has a population of 4,397,073 according to Kenyan census 2019 (KNBS 2019*a*). It is also the central area of the country's largest ethnic group, the Kikuyu people. The Kikuyus traditionally follow the environmental philosophy, which in the African way of thinking is one of the cornerstones of nature knowledge and respect for nature in accordance with environmental ethics. The gap between this and Western (European) attitudes also causes the cultural tension and discrepancy in knowledge interpretation that Tomory discusses in the perspective of enculturation-socialization and educational challenges and paradoxes. Agreeing with her, this is also why it is important to collect local knowledge in all aspects, especially with regard to natural knowledge, for which first-hand information is the most valuable (Tomory 2018, 2024).

Makueni County (4) is in the former Eastern Province of Kenya. The county's population, as documented in the 2019 Census (KNBS 2019*b*), is at 987,653. The county is located between the geographical coordinates of latitude 1° 35′ and 2° 59′ S, and longitude 37° 10′ and 38° 30′ E. The county experiences a semi-arid climate, characterized by an average temperature range of 15 °C to 26 °C (MCIDP 2018). The majority of the population here belongs to the Kamba ethnic group. The Kamba culture has also encountered a widening gap between Western and African ways of thinking, a marked manifestation of which has been the shift from natural material pots to plastic containers. This was opposed in 2001 by the Kamba Kyanika Adult Women Group (KAWG), who approached the International Plant Genetic Resources Institute (IPGRI) (now Alliance of Bioversity International and CIAT) and the National Muse-

ums of Kenya (NMK) to seek a solution to the impending loss of landscape varieties and knowledge. KAWG members expressed a number of concerns, including the fact that the cultivation of Kitete (*Lagenaria siceraria*, a particular type of pumpkin) and the availability of many traditional varieties are in decline. They expressed concern that younger women did not have enough knowledge about the varieties available and that older women were not passing on knowledge to younger women because either there was low interest, or the squash varieties were no longer present in the fields (Kennedy *et al.* 2022).

The climate conditions of Kenya (Fig. 2) are characterized by a tropical climate on the coast meaning it experiences higher rainfall (between 760–1,270 mm) and temperatures (average 27 °C) throughout the year, a moderate climate inland, and a desert environment in the northern, northeastern, and eastern parts of the country (Lawrence *et al.* 2023). The Köppen-Geiger climate classification follows Beck *et al.* (2018). The country undergoes two distinct periods of precipitation, one is lengthy (long rains occur from March/April to May/June) and the other is the short rainy season (from October to November/December). Climate change is altering the natural distribution of rainfall, causing the short rainy season to become longer (currently exceeding 3 months), which leads to increased flooding. Additionally, the dry period, which used to occur every ten years, recently occurs every year, resulting in more frequent and severe droughts, especially in arid and semi-arid areas (Rono *et al.* 2023).

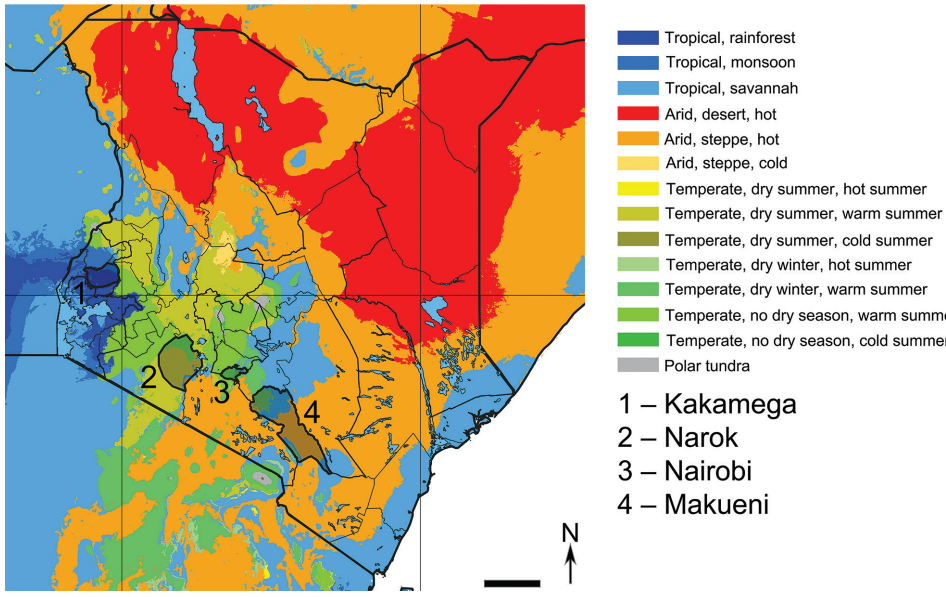

Fig. 2. Köppen-Geiger climate classification map of Kenya (1980–2016) (Beck *et al.* 2018) presenting the localization of study areas within county boundaries. Scale 100 km

Kakamega County, known for its biodiverse rainforest habitat, offers an ideal setting for investigating the variety and ecological functions of lichens. These conditions supply an ideal environment for a diverse range of plant species, also resulting in unique ecological conditions that promote the spread of a great number of lichen species. Makueni and Narok counties, known for their long-standing commitment to preserving culture, offer a unique chance to explore the traditional ecological knowledge related to lichens. It is believed that these regions have a large amount of accumulated local knowledge including information about the applications, importance, and methods of preserving lichens (CoG 2022, MCIDP 2018, Nankaya *et al.* 2020). The study area of Nairobi County is remarkable due to its conflicting yet equally important characteristics, including a high population density and a wide range of literacy levels (Ren *et al.* 2020). The hypothesis that an increased and varied population could result in a higher quantity of data on lichen knowledge prompts a thorough investigation of the impact of urbanization on awareness, attitudes, and conservation actions related to lichens.

Data collection

Data collection was carried out by combining the two research approaches mentioned above, using two basic sources: available literature and information from the field. Today's recent scientific disciplinary approach moves away from a sharp distinction among them and accepts the benefits of combining them. The use of qualitative methodology and participatory data collection in anthropology has been achieved. This specific method involves fieldwork, on-site observation, which can easily be supplemented by spontaneous and semi-structured interviews, conversations, even questionnaire-based data collection, due to the fact that one of the authors is Kenyan, so the interaction with the respondents is authentic as much as possible (Babbie 2016).

A semi-structured interview using predetermined set of open-ended questions (see Appendix 1) allows exploration for particular topics in details freely, where the respondents have more extended knowledge. This is a "conversation with a purpose" according to Burgess (1984).

In line with this approach, a cornerstone of the research is the relativist approach of cultural anthropology, according to which each culture can only be understood in its own system and no one culture can be placed above the other (Boglár 2001, Kottak 2021).

An important research and analytical component is cautious comparison, which in ethnographic terms means that only in the light of reliable data collected with an attentive and accepting attitude allows an opinion to be formed about a given group or area, but which is based on the assumption

that all cultures are equivalent and can only be examined and evaluated in their own right, within their own system. On the other hand, the emphasis is on exploration and not necessarily on testing hypotheses. An important research characteristic is that the reliability of the research is not based on quantitative, statistical grounds, and therefore the number of respondents is smaller. However, the information gathered is deeper. This is one of the pillars of research reliability, as it has a local focus. In contrast to the large number of interviews, however, the fact that communication with local people can reveal background factors, contexts and knowledge elements that would remain hidden or obscured by external manifestations in other methods contributes to reliability (Babbie 2016, Boglár 2001, Kottak 2021).

Ethnoecology is also a less well-known and applied field, but considering its basic principle, that traditional ecological knowledge views the landscape and man in unity and cooperation, this approach is very effective for exploring the topic in as many ways as possible. Its approach is based on the cultural anthropology principle that the local people have the appropriate knowledge about their own environment, its functioning and the changes affecting it and with it themselves so that local knowledge is absolutely necessary for the success of the appropriate programs, protection and support. In this case, it means the ecological perspective of traditional knowledge, which is connected with the elements of life support and healing.

The field data-collecting methodology utilized semi-structured interviews that included both closed and open-ended questions. To achieve the quality of the study the selected questions were discussed in collaboration with the Traditional Ecological Knowledge Research Group in the HUN-REN Centre of Ecological Research (Vácrátót) for pre-screening and approval before delivering them to the participants.

The study was done in the dry season between July and September 2023 when most of the regions were accessible and participants were not busy on their farms. It was geared toward understanding the relationship between age, literacy levels, traditional knowledge, and urbanization and how this affects basic biological and ecological knowledge on lichens and their application, furthermore conservation issues especially lichens in Kenya.

The target people were citizens above 18 years who were grouped into 4 major groups: 15 participants 18–25, 23 participants 26–35, 15 participants 36–45, and 7 participants above 46. The literacy levels were also considered. The rural people and aged people were hypothesized to be rich in traditional knowledge while the literate and experts in ecology found in the forest conservation centres (Kakamega, Karura, Ngong Forest) were assumed to have detailed knowledge of the status of lichens. Knowledge levels were interpreted as none, low, medium, high as follows: none, if not existing; low, if the respondent shows limited familiarity with lichens. They might only have heard

of them but cannot provide any meaningful details or explanations about them; medium, if the respondent demonstrates a basic to moderate understanding of the biological nature of lichens. They can describe some key characteristics on morphology or mention general functions or occurrences. Their understanding may come from personal observation or basic knowledge, rather than formal education or expertise; high, if the respondent shows a thorough understanding of several aspects of lichenology, including specific details, terminology, and possibly conservational and/or ecological insights, e.g., they are able to explain the role of lichens in the ecosystem, provide examples of species, describe the conditions they need to thrive, or refer to conservation efforts or studies. Their knowledge often comes from specialized education, work experience, or extensive personal study.

A few voucher specimens collected are deposited in Lichen Herbarium VBI (Vácrátót, Hungary) (abbreviation follows Index Herbariorum, Thiers continuously updated).

High performance thin layer chromatography method

High performance thin layer chromatography (HPTLC) analysis of lichen specimens for identification was carried out according to standard methods for analysing lichen samples described by Arup *et al.* (1993) and Molnár and Farkas (2011). CAMAG horizontal chamber of 10 cm × 10 cm, CAMAG TLC Plate Heater III, 10 cm × 10 cm HPTLC plates (Merck, Kieselgel 60 F254) were used. The solvent systems A (toluene – dioxene – acetic acid, 45 : 15 : 2 v / v / v), B (cyclo-hexane – methyl-tert-butyl ether – formic acid, 6.5 : 5 : 1 v / v / v) and most often solvent system C (toluene – acetic acid, 20:3 v/v) were applied. Plates were investigated under UV 254 nm and UV 366 nm after development, then fatty acids and water-repellent substances were studied, while sprayed with water, finally it was followed by spraying with 10% sulphuric acid and spots were observed at daylight.

Morphological investigations

The morphology and anatomy of some lichen specimens for identification were studied by using a NIKON Eclipse/NiU (DIC, epifluorescence) compound microscope (Nikon Corporation, Tokyo, Japan), as well as a Nikon SMZ18 stereo microscope (Nikon Corporation, Tokyo, Japan). Micrographs were prepared using Nikon DS-Fi3 camera (with NIS-Elements BR software, Nikon Corporation, Tokyo, Japan) with the above-mentioned microscope.

Data analysis

The first approach to analysing the data was interpreting written and recorded materials originated from respondents and shared through the semi-structured interviews (Appendix 1). Subsequently, all data was presented in written form and later recorded in an Excel sheet for further analysis (Table 1). The deeper understanding of responses on lichen biology and conservation aspects in Kenya from the data received was improved by carefully examining and organizing the material, looking for patterns, variations, or contradictions, and assessing the importance of the information. Ultimately, the data were visualized using Microsoft Excel charts and tables.

RESULTS AND DISCUSSION

Semi-structured interviews were conducted in 4 study areas in Kenya (Fig. 1, Appendix 1 and Table 1) and citizens of these areas (both urban and rural) from different age groups were interviewed on their understanding of the biological nature and morphology of lichens, their habitats, their use and possible applications. Subsequently, conservation ways of nature and lichens were also discussed and if people thought lichens to be threatened, possible ways of conservation were also asked.

Concerning the general knowledge on lichens, only two respondents (Resp. 37 and 57, Appendix 1) mentioned the "symbiotic relation" of the partners in lichens. Some regarded them fungi (Resp. 20, Appendix 1), algae or mosses (Resp. 36, Appendix 1). Most often foliose forms were recognised as lichens, sometimes foliose and fruticose were both mentioned (Resp. 10 and 27, Appendix 1), and those living on leaves (foliicolous lichens – Resp. 28, Appendix 1) was only known by a forest warden, in age group 36–45. Their direct attachment to substrate without roots was mentioned in one case (Resp. 56, Appendix 1). In Narok the local name of lichens was known as "narara" with the meaning "part or extension of the bark" (Resp. 33 and 39, Appendix 1). Lichens belonging to cryptogamic organisms and being autotrophs were only known by an urban citizen with BA degree (Resp. 58, Appendix 1). Their ecological requirements, namely for microclimate and their extreme tolerance were noted by a rural person with a certificate and an urban biology teacher (Resp. 48 and 54, respectively, Appendix 1).

According to demographic results, few respondents (including the highest number of people between 18–25 years) from the urban locations had no basic knowledge of lichens and their conservation (Fig. 3, Table 1). This could be related to the lack of background knowledge in biology, the lack of exposure to natural ecosystems, or the lack of interest. At the same time, more re-

Table 1

Characterization of respondents (Rp; see Appendix) and data gained from their responses through the semi-structured interviews in different regions of Kenya. G = gender (F = female; M = male), LOC = location, KLL = knowledge level of lichens, ROL = role of lichens.

Rp	G	Age	LOC	Education	KLL	ROL	Threats to lichens	Conservation strategies
Makueni								
1	F	26–35	rural	postgraduate	intensive knowledge	monitoring of pollution	forest encroachment (B), pollution (C), climate change (E)	strict rules of forest conservation (L)
2	F	18–25	urban	bachelors	medium	not aware	forest encroachment (B), climate change (E)	strict rules of use of forests and management (L)
3	M	26–36	urban	bachelors	low	not sure	not sure (A)	need for more knowledge to people on what are lichens (E)
4	M	26–35	rural	postgraduate	intensive knowledge	lighting and maintaining fire	overcollection, forest encroachment, settlement increase, and agricultural activities (B)climate change (E)	strengthening forest Act 2016 (L), taxonomy and documenting the lichen diversity (R)
5	M	18–25	urban	bachelors	none	not aware	not aware of any knowledge of conservation (A)	general forest protection (L)
6	M	26–35	urban	bachelors	medium	not aware	industrialization (C)	no response (A)
7	M	26–35	urban	bachelors	low	not aware	settlement increase, agricultural practices (B), climate change (E)	sensitize people on conservation (E)
8	M	26–35	rural	bachelors	intensive knowledge	nests for insects	forest encroachment and agricultural practices (B), climate change (E)	sensitizing on conservation (E), penalties for destruction of forests (L)
9	M	46–	rural	none	medium	not sure	settlement increase and agricultural practices (B), climate change (E)	teaching citizens on conservation (E)
10	M	26–35	rural	certificate	medium	lighting and maintaining fire	settlement increase and agricultural practices (B), climate change (E)	sensitize on the importance of lichens (E)
11	F	18–25	rural	bachelors	medium knowledge	none	settlement increase and forest encroachment (B), climate change (E)	government to regulate settlement areas (L)

Table 1 (continued)

Rp	G	Age	LOC	Education	KLL	ROL	Threats to lichens	Conservation strategies
Makueni								
12	M	26–35	urban	postgraduate	medium knowledge	not sure	illegal firewood collection and illegal tree logging (B)	importance of conservation should be sensitized (E)
13	M	26–36	rural	bachelors	low	plant parasites	not aware of any knowledge of conservation (A)	introduce conservation lessons in schools (E)
14	M	26–35	rural	bachelors	medium	lighting and maintaining fire	tree logging and agricultural practices (B)	enlighten citizens on lichen importance and its role of conservation (E)
15	F	46–	rural	none	medium	medicinal use, lighting and maintaining fire	environmental changes (E)	increase conservation strategies (L)
16	F	26–35	urban	certificate	low	not aware	not sure (A)	enlighten citizens on role of lichens (E)
Kakamega								
17	F	26–35	urban	postgraduate	low	not sure	forest encroachment and illegal tree loggings (B), climate change (E)	strict measures to protect lichens (L)
18	M	26–35	rural	bachelors	high	plant parasites, cause tree decay, lighting and maintaining fire	forest encroachment and increased agricultural practices (B), climate change (E)	restricting people from forested areas (L)
19	F	35–45	urban	postgraduate	medium	not aware	climate change (E)	conservationists sensitize on the importance of protecting species (E)
20	M	26–35	rural	postgraduate	medium	not sure	settlement and forest encroachment (B), climate change (C)	restricting people from forested areas (L)

Table 1 (continued)

Rp	G	Age	LOC	Education	KLL	ROL	Threats to lichens	Conservation strategies
Kakamega								
21	F	36–45	urban	none	low	not sure	climate change (E)	no response (A)
22	M	18–25	urban	certificate	none	not sure	no response (A)	no response (A)
23	F	36–45	rural	bachelors	medium	protect tree barks	tree logging, agricultural practices and encroachments (B), climate change (E)	conservation sensitization (E), strict management of forests (L)
24	F	36–45	rural	postgraduate	high	lighting and maintaining fire	agricultural activities, climate change (B, E)	conservation education be impacted to citizens (E)
25	M	26–35	urban	none	low	not sure	forest encroachments and increased settlements (B), exotic invasive species (F)	improve forest management and regulate introduction of species (L)
26	F	18–25	urban	bachelors	medium	not sure	more focus on conservation of higher plants (D)	inclusive conservation strategies (L)
27	M	36–45	urban	postgraduate	high	research use, bioindicators	industrialization (C), climate change (E), invasive species (F)	ecologists sensitize people on conservation (E), strict rules on forest management and proper settling zones (L)
28	M	36–45	rural	bachelors	high	part of the forest diversity	illegal tree logging (B), documents on species (D)	work on species documentation (R)
29	F	36–45	rural	bachelors	high	habitats for insects	forest encroachments, exotic trees and illegal tree logging (B), climate change (E)	update diversity and species of lichens (R)
30	M	36–45	urban	postgraduate	minimal	lighting and maintaining fire	industrialization and pollution (C)	conservation of species (R)
31	F	46–	rural	none	minimal	lighting and maintaining fire	no response (A)	no response (A)
32	M	36–45	rural	postgraduate	low	not sure	no documents on species diversity (D)	update classification of lichen species (R)

Table 1 (continued)

Rp	G	Age	LOC	Education	KLL	ROL	Threats to lichens	Conservation strategies
Narok								
33	M	26–35	rural	certificate	minimal	lighting and maintaining fire	climate change (E)	no response (A)
34	F	26–35	rural	none	low	dyes	no response (A)	no response (A)
35	M	36–45	rural	bachelors	medium	lighting and maintaining fire	no response (A)	no response (A)
36	F	18–25	rural	bachelors	medium	not sure	bias on conservation (D)	update all species and prioritise all in conservation (R)
37	M	18–25	rural	bachelors	low	symbiotic nature	lack of a list of threatened lichen (D)	systematics on diversity and update all lists of lichens (R)
38	M	36–45	rural	certificate	medium	dyes	overcollection and overpopulation (B)	have an alternative for dyes (H), have specific settlement schemes (L)
39	M	46–	rural	none	low	protect tree barks	illegal tree logging and clearing lands for settlements (B)	issue permits for before forest logging (L)
40	F	46–	rural	none	low	lighting and maintaining fire, dyes	no response (A)	no response (A)
41	M	18–25	urban	bachelors	low	no response	no response (A)	no response (A)
42	M	26–35	urban	certificate	low	plant parasites	collection to burn (B)	sensitize people what lichens are, their role and conservation (E)
Nairobi								
43	F	36–45	urban	bachelors	high	food for animals	overgrazing (B), industrialization and pollution (C)	restricting people from forested areas (L)
44	M	26–35	rural	bachelors	high	ecosystem balance	overgrazing (B), climate change (E)	destocking (H)

Table 1 (continued)

Rp	G	Age	LOC	Education	KLL	ROL	Threats to lichens	Conservation strategies
Nairobi								
45	M	26–35	rural	bachelors	high	ecosystem balance	overstocking and forest encroachments (B), climate change (E)	enlighten people on conservation (E), strict forest management (L)
46	M	18–25	rural	certificate	minimal	not sure	forest encroachment and increase in human population (B)	law enforcements (L)
47	M	18–25	rural	certificate	minimal	not sure	overstocking (B), arid land (E)	destocking and afforestation (H)
48	M	18–25	rural	certificate	minimal	not sure	overgrazing and overstocking (B)	destocking (H)
49	F	36–45	rural	certificate	low	not sure	unfavourable climatic conditions (E)	afforestation (H
50	M	26–35	urban	bachelors	high	diversity in the forest	pollution and industrialization (C)	government to allocate industry land away from industries (L)
51	F	26–35	urban	bachelors	minimal	maintain diversity	firewood collection (B)	alternative lighting and maintaining fire (H)
52	F	36–45	urban	bachelors	minimal	forest in the forest	forest encroachment (B)	restrict tree logging (L)
53	M	26–35	urban	postgraduate	high	diversity in the forest	industrialization and pollution (C)	enlighten people on conservation (E), strict forest management (L),
54	F	46–	urban	postgraduate	high	diversity in the forest	increased settlement (B), pollution and industrialization (C)	enlighten people on conservation (E), strict forest management (L)
55	F	18–25	urban	bachelors	low	not sure	not sure (A)	not sure (A)
56	M	36–45	urban	certificate	low	not sure	not sure (A)	not sure (A)
57	M	26–35	urban	bachelors	medium	diversity in the forest	not sure (A)	not sure (A)

Table 1 (continued)

Rp	G	Age	LOC	Education	KLL	ROL	Threats to lichens	Conservation strategies
Nairobi								
58	F	18–25	urban	bachelors	very low	not sure	not sure (A)	not sure (A)
59	M	18–25	urban	certificates	very low	not sure	not sure (A)	not sure (A)
60	F	18–25	urban	certificate	none	not sure	industrialization, pollution (C)	not sure (A)

Abbreviations: "Threats to lichens": A = unaware of lichen threats; B = human factors; C = industrialization; D = unprioritized conservation efforts; E = environmental factors; F = invasive species; for column "Conservation strategies": A = unaware; E = education-based; H = habitat-related; L = law-related; R = research-based

Table 2
Knowledge of lichens across different age groups in Kenya in the numbers of respondents (n = 60)

Knowledge of lichens	Age			
	18–25	26–35	36–45	46 and above
None	5	0	0	0
Low	7	7	4	3
Medium	3	8	6	3
High	0	8	5	1

spondents from rural areas had more knowledge on lichens and conservation (in total of knowledge groups low, medium and high) compared to urban respondents. The results also depicted a proficiency in lichenology for most of the rural people which might be a result of access to natural ecosystems and the transfer of knowledge from forefathers on the use and conservation measures of surrounding environments. Most of the people in such areas treasure such knowledge and pass it to their following generations as wealth, especially the medicinal use of substances originating from various organisms including lichens (Devkota *et al.* 2017, Supyan *et al.* 2021).

Traditional knowledge transmission to newer generations is a key to the preservation of cultures. Additionally, studies show that this wisdom is the basis of conservation, since there is a strong correlation between the knowledge of a particular plant species and conservation awareness (Ibrahim *et al.* 2022, Susanto and Numata 2023). The transition is determined by the receptive nature of the new generation. As it has been established recently (Supyan *et al.* 2021), and confirmed also by the current results (Table 2), there is a gap between old and young regarding knowledge. According to the demographic relations of the analysis, the results show that the young seem to have a limited knowledge on ecosystems compared to their older generation that

have proficiency in the same. This might be brought about by the digital era, modernization, and changing literacy trends. Concentrating on recent, novel matters can result in the decline of traditional knowledge. Most of the knowledge is concentrated in the age groups 26–35 and 36–45 with the highest level in 26–35 years. The age group 46 and above recorded the lowest numbers as most of them were not willing to share their knowledge due to busy schedules and only one had proficient knowledge of lichens and conservation. Fortunately, their knowledge ranged from low to high with most of them having low to medium knowledge and no cases for lack of knowledge. This calls for integrating traditional and modern education in conserving both culture and the environment (Huntington 2018).

Knowledge, traditional or modern, has a direct impact on the pro-environmental activities / behaviour and attitudes of a community (Susanto and Numata 2023). According to the research done (Fig. 4), a few uneducated people know about the biological/symbiotic nature of lichens (cf. Hawksworth and Grube 2020) and about conservation matters which might be related to traditional knowledge passed by their forefathers and their direct contact with the environment. However, several people with certificates (two) and bachelors (one) reported no knowledge on lichens. At the same time, there was no record of a lack of knowledge of lichens or conservation among uneducated people or postgraduates. In the case of the uneducated group, it was hypothesized that most of them live near the natural ecosystems and thus learn through apprenticeship from their parents, while the postgraduate knowledge would originate from their close to nature professional activity.

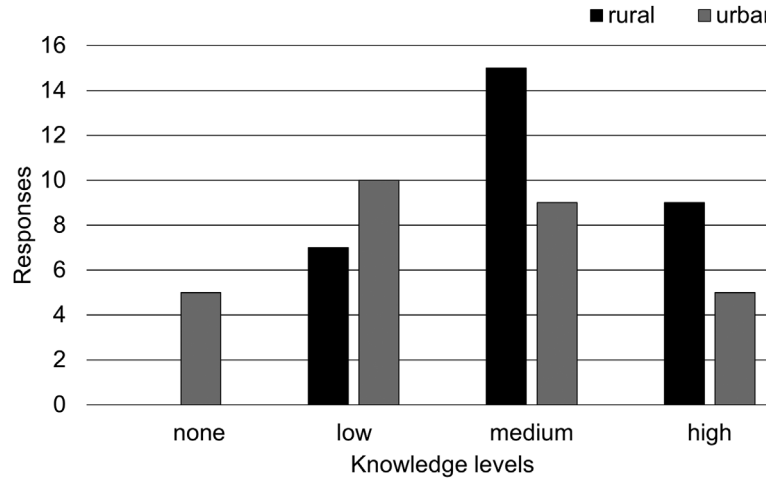

Fig. 3. Responses about the knowledge of lichens from rural and urban sites within the study areas

Table 3
The role of lichens known in Kenyan communities in the numbers of mentions by respondents

Role of lichens	Respondents
Not aware	28
Lighting fire	11
Ecosystem diversity	10
Plant parasites	3
Dyes	3
Protect tree barks	2
Insect habitats	2
Bioindicators	2
Research	1
Medicinal use	1
Food for animals	1

According to Albuquerque *et al.* (2021) traditional knowledge and modern education have to find a point of convergence on the topic of conservation to maximize knowledge on the subject matter including lichens and increase awareness of pro-environmental activities.

Lichens, especially in Kenyan ecosystems and human life have diverse uses as shown in Table 3. Their use was region and environment-specific, for example, near conservation facilities (forests of Kakamega, Karura and Ngong), people could recognize the role of lichens in biodiversity, and as habitats for insects (Resp. 8 and 10, Appendix 1), while in most of the rural areas, lichens are either passively collected with firewood or used independently to light and maintain the fire (Resp. 10, 24, 30, 34, 59, 51, Appendix 1, Fig. 5). Among the Maa groups in Narok County, lichens are used as dyes (e.g. hair dye – Resp. 34, Appendix 1) in some of the life pas-

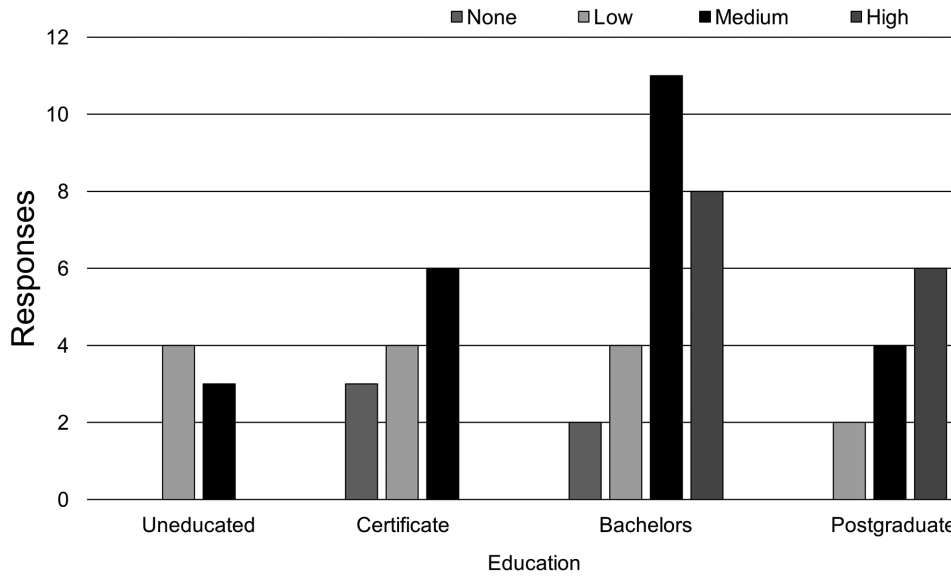

Fig. 4. Knowledge of lichens across different literacy levels in Kenya

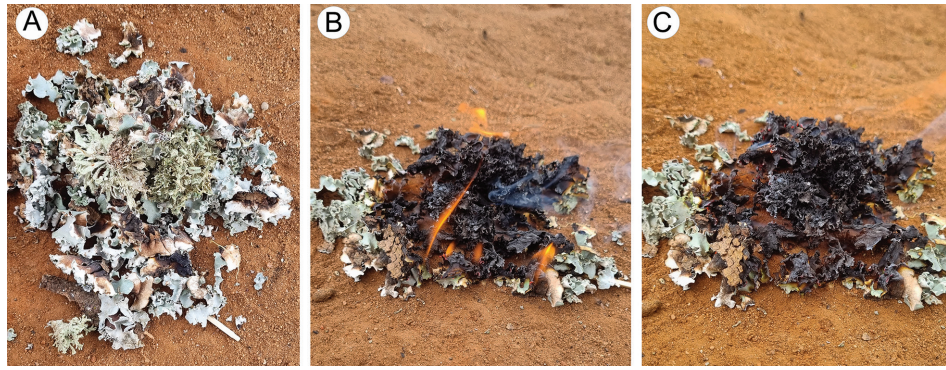

Fig. 5. Lichens used to light fire: A = intact thalli of various lichen species, mostly *Parmotrema* species and *Ramalina africana* in the centre; B = an early moment with flames of the fire lit by dry thalli; C = burnt remnants of lichen thalli and smoke

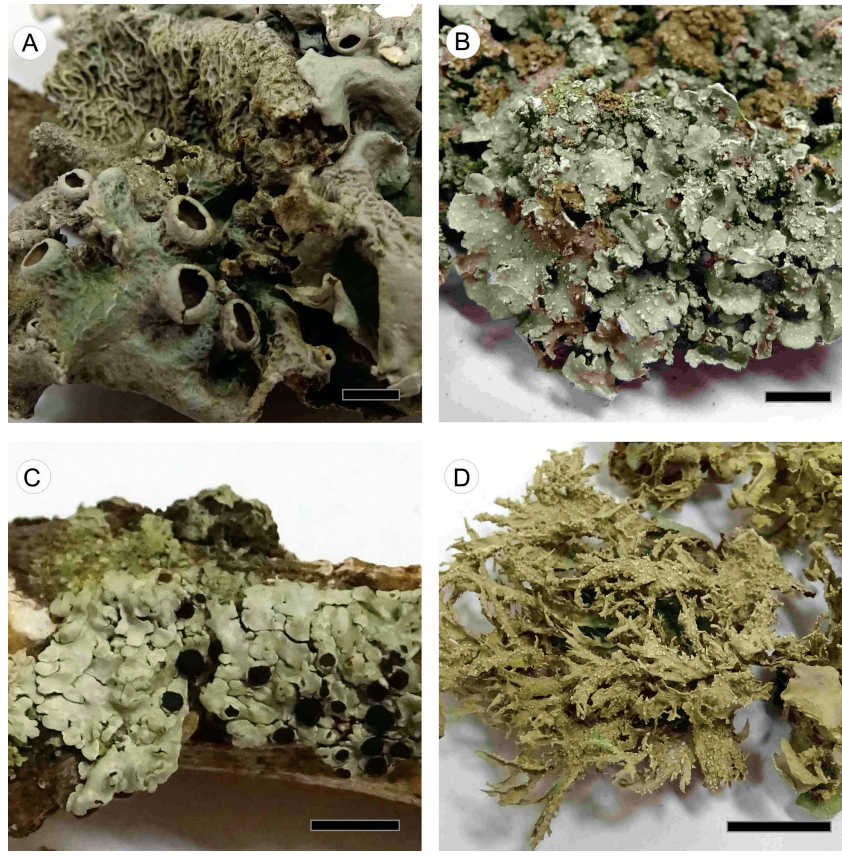

Fig. 6. A few examples of lichens used to light fire in Makueni study area: A = *Parmotrema eunetum*, B = *Punctelia stictica*, C = *Pyxine convexior*, D = *Ramalina africana*. Scales 1 cm

sage rituals. A substantial number of people did not know about lichen uses, especially the age group of 18–25 (see Table 1). Lichens were also regarded as having parasitic nature, especially those living on tree bark (corticolous ones) on specific valuable timber where according to the respondents, lichens (e.g., *Parmotrema austrosinense*, *P. eunetum*, *P. hababianum*, *P. reticulatum*, *Punctelia stictica*, *Pyxine convexior*, and *Ramalina africana* as identified by HPTLC) (Fig. 6) were scraped off and burnt.

Medicinal use of beard lichens (e.g., *Usnea bornmuelleri*, Fig. 7) was mentioned from Makueni county (Resp. 16, Appendix 1) where the tradition still exists even in the past 2–3 decades. The thalli, collected from rock boulders, is ground into powder and mixed with tea or soup and the bitter liquid is taken against headaches. This effect of usnic acid, also present in the applied lichen, has been reported from *U. diffracta* (that contains also diffractaic acid) (Nash 2008, Okuyama *et al.* 1995) for analgesic effects).

The responses on the uses of lichens were recorded to investigate lichen uses in all age groups, while almost half of the respondents were not aware of any roles. The results agree with opinions expressed by Pereira *et al.* (2020) and Supyan *et al.* (2021) who indicated a gap in awareness of nature by the young generations, however that (gap) can be filled by traditional knowledge (Supyan *et al.* 2021). The responses for the role of lichens in the four study

Fig. 7. Usnea bornmuelleri, a lichen applied in tea against headache in Makueni study area: A = the habit of some thalli; B = a detail of a high performance thin layer chromatographic plate, used to identify lichen secondary metabolites from the thalli responsible for the alleviating effect. Scale 1 cm

Table 4
The types of threats to lichens determined in different study areas by interviews of 60 respondents (see also column "Threats to lichens" in Table 1)

	Threats to lichens						
	A	B	C	D	E	F	
Kakamega	2	9	1	3	8	1	
Narok	5	2	0	2	1	0	
Nairobi	5	9	5	0	4	0	
Makueni	4	10	2	0	9	0	
Total	16	30	8	5	22	1	82
Percentage	20%	37%	10%	6%	27%	1%	

The number of mentions is given irrelevant to the number of respondents (n = 82). A = unaware of lichen threats; B = human factors; C = industrialization; D = unprioritized conservation efforts; E = environmental factors; F = invasive species

areas revealed the great importance of the lichens, "the unsung giants" in nature that cut across from human use to natural biological indicators of pollution (Resp. 1 and 27, Appendix 1) (Bergamini *et al.* 2005, Nash 2008, Sutar *et al.* 2021). Therefore, conservation of lichens is justified by their multiple applications.

Conservation threats of lichens and their environment in the four study areas (Table 4, Appendix 1, Table 1) were location-specific, driven by the geographical, climatic, consequently vegetational variation in Kenya and the varied communities in the areas. A threat to lichens might either affect their habitat or substrate, or their species (Hogue and Breon 2022). The results (Table 4) show that the highest threats originate from human factors which were related to increase in population, agricultural activities, land grabbing and settling increase of Kenyan population (Njuguna *et al.* 2016). Agricultural activities led the human factor category, since agriculture is the backbone of the Kenyan economy, agricultural activities cut across all the four counties. Climate change is coupled with events like floods, drought and unreliable weather patterns mentioned as the second highest threat to the four study areas (Lawrence *et al.* 2023). Although the climate change (Ellis 2019) is hard to be controlled, protective measures can be introduced to reduce the future loss of lichens. Narok County led the challenge related to the lack of knowledge on threats of lichens. It can be explained by the following facts. Though the Maa communities have a good knowledge and awareness on their environment, the vast lands where they have their pastoral activities do not allow developing considerable knowledge on these cryptogamic organisms, rather on a few vascular ones, those they can use as herbs and dyes. Even more importantly, their focus might be on their cattle (which is the sole source of livelihood).

Nairobi County's major threats came from human factors and industrialization. The increase in rural-urban migrations has increased the population in Nairobi County, thus more land is converted to built-up areas within the settlement at the expense of the habitats and conservation of species including the encroachment of Karura Forest. From the research done, it was clear that the rise in industries, as the increasing influence of human factors, and climate change (Resp. 1, Appendix 1) have a significant negative impact on lichen survival (Fryday *et al.* 2022, Naeku 2020). Additionally, not knowing the threats of a species (e.g., lichen species) is a threat itself, since it can slow down conservation efforts by a community where conservation matters could be addressed when the species is almost extinct.

Conservation is a way of protecting the treasures of a country including its living organisms. Responses collected represented effecting agents, and the frequency of responses was expressed in the number of mentions regardless of the number of respondents (Fig. 8 and Table 1). According to the results (Fig. 8) setting laws that govern and penalties in case of breakage of any law, education on lichens, and conservation (Naeku 2020) were proposed as leading factors to conservation gain. Two major bodies, Kenya Wildlife Services (KWS) and Kenya Forest Services (KFS), furthermore Forest Act 2016 having a role in conservation were mentioned by respondents (Resp. 6 and 28, Appendix 1). Habitat protection (Resp. 29, Appendix 1) where species thrive attracts attention from the government and the community surrounding any conservation facility (game reserves, national parks, protected forests and sanctuaries) in Kenya termed as friends of the specific facilities. The fact that a few people did not know about conservation, calls for attention to either the government of

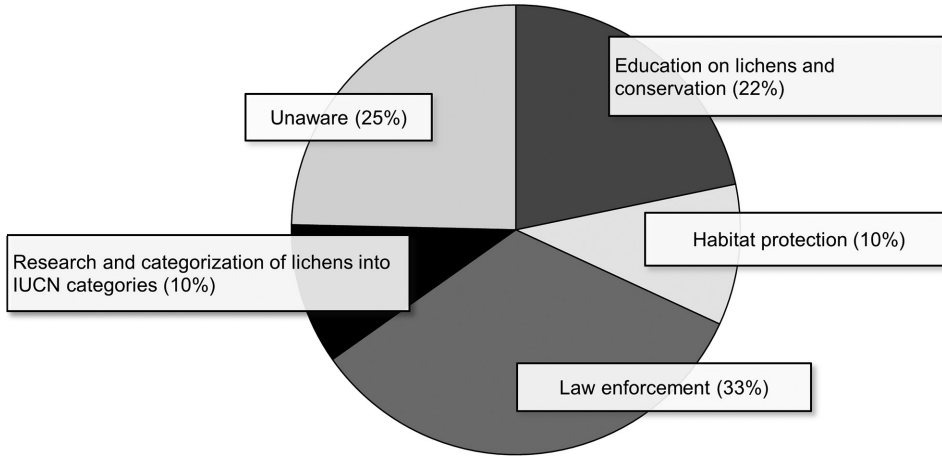

Fig. 8. Knowledge on conservation-related matters of lichens (see also column "Conservation strategies" in Table 1)

Kenya or ecologists to create a schedule for sensitizing its citizens and maybe include them in basic academic programs in schools (Cockerill and Hagerman 2020). Kenya is a frequent target of tourism, and although much has been centralized on wildlife (mostly large mammals) conservation, especially in savannas and forests, in their habitats formed by higher plants further small living organisms and geological formations are highly protected for their survival.

CONCLUSIONS

The study shows a diverse pattern of knowledge by the various age groups, and literacy levels from urban and rural study areas and confirms evidence of unused local knowledge, traditions and applications among the Kenyan communities which are rapidly being eroded by modernization and the development of academic knowledge. In order to prove the viability of a concept acquired in traditional knowledge, laboratory analysis should be involved as a recent possibility originating from modern education. Traditional knowledge must be documented, and its transmission to younger generations through oral tradition or in many other ways cannot be postponed. In addition to making the research and data collection process more effective, introducing a multi-disciplinary approach, the involvement of cultural anthropology (action anthropology) and its mediating role can also be of great help in this.

However, to conserve lichen biodiversity in Kenyan hotspots, traditional and academic knowledge should be integrated. In addition, updating practical knowledge incorporated into the framework of formal education and coordinated with one's own environment can also be a forward-looking solution, the role of lichens should be better explained in regular education, and the awareness of the elderly needs to be increased and motivated.

Furthermore, informing communities about alternative sources and energy can also be an effective solution, they should be sensitized on alternative sources of energy as most are over-collecting and destroying several tree species in the form of firewood, in extended rural areas, where forest trees represent substrate (bark and wood) for epiphytic lichens.

*

Acknowledgements – Authors are grateful to the head and members of the Traditional Ecological Knowledge Research Group in the HUN-REN Centre for Ecological Research, Vácrátót (especially to Dr Zsolt Molnár and Mr Edwin Wagah) for the useful discussions and methodological advice for the preparation of questions concerning the interviews, for pre-screening and approval before delivering them to the participants. The most valuable consultation with Dr Ibolya Tomory (Óbuda University Ágoston Trefort Centre for Engineering Teacher Education, Budapest) was an indispensable step towards a revised version of a former manu-

script. This study was supported by the National Research Development and Innovation Fund NKFI K 124341 and the Stipendium Hungaricum Scholarship (2022–2026).

REFERENCES

Albuquerque, U. P., Ludwig, D., Feitosa, I. S., de Moura, J. M. B., Gonçalves, P. H. S., da Silva, R. H., da Silva, T. C., Gonçalves-Souza, T. and Júnior, W. S. F. (2021): Integrating traditional ecological knowledge into academic research at local and global scales. – *Reg. Environ. Change* **21**(2): 45. https://doi.org/10.1007/s10113-021-01774-2

Andole, O. H., Matsui, K. and Antwi, A. O. (2020): The role of women enterprises for the conservation of Kakamega forest, Kenya. – *J. Adv. Res. Soc. Sci. and Human.* **5**(3): 52–56. https://doi.org/10.26500/JARSSH-05-2020-0301

Arup, U., Ekman, S., Lindblom, L. and Mattsson, J. E. (1993): High performance thin layer chromatography (HPTLC), an improved technique for screening lichen substances. – *Lichenologist* **25**(1): 61–71. https://doi.org/10.1006/lich.1993.1018

Babbie, E. R. (2016): *The practice of social research.* 14th ed. – Cengage Learning, Belmont, 566 pp.

Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A. and Wood, E. F. (2018): Data descriptor: present and future Köppen-Geiger climate classification maps at 1-km resolution. – *Sci. Data* **5**: 180214. https://doi.org/10.1038/sdata.2018.214

Bellino, M. J. (2018): Closing information gaps in Kakuma Refugee Camp: a youth participatory action research study. – *Amer. J. Comm. Psychol.* **62**(3–4): 492–507. https://doi.org/10.1002/ajcp.12277

Bergamini, A., Scheidegger, C., Stofer, S., Carvalho, P., Davey, S., Dietrich, M., Dubs, F., Farkas, E., Groner, U., Kärkkäinen, K., *et al.* (2005): Performance of macro lichens and lichen genera as indicators of lichen species richness and composition. – *Cons. Biol.* **19**(4): 1051–1062. https://doi.org/10.1111/j.1523-1739.2005.00192.x-i1

Boglár, L. (2001): *A kultúra arcai. Mozaikok a kulturális antropológia köréből.* (Faces of culture. Mosaics from the field of cultural anthropology). – Napvilág Kiadó, Budapest, 106 pp.

Burgess, R. (1984): *In the field: an introduction to field research*. – Allen and Unwin, London, 254 pp.

Cockerill, K. A. and Hagerman, S. M. (2020): Historical insights for understanding the emergence of community-based conservation in Kenya: international agendas, colonial legacies, and contested worldviews. – *Ecol. and Soc.* **25**(2): 1–19. https://doi.org/10.5751/ES-11409-250215

CoG (2022): *Narok County integrated development plan 2018–2022*. – Council of Governors (CoG). https://www.devolutionhub.or.ke/resource/narok-county-integrated-development-plan-2018-2022 (accessed 27 April 2024).

Devkota, S., Chaudhary, R. P., Werth, S. and Scheidegger, C. (2017): Indigenous knowledge and use of lichens by the lichenophilic communities of the Nepal Himalaya. – *J. Ethnobiol. Ethnomed.* **13**(1): 15. https://doi.org/10.1186/s13002-017-0142-2

Eller, D. J. (2020): *Cultural survival and revival in the twenty-first century*. – In: Nanda, S. and Warms, R. L. (eds): Cultural anthropology. Routledge, London and New York, pp. 322–344. https://doi.org/10.4324/9780429197710-18

Ellis, C. J. (2019): Climate change, bioclimatic models and the risk to lichen diversity. – *Diversity* **11**(4): 54. https://doi.org/10.3390/d11040054

Farkas, E. and Muhoro, A. M. (2022): Identification key to the lichen species of the parmelioid clade in Kenya. – *Lichenologist* **54**(5): 299–318. https://doi.org/10.1017/S0024282922000299

Farkas, E., Lőkös, L., Muhoro, A. M. and Varga, N. (2023): New records of lichens and lichenicolous fungi from Kenya and Tanzania (East Africa). – *Acta Biol. Plant. Agriens.* **11**(1): 107–128. https://doi.org/10.21406/abpa.2023.11.1.107

Fernández-Llamazares, Á., Lepofsky, D., Lertzman, K., Armstrong, C. G., Brondizio, E. S., Gavin, M. C., Lyver, P. O. B., Nicholas, G. P., Pascua, P., Reo, N. J. *et al.* (2021): Scientists' warning to humanity on threats to indigenous and local knowledge systems. – *J. Ethnobiol.* **41**(2): 144–169. https://doi.org/10.2993/0278-0771-41.2.144

Fryday, A. M., Beckett, R. P. and Kirika, P. M. (2022): Lichenology in Africa. – *Lichenologist* **54**(5): 227–230. https://doi.org/10.1017/S0024282922000329

Gakuya, D. W., Okumu, M. O., Kiama, S. G., Mbaria, J. M., Gathumbi, P. K., Mathiu, P. M., and Nguta, J. M. (2020): Traditional medicine in Kenya: past and current status, challenges, and the way forward. – *Sci Afr.* **8**: e00360. https://doi.org/10.1016/j.sciaf.2020.e00360

Gómez-Baggethun, E. (2022): Is there a future for indigenous and local knowledge? – *J. Peasant Stud.* **49**(6): 1139–1157. doi:10.1080/03066150.2021.1926994

Habel, J. C., Schultze-Gebhardt, K., Maghenda, M., Shauri, H., Kioko, E., Mwagura, L. and Teucher, M. (2023): Harmonizing multi-stakeholder interests to improve forest conservation in Southern Kenya. – *Biodiv. Conserv.* **32**: 1777–1785. https://doi.org/10.1007/s10531-023-02591-1

Hawksworth, D. L. and Grube, M. (2020): Lichens redefined as complex ecosystems. – *New Phytologist* **227**(5): 1281–1283. doi:10.1111/nph.16630

Hogue, A. S. and Breon, K. (2022): The greatest threats to species. – *Conserv. Sci. Pract*. **4**(5): e12670. https://doi.org/10.1111/csp2.12670

Huntington, H. P. (2018): *Traditional knowledge and resource development*. – In: Southcott, C., Abele, F., Natcher, D. and Parlee, B. (eds): Resources and sustainable development in the Arctic. Taylor and Francis, London, pp. 234–250. https://doi.org/10.4324/9781351019101

Ibrahim, M. S. N., Assim, M. I. S. A., Johari, S., Mohammad, S. K. W., Afandi, S. H. M. and Hassan, S. (2022): Public awareness on biodiversity conservation and well-being: case of Gunung Mulu National Park, Sarawak. – *GeoJournal* **88**(3): 3471–3496. https://doi.org/10.1007/s10708-022-10818-x

Kaasalainen, U., Biermann, L., Mollel, N. P., Schmidt, A. R. and Hemp, A. (2022): Peltigera (Lecanoromycetes) on Mt Kilimanjaro, East Africa. – *Lichenologist* **54**(5): 231–243. https://doi.org/10.1017/S0024282922000184

Kaasalainen, U., Kirika, P. M., Mollel, N. P., Hemp, A. and Rikkinen, J. (2023): The lichen genus Sticta (Lobariaceae, Peltigerales) in East African montane ecosystems. – *J. Fungi* **9**(2): 246. https://doi.org/10.3390/jof9020246

Kaasalainen, U., Tuovinen, V., Kirika, P. M., Mollel, N. P., Hemp, A. and Rikkinen, J. (2021): Diversity of Leptogium (Collemataceae, Ascomycota) in East African montane ecosystems. – *Microorganisms* **9**(2): 314. https://doi.org/10.3390/microorganisms9020314

Kennedy, G., Wang, Z., Maundu, P. and Hunter, D. (2022): The role of traditional knowledge and food biodiversity to transform modern food systems. – *Trends Food Sci. Technol.* **130**(1): 32–41. https://doi.org/10.1016/j.tifs.2022.09.011

Khasandi-Telewa, V. (2016): Folklore and environmental conservation among the Swahili and Luhya of Kenya. – *Int. J. Innov. Res. Develop.* **5**(5): 146–154.

Kinge, T. R., Jefwa, J. M., Houdanon, R. D., Kamalebo, H. M., Abdel-Azeem, A. M., Gryzenhout, M., Triebel, D., Weibulat, T. and Rambold, G. (2023): Management and publication of scientific data on traditional mycological and lichenological knowledge in Africa. – *Lichenologist* **55**(5): 169–179. https://doi.org/10.1017/S0024282923000294

Kirika, P., Mugambi, G., Lücking, R. and Lumbsch, H. T. (2012): New records of lichen-forming fungi from Kenya. – *J. East Afr. Nat. Hist*. **101**(1): 73–98. https://doi.org/10.2982/028.101.0105

Kirika, P. M., Ndiritu, G. G., Mugambi, G. K., Newton, L. E. and Lumbsch, H. T. (2018): Diversity and altitudinal distribution of understorey corticolous lichens in a tropical montane forest in Kenya (East Africa). – *Cryptog. Biodiv. Assessm*. Spec. Vol., 47–70. https://doi.org/10.21756/cab.esp87

Kirui, K. (2024): *Maa leaders call for preservation of Kenyan cultures*. – In: The Star, 28 April 2023. https://www.the-star.co.ke/counties/rift-valley/2023-04-28-maa-leaders-call-for-preservation-of-kenyan-cultures/ (accessed 9 July 2024).

KNBS (2019*a*): *2019 Kenya population and housing census results*. – In: 2019 Census, KNBS News. Kenya National Bureau of Statistics (KNBS). https://www.knbs.or.ke/2019-kenya-population-and-housing-census-reports/ (accessed 16 April 2024).

KNBS (2019*b*): 2019 *Kenya population and housing census. Volume I: Population by county and sub-county*. – In: 2019 Census, KNBS News. Kenya National Bureau of Statistics (KNBS). https://www.knbs.or.ke/?wpdmpro=2019-kenya-population-and-housing-census-volume-i-population-by-county-and-sub-county (accessed 27 April 2024).

Kottak, C. P. (2021): *Anthropology (Appreciating human diversity)*. 19th ed. – McGraw-Hill Education, New York, 594 pp.

Lawrence, T. J., Vilbig, J. M., Kangogo, G., Fèvre, E. M., Deem, S. L., Gluecks, I., Sagan, V. and Shacham, E. (2023): Shifting climate zones and expanding tropical and arid climate regions across Kenya (1980–2020). – *Reg. Environ. Change* **23**(2): 59. https://doi.org/10.1007/s10113-023-02055-w

MCIDP (2018): *Makueni County integrated development plan 2018–2022*. – Makueni: County Government of Makueni. https://repository.kippra.or.ke/xmlui/handle/123456789/646 (accessed 27 April 2024).

Mittermeier, R. A., Mittermeier, C. G., Brooks, T. M., Pilgrim, J. D., Konstant, W. R., Da Fonseca, G. A. B. and Kormos, C. (2003): Wilderness and biodiversity conservation. – *Proc. Natl. Acad. Sci. USA* **100**(18): 10309–10313. https://doi.org/10.1073/pnas.1732458100

Mittermeier, R. A., Robles-Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C. G., Lamoreux, J. and da Fonseca, G. A. B. (2004): *Hotspots revisited: earth's biologically wealthiest and most threatened ecosystems*. – Conservation International, Arlington, Virginia, USA.

Mittermeier, R. A., Turner, W. R., Larsen, F. W., Brooks, T. M. and Gascon, C. (2011): *Global biodiversity conservation: the critical role of hotspots*. – In: Zachos, F. E. and Habel, J. C. (eds): Biodiversity hotspots. Springer-Verlag, Berlin, Heidelberg, pp. 3–22. https://doi.org/10.1007/978-3-642-20992-5_1

Molnár, K. and Farkas, E. (2010): Current results on biological activities of lichen secondary metabolites: a review. – *Z Naturforsch C, J. Biosci.* **65**(3–4): 157–173. https://doi.org/10.1515/znc-2010-3-401

Molnár, K. and Farkas, E. (2011): Depsides and depsidones in populations of the lichen Hypogymnia physodes and its genetic diversity. – *Ann. Bot. Fennici* **48**(6): 473–482. https://doi.org/10.5735/085.048.0605

Muthee, J. K., Gakuya, D. W., Mbaria, J. M., Kareru, P. G., Mulei, C. M. and Njonge, F. K. (2011): Ethnobotanical study of anthelmintic and other medicinal plants traditionally used in Loitoktok district of Kenya. – *J. Ethnopharmacol.* **135**(1): 15–21. https://doi.org/10.1016/j.jep.2011.02.005

Naeku, M. J. (2020): Climate change governance: an analysis of the climate change legal regime in Kenya. – *Environ. Law Rev.* **2**(3): 170–183. https://doi.org/10.1177/1461452920958398

Nankaya, J., Gichuki, N., Lukhoba, C. and Balslev, H. (2020): Medicinal plants of the Maasai of Kenya: a review. – *Plants* **9**(1): 44. https://doi.org/10.3390/plants9010044

Nash, T. H. (2008): *Lichen biology*. 2nd ed. – Cambridge University Press, Cambridge, UK, 486 pp.

Njuguna, E., Brownhill, L., Kihoro, E., Muhammad, L. and Hickey, G. M. (2016): *Gendered technology adoption and household food security in semi-arid Eastern Kenya*. – In: Njuki, J., Parkins, J. R. and Kaler, A. (eds): Transforming gender and food security in the Global South. Routledge, London and New York, pp. 260–282.

Okuyama, E., Umeyama, K., Yamazaki, M., Kinoshita, Y. and Yamamoto, Y. (1995): Usnic acid and diffractaic acid as analgesic and antipyretic components of Usnea diffracta. – *Planta Med*. **61**: 113–115. https://doi.org/10.1055/s-2006-958027

Pereira, E. C., Da Silva, N. H., Buril, M. de L. L., Martins, M. C. B., Silva, H. A. M. F., Falcão, E. P. S., de Oliveira, H. P., da Costa, M. M., Legaz, M. E., Santiago, R. *et al.* (2020): *Bioactive compounds from Brazilian lichens and their biotechnological applications*. – In: Swamy, M. K. (ed.): Plant-derived bioactives: production, properties and therapeutic applications. Springer Nature Singapore Pte Ltd., Singapore, pp. 209–238. https://doi.org/10.1007/978-981-15-1761-7_9

Pretty, J. and Pilgrim, S. (2008): *Indigenous intelligence: diverse solutions for the 21st century*. – In: Nature and culture. Resurgence. Web Exclusives 250. Sept/Oct 2008. https://www.resurgence.org/magazine/article2629-nature-and-culture.html (accessed 10 July 2024).

Ren, H., Guo, W., Zhang, Z., Kisovi, L. M. and Das, P. (2020): Population density and spatial patterns of informal settlements in Nairobi, Kenya. – *Sustainability* **12**(18): 7717. https://doi.org/10.3390/su12187717

Rono, P. K., Rahman, S. M., Amin, M. D. and Badruddoza, S. (2023): Unraveling the channels of food security of the households in northern Kenya: evidence from an exclusive dataset. – *Curr. Dev. Nutr.* **7**(2): 100005. https://doi.org/10.1016/j.cdnut.2022.100005

Suija, A., Kaasalainen, U., Kirika, P. M. and Rikkinen, J. (2018): Taitaia, a novel lichenicolous fungus in tropical montane forests in Kenya (East Africa). – *Lichenologist* **50**(2): 173–184. https://doi.org/10.1017/S0024282918000026

Supyan, S., Susanto, A. N., Samadan, G. M. and Sulistiono, S. (2021): Traditional wisdom as a starting point for conservation: a review. – *IOP Conf. Ser. Earth Environ. Sci.* **890**(1): 012064. https://doi.org/10.1088/1755-1315/890/1/012064

Susanto, D. and Numata, S. (2023): Traditional ecological knowledge of the Tengger tribe and its influencing factors in Bromo Tengger Semeru National Park. – *J. Trop. For. Manage.* **29**(3): 254–264. https://doi.org/10.7226/jtfm.29.3.254

Sutar, R. R., Gaikwad, S. B., Mapari, S. V. and Behera, B. C. (2021): Lichens: traditional use and biological activities. – *Bot. Pacifica* **10**(1): 69–82. https://doi.org/10.17581/bp.2021.10202

Swinscow, T. D. V and Krog, H. (1988): *Macrolichens of East Africa*. – British Museum (Natural History), London, 390 pp.

Thiers, B. (continuously updated): *Index Herbariorum: a global directory of public herbaria and associated staff*. – New York Botanical Garden's Virtual Herbarium. http://sweetgum.nybg.org/science/ih/. (accessed on 12 May 2024).

Tomory, I. (2018): *The role of foreign aid in education and development: field experiences, examples from East Africa*. – In: Auer, M. E., Guralnick, D. and Simonics, I. (eds): Teaching and learning in a digital world: proceedings of the 20th International Conference on Interactive Collaborative Learning: Vol. 1. Springer Netherlands, Dordrecht, pp. 936–942. https://doi.org/10.1007/978-3-319-73210-7_106

Tomory, I. (2019): The cultural context of adaptation western education in East-Africa: paradoxons and missing links. – *WEJSS* **8**: 133–145. https://doi.org/10.36739/wejss.2019.v8.i2.23

Tomory, I. (2024): *Challenges of technical training and technical teacher training in Africa*. – In: Tovar-Caro, E., Vendrell-Vidal, E., Cukierman, U. R. and Auer, M. E. (eds): Towards a hybrid, flexible and socially engaged higher education. Proceedings of the 26th International Conference on Interactive Collaborative Learning (ICL2023), Vol. 2. Cham: Springer Nature Switzerland, pp. 250–261. https://doi.org/10.1007/978-3-031-52667-1_25

Yang, M.-X., Devkota, S., Wang, L.-S. and Scheidegger, S. (2021): Ethnolichenology – The use of lichens in the Himalayas and Southwestern parts of China. – *Diversity* **13**(7): 330. https://doi.org/10.3390/d13070330

van Breugel, P., Kindt, R., Lillesø, J.-P. B. and van Breugel, M. (2015): Environmental gap analysis to prioritize conservation efforts in Eastern Africa. – *PLoS ONE* **10**(4): e0121444. https://doi.org/10.1371/journal.pone.0121444

Vinayaka, K. S. and Kekuda, T. R. P. (2023): *Ethnic knowledge on medicinal and nutritional attributes of lichens with emphasis on the Western Ghats*. – In: Östürk, M., Sridhar, K. R., Sarwat, M., Altay, V. and Huerta-Martínez, F. M. (eds): Ethnic knowledge and perspectives of medicinal plants. Vol. 2: Nutritional and dietary benefits. Apple Academic Press, New York, pp. 57–69.

APPENDIX 1
Details (demographics, questions, responses) of semi-structured interviews in different regions of Kenya

DEMOGRAPHICS

1. Location (rural/urban)
2. Gender
3. Age (18–25, 26–35, 36–45, 46–)
4. Level of education

QUESTIONS

Section A: General knowledge on lichens

1. What do you know about lichens and how they look?
2. How would you describe the lichens growing where you live?
3. From what you know, what kinds of conservation places are there in Kenya?
4. Where do you think lichens grow best? Are these places protected in any way?
5. What do you think lichens do for the environment?

Section B: Threats to lichens

1. What changes, if any, have you observed in the population or diversity of lichens over time in your region?
2. What activities do you believe could pose threats to lichen species in your area?

Section C: Strategies for conservation

1. What laws or regulations, if any, are you aware of that protect lichens in Kenya?
2. In your experience or knowledge, how is the protection of lichens currently being implemented in the country?
3. What strategies do you think could be effective in improving lichen conservation efforts?
4. What kinds of lichens do you think should be protected by law in Kenya?

RESPONSES

Makueni County and immediate environments (15–27 July 2023)

Resp. 1. Rural, female, 26–35, postgraduate. – Has high knowledge about lichens. Conservation of species in Kenya is done in protected regions, but lichens are indirectly protected by protecting their substrates (tree barks, soils, and rocks), though lichens grow in protected and non-protected areas. Lichens are useful for ecosystem monitoring in terms of pollution. Climate change has been a great threat to the ecosystem though forest encroachments and agricultural activities have catalysed a decline of diversity in the rural setups. Thus, using strict rules can protect species, especially in Kenya.

Resp. 2. Urban, female, 18–25, bachelor. – Has medium knowledge and can identify some. Species are conserved in Kenya, but more energy is given to animals (big five) and higher plants. Bryophytes just thrive passively in parks, sacred grooves, in both protected and non-protected areas. Climate change and forest encroachments have enabled the decline of species thus government of Kenya ought to pass strict laws of conservation, especially lichens.

Resp. 3. Urban, male, 26–35, bachelor. – Has very limited knowledge of lichens though can show foliose on soils. A few lichens can be spotted in urban areas. Much conservation of species is done on protected areas though unaware if lichens are included in the conservation. Their roles in the ecosystem might be to balance food chains/web thus more work is yet to be done to make people aware of their importance.

Resp. 4. Rural, male, 26–35, postgraduate (ecologist). – High knowledge about lichens and cryptogams. There is a high diversity of lichens in rural setups. Conservation of species is highly a priority in the protected areas in Kenya especially for higher plants and animals though lichens grow in all environments regardless of protection. Lichens are collected accidentally with firewood as sources of energy which might be a threat to conservation. In protected areas forest encroachment and climate change have been a threat to existence over time while in rural areas agricultural activities, an increase in population, and climate have affected lichens' existence over time. Currently no idea if there is a protection law about lichens other than Forest ACT 2016 which is too general on all forest species. Documenting Kenyan lichens might be the solution, especially in identifying and knowing their diversity.

Resp. 5. Urban, male, 18–25, bachelor. – Not aware of the existence of lichens and their protection in the Kenyan context although conservation of species in Kenya is done in forests and protected areas.

Resp. 6. Urban, male, 26–35, bachelor. – Moderate knowledge of lichens from school. Lichens are scattered in different areas having diverse habitats. Species conservation for both animals and plants is done in protected zones and national parks and reserves in Kenya by 2 major bodies KWS (Kenya Wildlife Services) and KFS (Kenya Forest Services)) although not sure if there are lichen considerations. Not sure about their roles in the ecosystem but they have shown a gradual reduction in the area due to industrialization (clearing their habitats).

Resp. 7. Urban, male, 26–35, bachelor. – Low knowledge about lichens but can point to a few samples. Not sure of their conservation status in Kenya although the country conserves species in national parks and reserves, forests, and sacred areas (passive conservation). There is a gradual decrease of land species over due to climate change, an increase of settlement and population increase, and agricultural practices. Sensitization of citizens on what lichens are, and their role in the ecosystem maybe through documentaries and social media can improve their conservation.

Resp. 8. Rural, male, 26–35, bachelor. – Greatly aware of the existence of lichens in the region and growing in diverse habitats. They can also be found in protected areas though not sure of their priorities on protection criteria. In Kenya species of animals and plants are protected in national parks and reserves, and protected forests. There is a great role of lichens in the ecosystem to humans, animals, and plants. Some are mixed for concoction making of herbs and nests for insects. Their existence has declined due to changes in weather, it had been too dry recently, agricultural activities, and forest encroachments due to an increase in population. Forest management by the government can be tighter to stop species decline and maybe sensitize citizens to reasons for the conservation of species. Not sure of any species documented in Kenyan laws for conservation.

Resp. 9. Rural, male, 46 and above, none. – Aware of them but the name was new, locally referred to as tree parasites, and usually scrapped to prevent tree death. Not sure of their importance in the ecosystem but their existence has declined over time due to tree loggings, agricultural practices, and an increase in population that clears land for settlement. No knowledge of their conservation in Kenyan national parks and reserves and protected forests. Sensitization of lichen importance can change people's perception on their roles and maybe the conservation might be improved.

Resp. 10. Rural, male, 26–35, certificate. – They exist in the region. The foliose are shelters for insects and can be used to start and maintain fire in the area. Not sure of their protection regulations in Kenya though passively protected in sacred grooves. There has been a gradual decline of lichen species due to weather changes, agricultural practices, and

increased settlements in the region. The conservationists should sensitize people on lichens and their role in improving their protection.

Resp. 11. Rural, female, 18–25, bachelor. – Lichens are frequently spotted in the region, especially on rocks and barks of trees. Conservation is biased toward higher plants and wild animals because of tourism attractions and is mostly done in parks reserves and protected forests. Lichens are passively conserved in these areas because of the presence of substrates (barks of trees, leaves, and rocks). There has been a gradual decline of species including lichens due to forest encroachments, weather changes, and clearing land for settlement. I am not sure of any database of lichen conservation in Kenya or species under conservation. The government can regulate the settlement of people and restrict forest management to conserve species.

Resp. 12. Urban, male, 26–35, postgraduate. – Slightly aware of lichens which are rarely spotted in the area. Conservation of species in Kenya is done on protected forests, national parks, and reserves and passively conserved on sacred grooves. Lichens in these areas are conserved though not documented on the species present in the conservation areas. The only threat to lichen conservation in the forest is illegal firewood collection and tree logging. Forest encroachment for agricultural activities and settlement has reduced species conserved. Government and specialists should sensitize citizens on the conservation of species and their importance.

Resp. 13. Rural, male, 26–35, bachelor. – Lichens are highly referred to as fungi and termed as saprophytes thus scrapped off from items, they attached citing they cause decomposition, especially timber. They have no use in the area though traditionally used as sources of energy. There is a high conservation of species in forests though not sure if lichens have a priority. It is upon being told their use and importance in nature that people can change their perception. Conservation lessons on nature can be introduced in school to create awareness from tender ages.

Resp. 14. Rural, male, 26–35, bachelor. – Moderate knowledge from high school; lichens are frequently spotted in the area and are often found on tree twigs and accidentally collected with firewood as sources of energy. Mostly in Kenya, the conservation of species is done in protected areas and passively in sacred groves though not sure if lichens are given priority in conservation. They are important to the ecosystem as they act as shelters for some insects and their collection with firewood though recent is a gradual reduction of their evenness due to excessive tree logging and agricultural practices. There is a call for stakeholders to enlighten the citizens on the conservation of species to stop depletion of Moreso lichens where most do not know their roles.

Resp. 15. Urban, female, 26–35, certificate. – Aware of the existence but known as fungi. Rarely spotted in the area, mostly on undisturbed environments and stones. Highly seen in protected areas like forests and sacred groves. Not aware of their role in the environment. There is a need for more knowledge on lichens and their role in the environment to be spread to the citizens.

Resp. 16. Rural, female, 46 and above, none. – Slightly aware and use them with firewood to start and maintain a fire. The thin filamentous ones (locally called roots of stones) are used for medicinal purposes. Usually ground to fine powder and mixed with warm solvent and taken to cure headaches. There are several lichens found in the forest both protected and unprotected, and parks (on sand, rocks, and barks of trees). Due to environmental changes, some species have been wiped away inclusive of the filamentous ones. Therefore, more conservation of the remaining needs to be increased.

Kakamega County and immediate environment (29th July – 10th August 2023)

Resp. 17. Urban, female, 26–35, postgraduate. – Slightly aware of lichens' existence though mostly spotted in conserved environments in the barks of trees. Not sure of their role in the environments. There is a decline of species in the ecosystem though not keen on lichens, which could be caused by climate change, clearing lands for agricultural purposes, forest encroachments, and tree illegal logging for timber. Strict measures to protect forests could be tightened to prevent illegal practices.

Resp. 18. Rural, male, 26–35, bachelor. – Lichens are called tree parasites (fungi) mostly scrapped off so as not to cause tree decay. The leafy ones are used to start and maintain fire and are collected with firewood as a source of energy. They are also found in protected areas and sacred groves in high quantities though their protection is achieved through their substrate conservation (trees). There is a gradual change in their abundance over time due to climate change, forest encouragements, and an increase in agricultural practices. Issuing permits for tree logging and restricting people from protected areas can reduce the misuse of species.

Resp. 19. Urban, female, 36–45, postgraduate. – Slightly aware of lichen but rarely seen in the area. In Kenya, national parks and reserves, protected and sacred grooves act as conservation areas for species although higher plants and animals have high importance due to their economic value; the diversity of species in these areas is rich inclusive of lichens. Lichens might have importance in the ecosystem though not aware of specifics maybe the conservationists should sensitize their importance for people to be aware. Currently, not aware of any lichens that are conserved or protected due to threats, though generally there has been a gradual decrease in biota due to climatic conditions.

Resp. 20. Rural, male, 26–35, postgraduate. – Generally confused with fungi and highly spotted in the area and protected areas in the country. Though not sure of their priority in conservation, they are densely growing in forests, especially the aged trees. Not sure of any protected species in Kenya though the government doesn't allow the collection of species from conserved areas without permits. Adverse climate conditions, forest encroachments, and settlement are diminishing the conservation efforts.

Resp. 21. Urban, female, 36–45, none. – Limited knowledge of lichens and a few grow in the areas. Their role in the ecosystem is not well defined and often ignored in the region thereby not considered to have any importance for conservation purposes. There has been a decline of all species due to climate change, increased agricultural activities, and settlement areas for the increased population.

Resp. 22. Urban, male, 18–25, certificate. – Not aware of lichens and their roles. Aware that conservation is done in Kenyan forest, game parks, and reserves.

Resp. 23. Rural, female, 36–45, bachelor. – lichens but might be connected to fungi and generally termed as decomposing agents. They are found on tree bark where they get shelter and maybe nutrients. They have no specific roles though termed as protectants of barks from physical damage. Not sure of a priority in their conservation in the protected areas in Kenya though higher plant and animal species have been documented in those areas. Conservation of species has been faced with unrealistic climate changes, encroachments, and tree logging in both protected and unprotected zones. Sensitization needs to be done on the use and management of forests and strict management of conserved areas can be accompanied with penalties upon once guilty.

Resp. 24. Rural, female, 36–45, postgraduate. – Highly conversant with lichens and cryptogams which make part of the ecosystem in the area and protected areas though passively conserved due to their substrates. The leafy lichens are highly collected as sources

of energy in remote areas, reducing threat to their diversity in the region. Although the lichens thrive in diverse areas and harsh environments increased pollution, especially near towns, climatic conditions and agricultural activities have reduced their quantities which calls for conservation experts to educate people on their role and the need to conserve them and other species in nature for future use.

Resp. 25. Urban, male, 26–35, certificate. – Less familiar to lichens and less spotted in the region though often grow in conserved areas and protected forests. There has been a decline of forests and conservation areas because of encroachments, settlements, and invasive species that suppress indigenous ecosystems. Much needs to be done on the management of forests, the introduction of exotic species, and regulating settlement areas.

Resp. 26. Urban, female, 18-26, bachelor. – Limited knowledge of lichens though highly spotted in the area and conservation areas (unprotected and protected areas). Also, lichens are found in undisturbed areas in sacred grooves. Conservation is highly concentrated in protected areas though much is done to higher plants and animals compared to lower plants and fungi. Thus, documentation on the species number of lower plants might not be available. This calls for scientists to sensitize the connected government docket to update all species in the conserved areas.

Resp. 27. Urban, male, 36–45, postgraduate (ecology lecturer). – Excellent knowledge of lichens especially the foliose lichens. Conservation of species is both ex-situ and in-situ (seedbanks, gene banks, in forests and museums). Lichens can be found in the forests they are passively conserved because of their habitats and those found in museums are for research purposes. Lichens are highly sensitive organisms that detect the health of an ecosystem thus used as bioindicators. In Kenya, there is no data on documented species of the country on protected species categories of lichens. There has been a gradual depletion of species because of climate change, the introduction of invasive species in the forests, industrialization, the increase of agricultural activities, and clearing forests for settlements. The government, ecologists, and conservationists have a role in sensitizing on species importance, strict rules on collection and destruction of forests, and having proper settling zones away from forests.

Resp. 28. Rural, male, 36–45, bachelor (forest warden). – Conservation officer at Kakamega Forest (covers two counties) which is managed by both KWS and KFS. Has both animal and plant conservation. Lichens are densely populated in the forests inclusive of the foliicolous lichens. The management highly conserves species according to the Forest Act 2016 where all species are crucial, and no collection is done without a permit. The nearest community (friends of Kakamega Forest) usually has the mandate of reporting cases of tree logging and promoting the protection knowledge to other communities. There is minimal data on the number of species of lichen species in the forest thus no documents of any protected species in the forest.

Resp. 29. Rural, female, 36–45, bachelor (forest officer). – Kakamega covers Kakamega and Nandi counties having almost 80% indigenous trees some over 50 years including Elgon oak. It's protected by the Kenya Wildlife Service (KWS) in collaboration with the Kenya Forest Service (KFS). These old trees are used as habitats for species – birds, lichens, mosses, and other microorganisms. No tree logging is allowed. The forest has seen a gradual decline of species due to climate change, forest encroachments, illegal tree logging, and the introduction of some exotic trees which have allelopathic effects on the soil. Lichens have been conserved in the area, but the systematics of their diversity is not well known. Currently, no species have been classified under any threat in Kenya though much needs to be done on systematics and analysis of their diversity and conservation priorities.

Resp. 30. Urban, male, 36–45, postgraduate. – Minimal knowledge of lichens though they are often growing on soil. Traditionally they were used to light fire in the local areas which have been replaced with gas and electricity. Their conservation in the region is only on protected and sacred groves. The increase in industries and pollution have reduced the number of species growing in the area.

Resp. 31. Rural, female, 46 and above, none. – Not sure of their name though were used to quickly light fire in the old days and accidentally collected with firewood as sources of energy (thread-like ones). There is no need for their protection as they grow in high amounts everywhere in the area maybe the government-protected areas.

Resp. 32. Rural, male, 36–45, postgraduate. – Medium knowledge of lichens. They grow on bark, stones, and on soils and mostly in wet environments. Lichens also grow in quantities in forests, protected lands, and sacred grooves. Although their species might not be documented fully, their diversity in nature can be seen. Not sure if Kenya has a list of species of lichens in the country and if any are in declining situation.

Narok County (10–22 August 2023)

Resp. 33. Rural, male, 26–35, certificate. – I am not aware of the name but aware of lichens, locally called 'narara' which are assumed to be part of the bark. The leafy ones are used to start fires in remote areas and are accidentally collected with firewood as sources of energy. They are declining because of high and dry temperatures in the region.

Resp. 34. Rural, female, 26–35, none. – Not aware of the name but they had a traditional role as dyes. They were mixed with other herbs and used as hair dye during cultural events. They are often found on trees and shrubs. High amounts are found in protected areas- forests, national parks, and reserves.

Resp. 35. Rural, male, 36–45, bachelor. – Medium knowledge of lichens. They are spotted in the area in leafy forms and used in the villages as sources of energy. They are conserved with other species in protected areas and passively in sacred groves. Not aware of their priority in conservation but their habitats are highly conserved (trees) thus sustaining their growth.

Resp. 36. Rural, female, 18–25, bachelor. – Usually confused with algae or mosses as most are green and classified as lower plants. Mostly they do not have a specified role in the ecosystem. Their conservation in the protected areas is passively by conserving their substrate. Most protected areas have documented tree species, not lower plants. Conservationists and related stakeholders need to update all species and sensitize the people on the roles of distinct species in the ecosystem.

Resp. 37. Rural, male, 18–25, bachelor. – Basic knowledge of lichens from biological classes. They are a symbiotic relationship between algae and fungi. Their symbiotic nature is of significant importance in nature as they produce their food. Their conservation is not well known but lichens are hardy and grow in diverse environments which makes them survive. I'm not sure of species lists, but they are well-known for their forms. There need to do more on conservation and biological systematics to update the lists of species.

Resp. 38. Rural, male, 36–45, basic education. – The name is not known but the lichens are well known in the region especially their use as dye in traditional setups. They grow freely on surfaces and undisturbed soils. Their protection depends on their use in the area, especially the leafy ones are highly used as sources of energy. Though their collection has contributed to their decline and increased population the area which turns bare lands into settlements.

Resp. 39. Rural, male, 46 and above, none. – Locally termed as extensions of the bark. Mixed with concoctions and used as herbs for diverse ailments including fever and head-

aches. Not sure of their protection though they have reduced with time because of tree logging and charcoal burning, clearing lands for settlements.

Resp. 40. Rural, female, 46 and above, none. – The name is not known though the organisms grow randomly in the environment and on the barks of trees which are used to start and maintain fire. They were also used in the olden days as sources of dyes. Not sure of the need for their protection because they are in high amounts in the environment.

Resp. 41. Urban, male, 18–25, bachelor. – Not sure of the name but the lichens are spotted in the areas, especially on walls of old buildings but confused with mosses and algae because of the green nature during the rainy season.

Resp. 42. Urban, male, 36–45, certificate. – They are found in damp areas and green but not sure if they are plants or dead organisms. Mostly scrapped from planted trees as they are thought to cause diseases and cause plant decay. Mostly burnt after collection to prevent regrowth. No knowledge of their conservation though they are also found in protected areas. People should be sensitized about their use and role in nature to prevent further misuse.

Nairobi country at its environment (25th August 2023 – 12th September 2023)

Ngong Forest

Resp. 43. Urban, female, 36–45, bachelor (forest officer). – Ngong Hills/Forest is a conservation centre that accommodates plants and a few wild animals. Highly managed by KFS and friends of the forest. It allows the friends of the forest to access part of the forest through grazing as they are pastoralists. The forest is situated in an arid and semi-arid region with both exotic and indigenous varieties of trees. Some significant volcanic soils and stones harbour significant amounts of lichen. Conservation has highly been challenged by industrialization, pollution, and nearby communities (Maa people) who are pastoralists and graze in the forest, which causes disturbance in their growth.

Resp. 44. Rural, male, 26–35, bachelor (forest warden). – Lichens are passively conserved in the forest due to the presence of their substrates, especially shrubs and rocky environments. The forest has seen a decline of species over time and also lost land to a nearby increasing community. The decline has been due to harsh weather conditions and to its nature of tourist attractions thus construction ongoing. Forest encroachment for grazing lands has left part of it shrubby and losing some species of lichens where their habitats have been disturbed. Conservation sensitization to the pastoralists should be done to reduce forest disturbances and destocking of their cattle.

Resp. 45. Rural, male, 26–35, bachelor. – Conservation is highly key where all species are protected including a few wild animal species. Lichens often grow in the forests on the calcareous rocks, soils, and barks of the trees. A few can be spotted on rocks. The main challenge of conservation is the unpredictable weather conditions, pastoralist communities that graze near the forest, forest encroachments, and pollution due to its location near the capital centre. Recommendations are for the government to enlighten the community on the conservation of the forest, strict management of the forest, and setting grazing zones and demarcations of the forest.

Resp. 46. Rural, male, 18–25, certificate. – The forest contains diverse species which are protected by KFS. The knowledge of lichens is minimal though they are often spotted in the forest, especially the leafy/ branched ones. Their role in the ecosystem is not known and their protection might be of less important to the forest. The increase in population, pollution, and forest encroachments has led to the decline of species and grabbing of forest land.

Resp. 47. Rural, male, 18–25, certificate. – Lichens are not well known but they often grow in the area and in the Ngong Forest. Details on their conservation are not well known. Due to pastoralists found in this area and the arid and semi-arid climatic conditions, most land is bare, and a few shrubs can be found. Campaigns led by the government, the community, and conservationists for tree planting reclaim the land. Not sure if there are protected lichens.

Resp. 48. Rural, male, 18–25, certificate. – As a pastoralist, and a friend of the Ngong Forest; conservation of the forest is paramount due to its microclimate. Lichens are accidentally conserved because of their habitats, i.e. trees and stones found in the forests. There is a need to educate the pastoralists on the destocking of their flocks as they cause overgrazing in the area and immerse on other profitable agriculture. Overgrazing has led to a decline of species, biodiversity, and bare lands exposing them to runoffs.

Resp. 49. Rural, female, 36–45, certificate. – The rural area is very dry a clear characteristic of arid and semi-arid areas. Although the name is not common, the organisms are often found in the area. Mostly sticking on rocks and loosely attached to the bark of trees. Not sure of their conservation in the forest although they are spotted amidst other species.

Karura Forest

Resp. 50. Urban, male, 26–35, bachelor. – Karura Forest lies within the capital city of Nairobi County and is majorly under Kenya Forest Services (KWS) management and friends of Karura Forest which is the immediate community. Lichens are conserved in this conservation area passively as majorly higher plants of high priority. Not yet documented the species diversity of lichens in the forest. The old logs harbour high amounts of species of lichens and even other animals' bird nests. There has gradual loss of the forests due to industrialization and pollution which harms biodiversity and the density of species. The management can be strict on rules and allocation of industries' land.

Resp. 51. Urban, female, 26–35, bachelor (forest scout). – Lichens are classified under lower plants in the forest and part of the species conserved in the forest. The challenge is firewood collections that are legalized in the forest as most are attached to the branches. Pollution and climate change have also led to the gradual decline of species in the forest. The nearby should change to other sources of energy and firewood collection banned. This can restore some lichens.

Resp. 52. Urban, female, 36–45, bachelor (forest scout). – All species in the forests are protected from destruction inclusive of lichens and no collection is allowed without permit. The indigenous trees are highly protected as they harbour most epiphytes like lichens and logging results in a penalty. The friends of Karura protect the forest encroachment and report on matters of illegal logging.

Resp. 53. Urban, male, 26–35, postgraduate (forest officer). – Though they are not the main agenda of conservation, lichens are in large amounts in the forest. The forest is demarcated into hiking, leisure, and protected zones. Incorporation of the immediate community in conservation has improved the forest status although pollution is negatively affecting the diversity of species. Much of the forest land is lost to industrialization. This calls for the government to reallocate other lands for industrialization.

Nairobi Centre (Central Business District and nearby accommodation areas)

Resp. 54. Urban, female, 46 and above, postgraduate (biology teacher). – The ecosystem in the city centre can only accommodate a few plant and animal species due to industrialization, pollution, and the settlements of people. Lichens because of their nature to

survive in harsh environments are few, spotted in undisturbed places like rocks and buildings. In Kenya conservation and protection of species is done in forests, game reserves, game parks, and sacred groves.

Resp. 55. Urban, female, 18–25, bachelor. – Very low knowledge of lichens. Few are spotted in the centre, especially on walls of old buildings but highly seen in forests and protected areas. Conservation is only done in forests, game park reserves, and sacred groves. Not sure of their role or their conservation status in the country.

Resp. 56. Urban, male, 36–45, basic education. – Limited knowledge of their existence in the area but they are often found in forests. Their role is not known in the region, but they grow and attach themselves to substrates majorly because of their lack of roots.

Resp. 57. Urban, male, 26–35, bachelor. – Medium knowledge of lichens from biology classes in school. They are symbiotic and thus produce their food. Very minimal in the area but highly found in the outskirts of the city and the nearby forest and conservation areas like Nairobi reserve and Karura Forest.

Resp. 58. Urban, female, 18–25, bachelor. – Low basic knowledge of lichens which are classified under cryptogams/epiphytes. Just attach on substrates for support as they are autotrophs.

Resp. 59. Urban, male, 18–25, basic education. – Very low knowledge of lichens though conservation for species is often done in the forests and protected areas in the country. Not sure about their priority of conservation in Kenyan protection although they grow in diverse environments.

Resp. 60. Urban, female, 18–25, certificate. – No knowledge on the existence of lichens. Although in Kenya, conservation of species is majorly done in forests, game parks and game reserves. Threats to conservation have been pollution especially near towns and industrialization.