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Full Length Research Paper

Rosewood (*Pterocarpus erinaceus)* as a de facto forest common for local communities in Ghana

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This paper discusses how rosewood as a common-pool resource is managed and utilized at the local community level in the wake of aggravated exploitation of the resource for export to feed external markets. Non-probability sampling technique coupled with focus group discussion was used to collect primary data from two administrative districts in the transitional zone between the savannah and high forest in Ghana. In all, researchers interacted with 96 respondents in a survey and 77 participants in focus group discussions in 6 communities. The results indicate that the governance structure and management strategy for the sustainable use of rosewood and other forest commons are ineffective in the studied communities. Illegal rosewood harvesting thrived due to weak institutional structures, poor community knowledge of the value of rosewood logs in the international market and poor public knowledge about a ban on the harvesting and export of rosewood. Sustainable management and utilization of rosewood and other forest commons on village lands (lands outsider protected areas) could be improved if local communities are empowered and given technical support to manage forest resources on their lands. The conduct of natural capital accounting in forest resources and communicating the result to local communities could help residents appreciate the true value of forest resources and probably aspire for a greater quota of benefits. With a better understanding of the value of a forest, residents may be motivated to protect it from unsustainable use.

Key words: Institutional structures, natural resource use, sustainable management, illegal logging.

INTRODUCTION

Pterocarpus erinaceus Poir, a rosewood species, is a deciduous tree of African savannas and dry forests. It is usually found in open dry forests of semiarid and sub-humid lands with a mean annual rainfall of 600–1200 mm

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and mean annual temperature ranging from 15 to 32°C (Adjonou et al., 2020). The tree thrives on all soil types,preferably light to medium, free-draining, acid to neutral soils. It is drought tolerant thus has resilience towards the yearly savanna bush fires (Adjonou et al., 2019). Generally, rosewoods are hardwood species used to produce expensive furniture patronized by the elite class mostly in Asia (Zhu, 2020). The wood is also useful in the production of railway slippers, musical instruments, recreational products (e.g. chess pieces), and decorating the interior of ships. Rosewoods are species with significant economic importance to local communities across Africa (Dumenu, 2019; Ahmed et al., 2016; Dumenu and Bandoh, 2016). The use of rosewood species for fodder, charcoal, carving tools and instruments, building materials, and medicine are common in West African countries such as Cote d'Ivoire, Ghana, Nigeria, and Togo (Ahmed et al., 2016).

In Ghana, *P. erinaceus* occurs in ten out of sixteen administrative regions, namely; Ashanti, Bono East, Bono, Ahafo, Northern, North East, Savannah, Upper East, Upper West, and Oti regions. Ahafo region is said to have the highest volume of rosewood and in 2013 was estimated to have contributed about 70% of total rosewood production in the country (TIDD/FC, 2014). *P. erinaceus* has traditionally been exploited by local people in the savannas of Ghana mainly for charcoal and fuelwood production (Dumenu, 2019; Dumenu and Bandoh, 2016). *P. erinaceus* is also important in northern Ghana for the construction of musical instruments and farm tools such as the xylophone and the hand-hoe, respectively (Dumenu and Bandoh, 2016). As a leguminous tree, it has nitrogen-fixing ability and its foliage is a nutritious fodder for animals (Dumenu, 2019). It is also a medicinal plant used in concoctions for treating various diseases among residents in the areas where it occurs in Ghana. Until 2005, the greatest use of rosewood was for charcoal, produced mainly by women in the northern sector of Ghana (Bosu, 2014), thus the rate of exploitation was low. Commercial exploitation of the species began when international demand for it increased. In a space of 10 years (2003-2013), an estimated 111,110 m^3 of rosewood had been exploited in Ghana (Dumenu and Bandoh, 2016). The estimated figure does not account for the high incidence of illegal harvesting. In 2014, Ghana was ranked second to Nigeria in Africa and fourth in the world among top suppliers of rosewood logs to China by volume (Treanor, 2015). A high incidence of illegal harvesting of rosewood in Ghana occurs as a result of poor regulation of harvesting (Bosu, 2013). *P. erinaceus* is not a traditional timber species in Ghana and so regulating its exploitation is not as strict as it is for the traditional timber species in the high forest zone. Though permits are often given to timber contractors to exploit *P. erinaceus,* monitoring to ensure compliance is often weak or non-existent (Saibu, 2016).

Dumenu and Bandoh (2016) point out the species has become vulnerable due to its population structure and relatively slow growth rate. They conclude that the level of exploitation before a ban in 2014 was unsustainable. Due to indiscriminate commercial logging of rosewood, the Ministry of Lands and Natural Resources through the Forestry Commission imposed a series of bans on the harvesting, issuance and processing of the Convention on International Trade in Endangered Species (CITES) permits for the export of the species. (Abdul-Rahaman et al., 2016). The first ban was imposed in July 2014 while the second and third bans were declared in March 2019 and July 2021, respectively (MLNR, 2021; Abdul-Rahaman et al., 2016). The first ban was lifted in August 2017, ostensibly to salvage lying logs in regions where the species occur. The ban was reimposed as a result of poor enforcement and continuous illegal exploitation of rosewood. The latest ban imposed in 2021 is described as an outright ban on the harvesting and export of rosewood. While this ban is in force, all confiscated rosewood shall be auctioned only to players in the domestic market, and no rosewood acquired through such auctions shall be permitted for export, as was the case in previous bans. This implies, the Forestry Commission (the mandated state regulatory body) would not issue CITES permits to export Rosewood, whether the wood was acquired legally or otherwise (MLNR, 2021). Apart from ecological imbalances that could occur in the wake of rosewood extinction, some local livelihoods may be lost as the plant is important for economic activities such as charcoal production and the carving of tools and instruments. However, implementation of the ban was reported to be ineffective due to corruption and lack of enforcement of regulations (Abdul-Rahaman et al., 2016). Other reasons could be lack of community consultations and limited knowledge about the potential of the species for producing items of high economic value.

Although several studies have described the extent and nature of exploitation in Ghana (Aabeyir et al., 2011; Bosu, 2013; Treanor, 2015; Ansah, 2015; Dumenu and Bandoh, 2016), there is limited information on the socio-economic role of rosewood in local communities' livelihood and the impact of the recent extensive exploitation on their livelihood. The effects of governance and management of rosewood as a common-pool forest resource have not also been nuanced. This study is aimed at understanding the local context for governance, management, and exploitation of rosewood in the forest-savanna transitional zone in Ghana. Such understanding could inform decisions towards the design of strategies for sustainable management and utilization of the species and other forest commons in Ghana. Specifically, the study examines characteristics of the resource user group (the local communities), the socioeconomic importance of *P. erinaceus* to local communities, and institutional arrangements in place for the governance, management, and utilization of rosewood as a common-

pool resource.

Theoretical framework

The study is based on the common property theory (CPT). The CPT is essentially a corpus of literature from different disciplines that tries to explain the historical and contemporary institutional governance and management of valued natural resources such as forests, fisheries, oceans, atmospheric sinks, and even genetic material (Trejos and Flores, 2021; Pokrant, 2010). The CPT was fundamentally developed to get an understanding of the problems of managing valuable resources that are open to the use of all (principle of the difficulty of exclusion of users). One person's use of such common-pool resources reduces what is available to other users (principle of subtractability or rivalry), and usually, overuse/misuse and degradation occur in the long run (Slaev and Collier, 2018).

The study of forests as a common property has been one of the central scholarly approaches for developing the CPT, as many of the earliest contributions focused on forest studies (NRC, 1986; Singh, 1986; McCay and Acheson, 1987; Berkes, 1989; Stanley, 1991). This may be partly because forests produce multiple products that are of interest to many stakeholders for different purposes. Particularly, scholars have shown keen interest in the relevance of forests to the livelihoods of multitudes of rural residents across the world (Agrawal, 2007). Forests serve as important livelihood resources for local communities in agrarian and developing areas where much of subsistence still come from the natural environment (Widianingsih et al., 2016). Institutional arrangements for governance and management of forests are becoming more complex in contemporary times due to its multiple roles for global conservation and local livelihoods (Thompson, 2018), which often introduce more competing interests. It is therefore difficult to design lasting solutions to governance and management problems emanating from the use of forest commons because landscapes, demographics, development processes, and political alliances keep changing with time (Nightingale, 2019).

Agrawal (2001) posits that four clusters of variables are important for the successful governance of forest commons: the characteristics of the resource system, the user group, the institutional arrangements, and the external environment. These categories have been used in other empirical efforts to examine how governance-related variables affect forest conditions (van Laerhoven et al., 2020). The categories are also conveniently viewed as socio-political and economic variables (represented by 'user group'), biophysical and edaphic factors (represented by the cluster of variables classified as 'resource system's characteristics), and demographic, market, macro-political, and other contextual factors (represented by the category of factors termed 'external environment') (van Laerhoven et al., 2020). How these variables or factors are made to interact with each other to produce desirable results is what is termed institutional arrangements.

Characteristics of the resource system

In a broader sense, resource characteristics relevant to governance and management of common-pool resources include the boundaries, whether the resource is mobile, the extent to which resource units can be stored, rate and predictability of flow of benefits from the resource system, and ease of monitoring resource conditions (Nightingale, 2019; Agrawal, 2007). These are characteristics that help resource users to institutionalize governance through rules and regulations. While it is possible to change some of these features with technology and institutional arrangements (e.g. forest size, forest boundary, and ease of monitoring), others are almost impossible to alter (e.g. whether the resource is mobile). Biophysical characteristics such as soils, topography, fire, and pests are often considered in research on forest change and deforestation, but little attention has been paid to the significance of these factors on the management of forests commons. Even scholarly works that engage biophysical variables to give an understanding of forest conditions often end up using property rights, socio-economics, or politics to explain outcomes (Newton et al., 2015).

User group

In analyzing user group characteristics, researchers have often considered the size, boundary, level of heterogeneity of the group, interdependence among group members, and level of dependence on forest resources (Newton et al., 2015; van Laerhoven et al., 2020). Group size and heterogeneity may have a great impact on forests commons since they affect the ability of the group to take collective action. Disputes are often associated with governance decisions when a group is large and/or has poorly-defined boundaries (Hemant et al., 2019). Group heterogeneity usually occurs along ethnicity, indigeneity, gender, religion, wealth, and many other socially-defined groups, depending on the context and locality. The effect of heterogeneity on the governance of forests commons is always contested since the variables involved are many and influence each other. However, a significant portion of literature in this field suggests that almost invariably, group members with superior economic and political power often have a greater say in the governance of forest commons and gain a greater share of benefits accruing from the resource (van Laerhoven et al., 2020).

Institutional arrangements

Institutional arrangements can be a pivotal factor in the governance and management of forest resources. Research on how different institutional set-ups affect forest conditions has been of great interest to researchers in the sector since the concept of forests commons emerged. The output from this research has helped clarify understanding of how rules affect the behavior of forest users. It is generally recognized that when rules are locally made and can easily be understood and enforced, they are likely to lead to effective governance (Hemant et al., 2019). Again, such rules should be able to cover a wide range of possible violations, deal with potential conflicts, and instill accountability in resource users and officials. Although these rules are helpful, their better form will come from good policies, and effective implementation will be influenced by local and national politics (Merino-Saum et al., 2018).

The external environment

External environment regarding governance and management of forest commons are context-specific, and often refers to demographic, cultural, technological, and market-related factors. Other factors include the nature of state agencies, international aid flows, and the level of involvement of other actors and forces such as NGOs (Agrawal, 2007). Though some scholars consider external issues as less important compared to institutional matters (Nkhata et al., 2012; Young, 1994), others are of the view that changes in population and market forces are equally important in influencing forest condition (Bray et al., 2006; Power, 2006). Technological innovation has the potential to increase the efficiency of harvesting and processing of forest products, but it can also disrupt institutional mechanisms that defined and held together forests' commons (Hemant et al., 2019). For example, technology makes it easy for individuals to exploit forest common resources beyond sustainable levels and run stocks depleted. Foreign inflows into developing countries that go with conditions may also catalyze the depletion of forest resources. For instance, the International Monetary Fund loans to Ghana in the 1980s promoted the wood processing industry which in turn encouraged excessive logging and for that matter deforestation (Oduro et al., 2015).

MATERIALS AND METHODS

The study area

The study was conducted in two districts, Kintampo North and Nkoransa North in the Kintampo Forest Districts (GFD) of the Bono East Region of Ghana (Figure 1). Kintampo North is located between latitudes 8° 45'N and 7° 45'N and longitudes 1° 20'W and 2° 1'E with a population of 95,480 (GSS, 2014). Nkoransa North is located within longitude 10 10' and 10 55' W and latitude 70 20' and 70 55' N. The district has a population of 65,895 (GSS, 2014). Both districts are located in the forest-savannah transition zone of Ghana with the wet-semi equatorial type of climate and mean annual temperature and rainfall of 27°C and 1,800 mm, respectively. The rains occur in two seasons; from May to July and from September to October. The vegetation is savanna woodland with scattered trees including *Acacia* species*, Anogeissus leiocarpus, P. erinaceus,* and *Vitellaria paradoxa.* The soils are predominantly savanna orchrosols (richer in organic matter and nutrients). Traditionally, the local economy is agrarian with agriculture engaging 60% of households (GSS, 2014). Agricultural production is largely under rain-fed conditions and common crops grown include yam, maize, cassava, and groundnuts.

Kintampo and Nkoransa North Districts in the Kintampo Forest District are major areas for the production, collection, and transportation of charcoal. Farmers generally supplement farming with charcoal production as a significant source of income to support their families. The population of most trees is severely declined near townships and may be found only some 20 km away. Rosewood exploitation is highly prevalent in the area.

Sampling technique and sample size

The KFD was selected for the study because there was widespread rosewood harvesting in the area. To effectively achieve the aim of the study through the methods employed, three communities each were purposively selected based on the extent of rosewood harvesting activities (Campbell et al., 2020). The selected communities include Bonsu, Dotobaa, and Brahoho in the Nkoranza North District and Dawadawa No. 2, Busuama, and Portor in the Kintampo Municipal. Households represented sampling units and 16 households were selected from each community using the linear snowball sampling technique (Anieting and Mosugu, 2017). This sampling technique was chosen because rosewood loggers do not form a population that can easily be identified. They are scattered but they know each other. In all, 96 household representatives were interviewed. Residents who lived in the community for more than 10 years and were involved in the rosewood business were targeted.

Methods of data collection

Secondary data for the study was collected by reviewing relevant literature from various sources including the internet, hardcopy books in libraries, and documents from government institutions. Primary data was collected using focus group discussions (FGD) and non-probability sampling techniques (snowball sampling). The FGDs involved residents who were in rosewood businesses, landowners, farmers, and community leaders. One FGD was held in each of the six communities in the two administrative districts and the number of participants ranged from from ten to fifteen. Seventy-seven (77) individuals participated in the FGDs. The checklist of questions to guide the discussions centered on the governance, management, and utilization of forest resources in general and rosewood in particular. Other questions were around the importance of rosewood to residents in the community, especially those involved in the exploitation of rosewood for sale to merchants who exported the logs. Finally, there were questions on land tenure and land use rights in the communities visited.

Other questions targeted at people who were into rosewood exploitation for traditional economic uses such as charcoal production and carving, and those who were logging the species mainly for timber to sell to merchants engaged in exporting

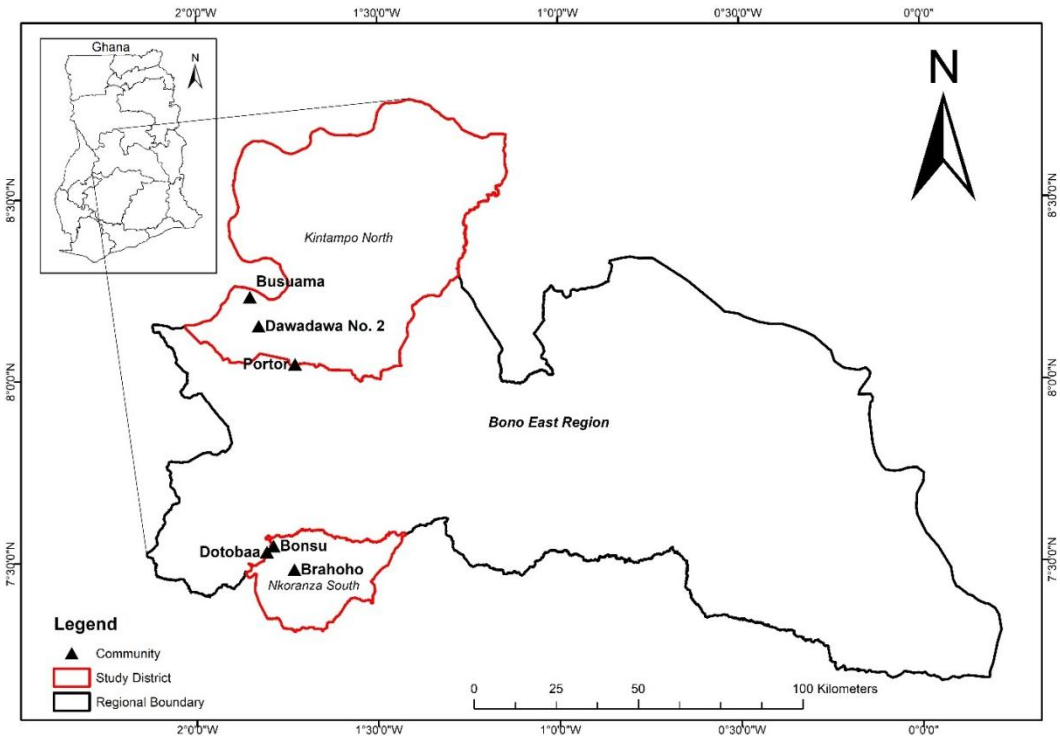

Figure 1. Map of the study area showing study districts and communities.

Table 1. Age category of respondents in the Kintampo Forest District.

Age category	Number of respondents (N = 96)	Percent
20 - 29	8	8.3
30 - 39	23	24.0
40 - 49	37	38.5
50 - 59	25	26.0
60+	3	3.1
Total	96	100

the logs. For this, 16 individuals were interviewed in each of the six communities giving a total of 96 respondents. Going by the sampling technique employed, the first respondent were identified through a tipoff. The first respondent then volunteered information about the next potential respondent and the process repeated until we got the required number of 16 respondents in each community. Where a potential respondent would not grant an interview, researchers would fall back on previous interviewees to suggest new potential respondents. The questionnaire was structured into four sections covering demographic information of respondents, governance issues, management structures in place for the exploitation of rosewood, the extent of exploitation, perception of availability of rosewood for timber and perceived drivers of the extensive exploitation of the resource.

Perception of the relative distribution of rosewood compared with other important species in the study area was assessed. Questions in this section measured the perception of respondents on the abundance of rosewood, relative to other species that were used as substitutes for rosewood in the study communities.

Data analysis

Statistical Package for Social Sciences (SPSS) version 20 and Microsoft Excel were used to produce descriptive statistics. The results have been presented in tables, graphs and text.

RESULTS

Demographic information of respondents: Characteristics of the resource user group

A total of 96 respondents were interviewed with 57.3% of them being male and 42.7% being female. Almost 90.0% of all respondents were in the active working-age bracket (30 - 59 years) as this is the energetic group that is involved in farming activities (Table 1).

Over half of the total respondents (63.5%) have had some form of formal education with the majority (50.0%) ending at the junior high school (JHS) level and only 12.5% proceeding to the senior high school (SHS) level. About one-third (36.5%) had no formal education and only one respondent had tertiary education. The ethnicity of respondents was well mixed, as natives and non-natives occurred almost equally with 53.1 and 46.9%, respectively. Since the study area is agrarian, the majority of respondents (87.5%) were farmers while 5.2 and 7.3% were engaged in charcoal production and other trades, respectively. Other trades mentioned included petty trading, agriculture machinery operation, and over-the-counter chemical selling. However, residents who had farming as their main occupation also engaged in other livelihood activities to supplement their income. They take up these activities (e.g. charcoal production, hunting, construction labor work, etc.) when they have downtime from their farming activities.

Importance of rosewood as a traditional resource: The resource base

Per the views of respondents, rosewood has a substantial function in local communities in the Kintampo Forest District as it is recognized as an essential customary resource by 75% of the respondents. Although international demand for rosewood made it an instant export commodity in Ghana, it appeared many residents in the study area did not know the international market value of the species. Many attested that demand for rosewood logs in their communities had gone up sharply, it became clear in the FGDs, that few people knew about the international demand and value of the species which made it an instant export commodity. Consequently, landowners continue to lease out concessions as if they were going to be used for traditional production activities like charcoal production. However, people who joined the brisk rosewood business as loggers, loaders, guides, etc., were happy with their earnings because according to them it was far better than proceeds from charcoal production. It appeared that most young men and women who worked for rosewood merchants in the communities were hitherto involved in charcoal production. As rosewood continued to diminish in the Kintampo Forest District, residents shifted to the use of alternative tree species to produce traditional tools and equipment like gunstocks and pestles.

In terms of traditional benefits derived from rosewood, 61% of the respondents indicated that rosewood was often harvested as a raw material for various purposes including charcoal production, carpentry works to produce door and window frames, and carving of gunstocks and agricultural tools. However, only 18% of respondents indicated that they made income from the sale of rosewood logs to merchants, suggesting that the involvement of residents in the rosewood business was minimal. The majority of loggers and merchants may have been outsiders. A small number of the respondents (7%) however opined that rosewood was important as fodder for animals, whilst 13% placed value on the species for its ecological role of nitrogen fixation.

Rosewood abundance in the local communities: The resource system

Based on the perception of respondents, rosewood was reported to be the least abundant among local species occurring in the Kintampo Forest District. Figure 2 shows the perceived abundance of rosewood in comparison with other tree species occurring in the studied areas. Residents revealed that it was becoming difficult to get rosewood for traditional uses like charcoal production and fodder harvesting for livestock. This development started putting pressure on other tree species that are used alternatively for charcoal. For example, due to the increasing scarcity of rosewood, it was revealed at an FGD that many charcoal producers who preferred rosewood had shifted to Kane (*A. leiocarpus*) as alternative species for charcoal production. This shift may put pressure on Kane too and the combined pressure on *P. erinaceus* and *A. leiocarpus* may trigger rapid deforestation and ecological imbalance in the Kintampo Forest District.

Combretum glutinosum and *Terminalia mollis* were perceived to be more abundant than *P. erinaceus* because the former are alternatives to the latter for charcoal production. Hence, respondents compared the availability of species usually used for producing customary items. The perceived reduction in stand density of rosewood was attributed to its over-exploitation. Few respondents attached importance to the resource for its new status as an export commodity. This is apparently due to a lack of knowledge of its value shift from low demand timber to high demand timber. However, no stocks were taken on the species, and for that matter, actual volumes were not known to inform sustainable levels of exploitation.

Institutional arrangements: Governance and management of rosewood as a common-pool resource

Interaction with local authorities and key informants revealed that before the sharp increase in demand for rosewood, there were no rules in place for its harvesting. This is because the level of exploitation of the resource was considered to be at sustainable levels thereby warranting no limitation to exploitation. Typical with the exploitation of common-pool resources in Ghana, neither national nor local-level authorities have any working

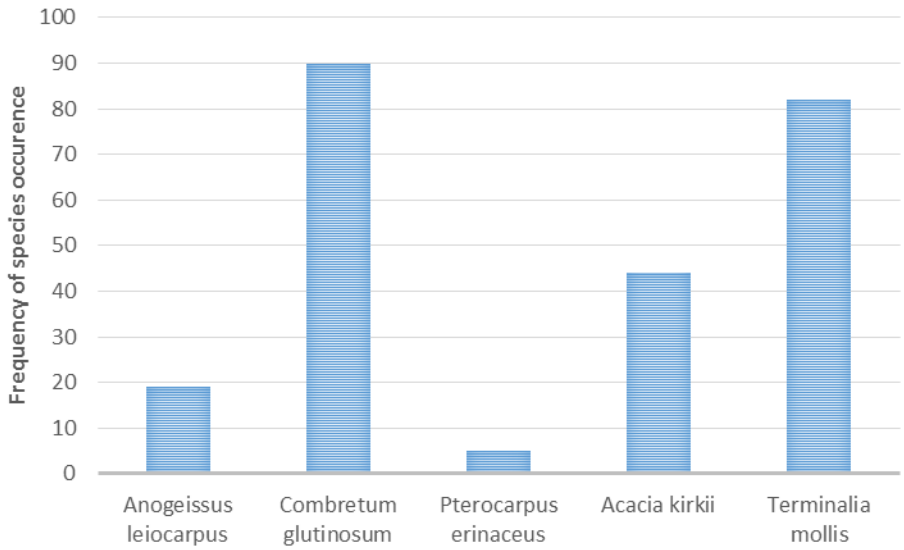

Figure 2. Perception of residents on the occurrence of *Pterocarpus erinoceus* compared with other similar naturally occurring species at same locations.

governance structures to regulate harvesting levels and the sharing of benefits accruing from rosewood. Trees occurring in off-reserve areas in Ghana are held in trust by the president for the people and therefore the Forestry Commission is the statutory institution with the responsibility to manage and regulate the exploitation of such trees. However, by convention, citizens at the local community level do not need to apply for any permit before exploiting trees as a customary resource for their day-to-day needs. This situation, therefore, makes trees and other resources in off-reserve areas in Ghana appear as common-pool resources. However, during the rush for rosewood, some traditional authorities (chiefs) arrogated to themselves the power of issuing felling permits to individuals and groups for fees and royalties. After the ban was placed on the harvesting and export of rosewood, some kind of loose management structure was put in place for government agencies and the local communities (Table 2). However, monitoring and enforcement of the ban and other forest regulations were still poor as the illegal acts of felling and trading in rosewood continued under fake and inappropriate salvage permits. It would appear that some government officials in charge of the regulation and some elites in the local communities were behind the illegal harvesting of the species. Salvage Permits were issued to some contractors to cover their illegal activities. Salvage Permits usually state the particular species, number, diameter classes of threes to be salvaged in an identified area within a stipulated time frame. However, some players in the rosewood business alleged that none of the specifics mentioned above were clearly stated in the permits issued to contractors to 'salvage' rosewood. Residents also reported that fresh cutting was made in the name of the salvage permits which is illegal.

External environment: Factors that influence over-exploitation of rosewood

Major factors that led to the extensive exploitation of rosewood were identified as market-related and poor resources governance (regulation). Figure 2 presents details of the reasons for the over-exploitation of rosewood. As wood quality may be the main factor driving the high demand for rosewood in the international market, residents in the KFD might not have been privy to this fact because they could not link wood quality to the rising demand for rosewood logs in their communities. Almost two-thirds of respondents cited harvesting 'to sell logs for income' as the main reason for the over-exploitation, yet only 4% of respondents indicated that rosewood was in high demand for its wood quality (Figure 3). Demand for rosewood from external markets was therefore the major driver of overexploitation of the species in the KFD.

As a sign of poor resource governance, even information on the ban on rosewood exploitation was not effectively communicated to the local communities since over two-thirds (68%) of respondents did not know there was such a ban. The use of rosewood for socio-cultural purposes remains minimal since rosewood is used with other species for these purposes (e.g. carving and charcoal production).

Efficiency of public education on forest policies and sustainable use of forest resources

It was discovered from the FGDs that residents of the studied communities had little knowledge about laws and policies about the sustainable use of forest resources in

Table 2. Misshape governance and management structure put in place when a ban was imposed on rosewood exploitation.

Policy action	Responsible institution	
	Government (Forestry commission)	**Traditional community**
Official ban on commercial exploitation	To be imposed by the state mandated body; the Ministry of Lands and Natural Resources through the Forestry Commission	To be educated on the guidelines of the ban. To support state actors in implementing the ban
Official permit issued for salvage harvesting	To be issued by the Forestry Commission	Traditional leaders to help state actors in checking permits of loggers and fishing out illegal operators
Harvesting of wood from dead trees for fuel	Extreme and dubious cases to be reported to state actors	To be monitored by local actors, e.g. chiefs and other community leaders
Harvesting of only branches from live trees for firewood	Guidelines to be given by the Forestry Commission	Local actors, e.g. chiefs and other community leaders to monitor and ensure compliance with the guidelines

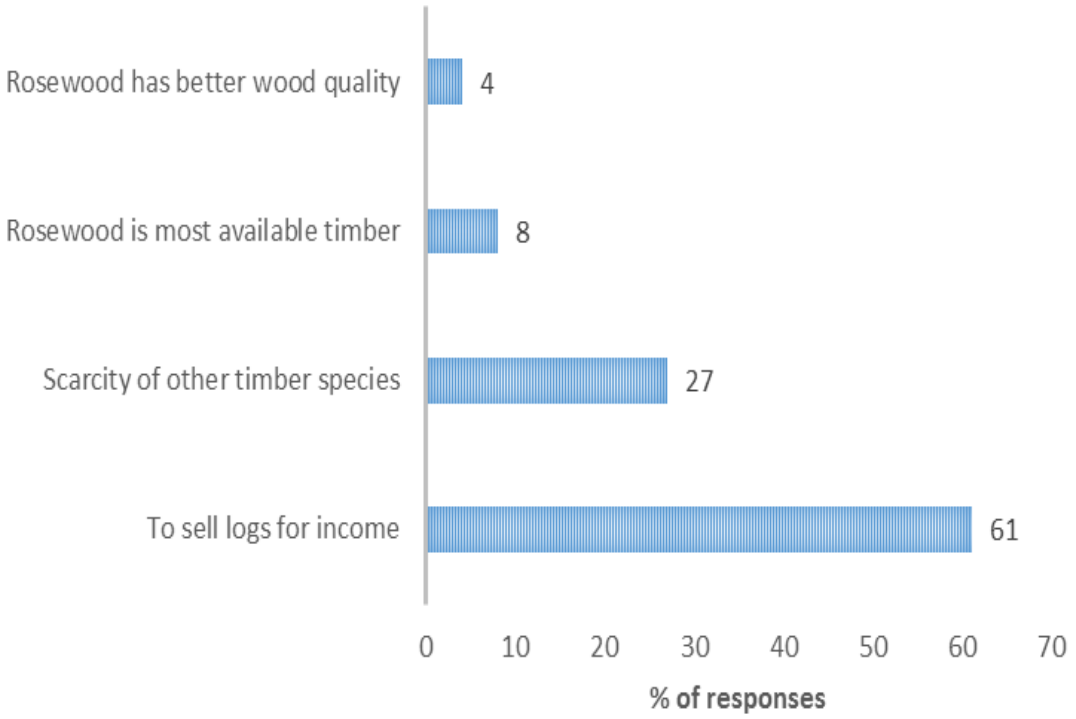

Figure 3. Residents' perception of the reasons for rosewood extensive exploitation in the Kintampo Forest District.

the country. Many revealed that they did not know it was important to regulate the harvesting of trees outside logging concessions or state-owned protected areas. Rosewood until its value shift, was considered a low-valued timber species since it was only used for traditional exploits such as fodder, medicine firewood, and charcoal production. When demand for it increased in Asia and its status changed from low-priced to high-priced timber, many of the resource owners (local communities) did not know about it. Timber merchants took advantage and

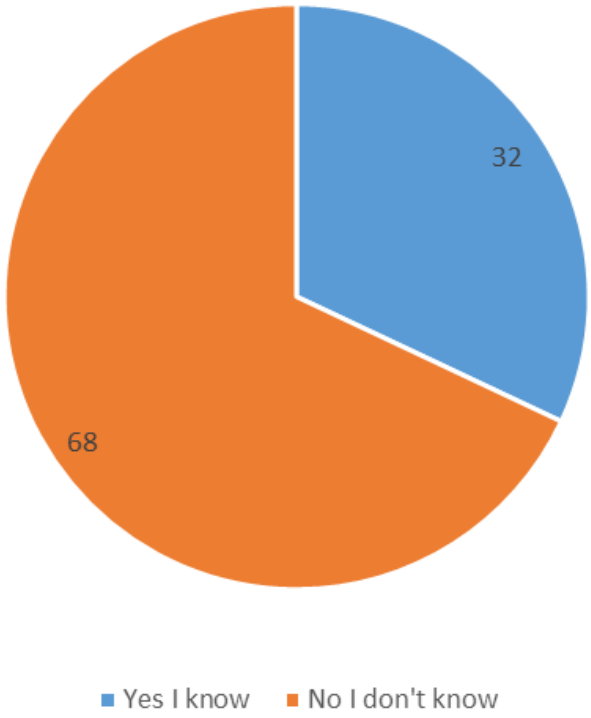

Figure 4. Respondents' knowledge about the ban on the harvesting and export of rosewood in Ghana.

bought concessions at ridiculously low prices from local landowners. The merchants also got cheap labor from residents which led to overexploitation of the resource. When the government banned the harvesting and export of rosewood, few residents in rosewood endowed communities knew about it (Figure 4).

This facilitated the continuous illegal logging of the species. It appeared that communication of the ban was carried mainly in the print media (national newspapers) which are hardly consumed by rural residents. A more efficient communication could have been through local radio stations in local dialects.

DISCUSSION

The resource user group (the local communities)

Findings of the current study reveal that local communities in the KFD are heterogeneous in terms of ethnicity which may explain why there is no traditional resource management system in place to check the exploitation of forest resources including rosewood. Some ethnic groups in northern Ghana (e.g. the Dagbamba and Tallensi) do have well-structured political institutions with oversight responsibility on how forest and wildlife resources are managed and exploited on traditional lands (Bonye, 2007). The presence of such structures in the communities within the KFD could help check the over-exploitation of rosewood in the area. Heterogeneity of a group may not promote what Nkhata et al. (2012) described as collective identity, which refers to the common meaning, experiences, and expectations that drive the group's attitude towards the management and utilization of a resource.

Lack of a well-defined user group (the members of a community in this case) is a characteristic of communities in the KFD. Generally, in Ghana, local community authorities do not keep a register of people in a community and so outsiders can easily move into the territory of a village and take any resource without notice. Interactions with participants in FGDs revealed that the majority of people who engaged in rosewood logging in the KFD were outsiders, and many of them cut rosewood without the knowledge of village authorities and landowners. Though rosewood is recognized as an important customary resource, dependence on it as the main source of traditional livelihood is low. The majority of people in the KFD are into farming as against charcoal production, carving, and carpentry that involve the use of rosewood as raw material. Even for those who use rosewood in their main livelihood activities, there are other species used as substitutes and complements for the purposes mentioned above, and this may explain why residents in the KFD did not give any special attention to rosewood until the mad rush for it. Agrawal (2007) suggests that the degree of dependence of a group on a forest resource could be proportional to the attention

given to the resource in terms of its management. The general lack of knowledge about the value of forest resources in Ghana may be due to a lack of valuation of natural resources to put a market value on them. It is easy for people to appreciate the importance of a resource when they can put a monetary value on it (Christie et al., 2012). Apart from traditional uses of forest and wildlife resources, residents (especially those in rural communities) hardly know the economic value of forest resources.

Rosewood as a forest common of importance to the community

Rosewood is very well recognized as an important customary resource in communities within the KFD. However, it was indicated through FGDs that characteristics relevant for effective governance of forest commons are not known for rosewood in the local communities. Agrawal (2007) recognized some resource characteristics relevant to effective governance of forest commons as the size of the resource base, the boundaries, whether the resource is mobile, the extent to which resource units can be stored, rate and predictability of flow of benefits from the resource base, and ease of monitoring the resource conditions. Local communities in the KFD like others in Ghana, who use traditional resources without any structured management systems, do not take cognizance of these characteristics and this allows outsiders easy access to common-pool resources. It became clear after discussions with the local communities that, abundance and distribution of rosewood within the village lands were not known. This suggests that the value of the resource could not be estimated, hence the apparent lack of attention on its exploitation mainly by outsiders. Dumenu and Bandoh (2016) reported that even the Forestry Commission which is the state organization entrusted with the management of forest resources did not have actual volumes of rosewood anywhere in the country. Lack of physical landmarks indicating the boundaries of village lands also contributes to the inability of communities to monitor the exploitation of common-pool resources like trees. In the studied communities, residents could not agree on exact points where they share boundaries with neighboring communities, making it difficult to know if rosewood loggers at the periphery are intruding in particular village lands. In some cases, the majority of residents are settler-farmers who do not know about land boundaries and may also have little or no interest in trees because they have no right to use the trees.

Governance issues in the management of rosewood

There were no regulations for harvesting or permissible harvest levels for rosewood species in the various communities that the study covered. There is no sustainable harvest threshold for any species in areas outside logging concessions and forest reserves in Ghana (Lund et al., 2012) and local communities are not given the power to monitor harvest levels of timber species. Community ownership rights and applicability of customary laws to surface land are well recognized in the constitution (Article 267(1)), where community lands are referred to as ‘stool/skin’ lands. However, it is only the president of the republic who has the power to decide how standing timber resources on these community lands (stool/skin lands) should be used. This power is usually exercised by the Forestry Commission, the state institution in charge of managing forest and wildlife resources. This handicaps communities on decisions of how forest resources on land should be managed and exploited.

Nonetheless, during the mad rush for rosewood in the KFD, elite members of some communities tried to assume governance responsibilities over the resource to take advantage of the situation. Community leaders such as chiefs, youth leaders, assembly persons (local government representatives), opinion leaders, and even chairpersons of political parties, tried to collect and share rent and royalties from rosewood loggers. These leaders were only interested in collecting and sharing benefits and not monitoring whether rosewood was being harvested at sustainable levels. In an attempt to effect a ban on rosewood exploitation in 2014, some misshape governance structure was put in place with roles for the Forestry Commission and local communities. However, the roles were not new but the insistence on existing regulations in the Timber Resources Management Regulation of 1998 (LI 1649). The Forestry Commission had the responsibility to enforce the ban, be stringent in issuing and monitoring salvage permits, and ensure only dead wood of rosewood is harvested. Local communities, on the other hand, were to ensure that only branches of rosewood could be harvested for traditional uses such as fodder and making of tools and that only dead wood was taken for charcoal and firewood. Even this interim arrangement was not effective according to Saibu (2016) who reported that illegal logging continued unabated especially in the northern part of the country.

Push factors of overexploitation of rosewood in the KFD

External factors that catalyzed over-exploitation of rosewood in the KFD and for that matter in Ghana, are encapsulated in the other factors including governance, management, and market-related factors. The main factor cited for the over-exploitation was the high demand for rosewood logs in external markets (e.g. China) which triggered price hikes for the commodity in Ghana. This corroborates the report of Bosu (2013) which indicates that the high demand for rosewood in China and other

external markets resulted in an unparalleled surge in the felling of the species in Ghana. Dumenu (2019) also reports that the highest export volume of rosewood logs in Ghana occurred in 2014, when China alone received 270,738 m^3. This made Ghana the second-highest exporter in Africa (after Nigeria) and the fourth-highest exporter in the world to the same destination. The devastative exploitation of rosewood thrived on the weakness of governance and management structures, which gave impetus to the actions of corrupt government officials and community leaders. The reports of Saibu (2016), as well as Dumenu and Bandoh (2016), indicate that officials of the Forestry Commission issued inappropriate salvage permits to contractors to fell rosewood when there was a total ban which criminalized harvesting, collecting of lying wood, and export of the commodity in 2014. Chiefs and other community leaders particularly in the north, also usurped powers of the president and authorized loggers to fell rosewood in their traditional areas (Saibu, 2016). The popular belief that rosewood is under pressure for its superior timber qualities did not quite reflect in this study because residents in the study area did not know about this fact, and only valued rosewood for its local uses. As Agrawal (2007) suggests, macro-political factors may directly or indirectly affect how forest resources are exploited in developing countries. Dogbevi (2019) suggests that the increasing in-flow of loans and grants from China to Ghana might have weakened Ghana's political will to stop Chinese involvement in the illegal exploitation of natural resources including rosewood. The export value of rosewood had never been known in Ghana until Chinese workers arrived in the country to start construction of a 400MW hydropower dam (Bui Dam) in the then Brong Ahafo Region in December 2009. The Chinese workers identified and started exporting rosewood that was part of felled trees in areas to be flooded by the new dam. The construction was the result of a US$562 million financial agreement signed between Ghana and China in 2007 (Otoo et al., 2013; Dogbevi, 2019).

Awareness of natural resource policies

Policies on the management and utilization of natural resources are hardly communicated to the masses who live with and use the resources. The current forest resources policy document (the 2012 Forest and Wildlife Policy) seems to have strategic action points to ensure sustainable and inclusive management and utilization of forest resources, yet the implementation process precludes local community education. This general dearth of information dissemination on natural resource policies contributed to the plundering of rosewood in local communities with little benefit to the resource owners. For instance, when demand for rosewood increased and the value of the species shifted from low to high in Ghana, local communities were not in the know. Even the Forestry Commission reneged on its duty to re-valuate the species and review its status of rosewood from low demand timber to high demand timber after it became an export commodity (Dumenu and Bandoh, 2016). The local communities, therefore, continued to compare proceeds from the commercial logging of the species to what was earned from charcoal production – the most popular traditional use of the species (Dumenu and Bandoh, 2016). This situation was exploited by rosewood merchants who made a fortune from the resource but paid paltry sums to local landowners who leased their lands out and residents who joined the value chain as loggers and loaders. Since rosewood became an export commodity in Ghana in 2005, its exploitation and export suffered three bans, the first in 2014, the second in 2017 and the third in 2021. However, only one-third of respondents in the current study indicated they ever heard about a ban on the harvesting and trade of rosewood in Ghana. Issues on natural resources management and utilization hardly gain adequate space in the media in Ghana. Natural resource policies in Ghana are mostly good but are often not widely communicated to the general citizenry. As a result, when criminals are engaged in illegal activities involving natural resources, they get away with it because many citizens do not know what constitutes legal and illegal activities in our environment.

Citizen participation in resource governance, management, and utilization are paramount for inclusive and environmentally sustainable development (Twum, 2019). This is seen as a necessary foundation for the political philosophy of pluralism in natural resources management (Gavin et al., 2018). However, no meaningful participation by citizens can happen without education and information dissemination on relevant resource policies. This is needed to empower citizens and make them cognizant of their rights and responsibilities in the sustainable management and exploitation of resources. Apart from strengthening relevant institutions and monitoring stakeholder activities effectively, it will be necessary to institute natural resources accounting in Ghana so that citizens can get to know the true value of resources in their environment. Knowing the value can serve as a motivating factor for them to protect and exploit forest resources sustainably and also demand an equitable share of benefits accruing from natural resources.

Conclusion

This study sought to examine the characteristics of the resource user groups, the socio-economic importance of *P. erinaceus* to local communities, and institutional arrangements in place for the governance, management,

and utilization of rosewood as a common-pool resource. It is clear that common-pool resources in non-protected lands are not managed at the community level but are only exploited. There is no management strategy for rosewood as a common forest resource and this led to unsustainable exploitation of the resource when the high demand for it in external markets triggered price hikes. Common-pool resources may become more sustainable if the central government devolves resource governance power and builds the capacity of local communities to manage forest commons in off-reserve areas in Ghana. The value of the resource base (forest resources) needs to be established through natural resources capital accounting and made known to local communities. If the real value of rosewood is made known to local communities they would likely get a bigger share of proceeds, thus ensuring equity in the distribution of benefits accruing from forest resources. This could also lead to locals using alternative tree species for traditional uses of rosewood such as charcoal production and harvest rosewood only for export. Perhaps reforestation schemes could be developed and would be more likely to be developed if locals knew the value of rosewood in the international market. Residents in local communities (as resource owners) may be motivated to protect natural resources from abuse and overexploitation if the benefits they derive rise significantly.

Community members as resource-user groups are not defined in the studied communities. This is a common phenomenon in Ghana which opens up common-pool resources at the community level to just anybody. The lack of proper governance and management of common-pool resources also makes it easy for elite few to arrogate ownership of such resources to themselves and therefore seek rent and royalties from other users. Chiefs and other community leaders were noted to have given concessions to rosewood loggers or charge rent and royalties but rendered no account of the proceeds to their communities. The value of rosewood as a timber resource was known to only a few in the communities. Therefore, no special attention was given to the species and its logging when the mad rush for it started. The conversion of rosewood from a non-timber forest product to a timber product was essentially triggered by demands in external markets. The illegal logging of the species went on due to weak institutional structures and non-enforcement of timber regulations in the country. The logging was reported to be at unsustainable levels, with potential negative effects on local livelihoods. Empowering local communities legally with defined responsibilities to put them at the forefront of managing forest resources in off-reserve areas could ensure sustainable management and utilization of forest common resources.

The study opens further research possibilities on the topic of rosewood as a forest common. We, therefore, recommend further research on (i) the best ways to disseminate information on policy relating to the use of forest resources at the local community level in Ghana; (ii) what is the possible impact on livelihoods in the case of a ban on the use of forest resources? (iii) what are the livelihood alternatives in the case of a ban on the use of forest resources for the local communities? and (iv) in the case of a ban, what would be the implication regarding the use of alternative species and/or biodiversity of the forest?

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Use and socio-economic values of *Ricinodendron heudelotii* (Bail.) Pierre, a wild oil species in Benin

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***Ricinodendron heudelotii* is a wild oil tree species native to sub-Saharan Africa. It is also found in Benin. Its oil is rich in the essential fatty acids (Omega 3, 6), fat-soluble vitamins (A, D, E and K) and trace elements, essential for human health. Currently, few people know about this oil, likely explaining its almost total absence in rural markets in Benin. The species is also neglected, as little scientific data is available on it in Benin, particularly regarding knowledge on its uses where it occurs. With the aim of filling this gap, ethnobotanical surveys were undertaken to assess the uses of the species, identify factors explaining the variation of its ethnobotanical value, and determine its availability and accessibility for local people. Data were analysed using the relative frequency of citation and generalised linear models. In total, eight uses were enumerated, of which six were for medicinal uses and one for cosmetic and handcraft respectively, and mainly based on its stem. The stem of *R. heudelotii* was mainly used for handcraft by Nagot and Holli socio-linguistic groups and mainly by men from the Pobe phytodistrict. Although individuals of *R. heudelotii* were absent in southern Benin, its kernel is mainly used for cosmetics and medicine by people from the Fon socio-linguistic group in this region. Field data suggest that the kernels and oil of *R. heudelotii* in this region mainly come from Cameroon and Côte d'Ivoire. The distance travelled to access the species at the time of this study is two times higher than 30 years before and positively correlated with the use-value (r=0.66, P-value<0.001). Our findings suggest that *R. heudelotii* is marginally used in Benin, and this might be a threat for its conservation and related knowledge.**

Key words: Commercial value, ethnobotanical value, phytodistrict, seed oil, kernel, use-value, West Africa

INTRODUCTION

Oil plants are important resources for human livelihoods, especially in sub-Saharan Africa (OCDE and FAO, 2018). They provide direct products to satisfy household needs, including cosmetics, food, fuel, medicine, etc. The oils

provide food rich in energy, vitamins, and essential fatty acids, especially in places, where malnutrition remains a challenge (van der Vossen and Mkamilo, 2007). Seed oils ranked highest (41%) as agricultural products most traded on international markets (OCDE and FAO, 2018). This proportion is expected to remain stable throughout the period (2018–2027), especially in West Africa (OCDE and FAO, 2018).

The seed oil sector occupies an important place in the economies of West African countries (that is, Benin, Burkina Faso), with an average annual added value of nearly 157 million USD (UEMOA, 2013). The sector contributes significantly to the creation of wealth and jobs in West African countries. However, the region is still net importer of seed oils with the total annual importation of seed oil into the region amounting 250,000 tons (UEMOA, 2013). For decades this sector has therefore been confronted by difficulties linked to its low level of global competitiveness (price hike of locally produced seed oils, low production capacity and yield) and a high penetration of similar foreign products or substitutes (UEMOA, 2013). Due to the deficit of seed oils in West Africa, and particularly in Benin, edible wild trees/shrubs bearing seeds with a high oil content can play a significant role in meeting the demand for seed oil. *Ricinodendron heudelotii* (Bail.) Pierre is one such species in Benin. It is used daily by local people, but its potential has been neglected from a scientific perspective including its contribution to households' livelihoods. For more than three decades, this species has been involved in several development programs of food security in Sub-Saharan Africa countries, including Cameroon, Democratic Republic of Congo, Gabon, Ghana, Côte d'Ivoire, Nigeria (Ndumbe et al., 2019).

The seed oils produced in Benin come primarily from *Elaeis guineensis* Jacq. (oil palm), *Gossypium* sp. (cotton), *Glycine max* (L.) Merr. (soya), *Arachis hypogaea* L. (peanut), *Sesamum indicum* L. (sesame), *Vitellaria paradoxa* C. F. Gaertn. (shea) and *Anacardium occidentale* L. (cashew) (Cruz et al., 2019; MAEP, 2008). *R. heudelotii* seed oil, less known and used across the country, can, however have important unsuspected nutritional, medicinal and cosmetic properties whose potentials is far from fully exploited (Codjia et al., 2015). In addition, with global climate change, the integration of resilient endogenous crops adapted to the local environment is necessary for sustainability of the seed oil sector.

R. heudelotii is a tree of the humid, semi-dry, wooded-savannah zone and distributed in the Central and West African countries. It is found in areas up to 1200 m altitude, with mean annual rainfall of 900 to 3500 mm, and is mainly found on medium textured, freely draining/acidic soils (van der Vossen and Mkamilo, 2007). Several studies (Arrey, 2018; Assanvo et al., 2015; Ogbuagu et al., 2019) have demonstrated the high importance of the physico-chemical properties and fatty acid profiles of the seed oil of this species. For instance, il extracted from the kernels of *R. heudelotii* contains 86.9–87% unsaturated fatty acids (oleic, linoleic, linolenic and α-eleostearic acids), 189.24-190.5 mg KOH/g saponification value, and 155-160 g I_2/100 g Iodine value (Arrey, 2018; Assanvo et al., 2015; Ogbuagu et al., 2019). With such properties, the oil of *R. heudelotii* exhibits anti-cancerogenic, anti-mutagenic and anti-inflammatory activities (Arrey, 2018). The seeds of *R. heudelotii* are highly valued in countries such as Cameroon (Ezekwe et al., 2014), Côte d'Ivoire (Assanvo et al., 2015) and Nigeria (Ogbuagu et al., 2019) in the cosmetic, food and medicine industries.

Despite the importance of this species in other regions of the continent (Ndumbe et al., 2019), there have been few scientific attempts to elucidate its uses and socio-economic importance in Benin where it also occurs (Akoègninou et al., 2006). As a first attempt to fill the gap, this study focused on the local uses and socio-economic values of the species and its seed-derived products. In addition, its neglect could lead to the erosion of the species uses and potential valuations by rural populations.

Knowledge on local uses as well as the socio-economic importance of plants is essential to reveal their value and how they can be managed to sustainably support livelihoods of rural people (Saad et al., 2019). Several studies have shown that the uses and socio-economic values of plant species in various places are linked to socio-cultural characteristics of the surveyed people. The importance of studying variations in the uses of a plant across cultural groups lies in the fact that relationships between people and nature may differ from one cultural group to another. As such, within a single geographical or ecological area, people's perceptions and practices of natural resource management and their use at the local level may vary with their background and ancestral inheritance (Avocévou-Ayisso et al., 2012).

The overall objective of this research was to assess the ethnobotanical knowledge on the uses and the socio-economic importance of *R. heudelotii*. Specifically, the study aimed to: (i) assess the diversity of uses of *R. heudelotii*, (ii) determine socio-demographic factors explaining the variation of its ethnobotanical value, and (iii) assess the species availability and accessibility for

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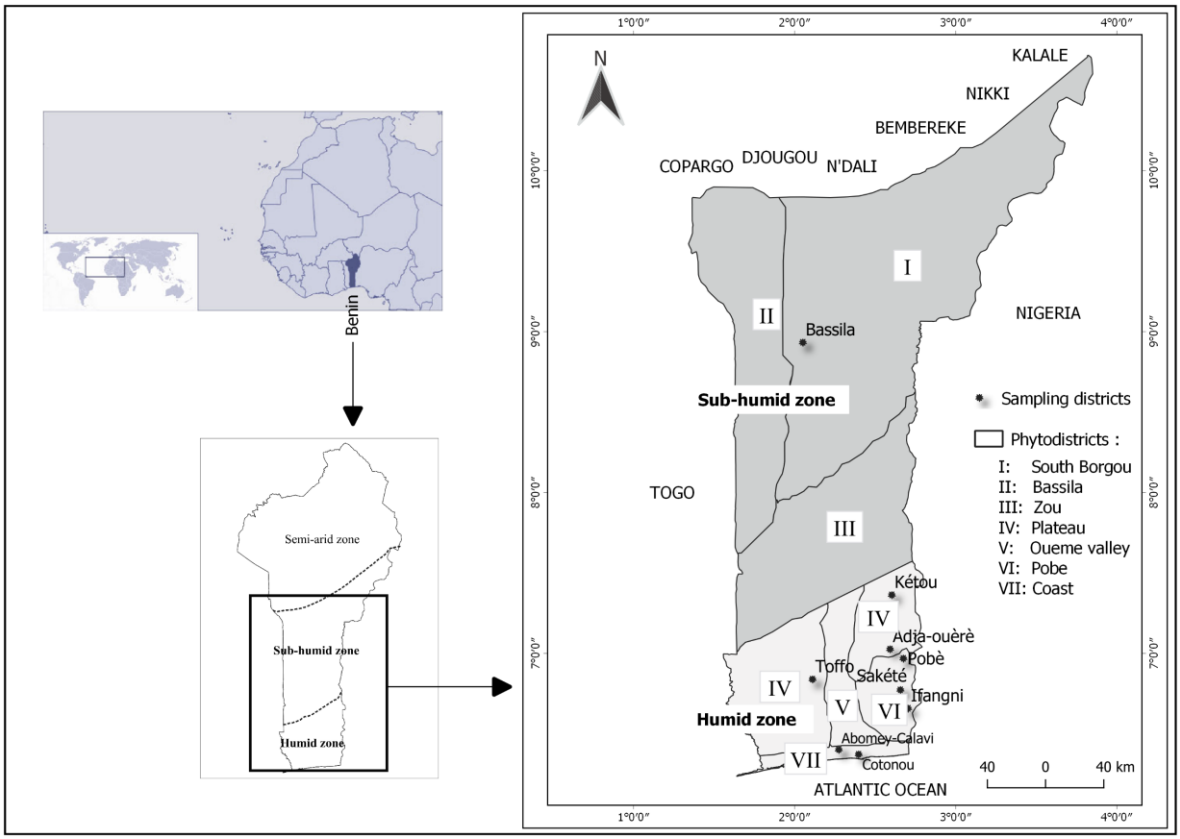

Figure 1. Map of Benin, showing the districts surveyed.

local populations.

MATERIALS AND METHODS

Study area

The study was conducted in five phyto-geographical districts of Benin: the Bassila and south Borgou phyto-districts in the sub-humid zone, and the Plateau, Pobe, and coastal phytodisticts in the humid zone (Figure 1). These phytodistricts are areas where the species are naturally distributed in Benin (Akoègninou et al., 2006). However, many native species in the country have experienced severe decline and threatened extinction due to anthropogenic activities (M'Woueni et al., 2019).

The population density is higher in the humid zone compared to the sub-humid and semi-arid zones (INSAE, 2015), and with quite diverse socio-linguistic groups. The Benin resident population was about 11,200,000 inhabitants in 2017 (UNDP, 2018), and was mainly young (more than 40% were under 15 years old) and slightly female-biased (51%). The local economy is dominated by agricultural activities, which are practiced by more than 70% of the population.

In Benin, poverty remains widespread, with national poverty rates of 36.8% in 2018 (UNDP, 2018). Non-Timber Forest Products (NTFPs) play a crucial role in the food security, nutrition, health, and income generation of the rural poor, and in developing adaptations to cope in the event of climate change (Heubach et al., 2011). For instance, *Adansonia digitata* L., *Tamarindus indica* L., *Vitellaria paradoxa* C. F. Gaertn., and *Parkia biglobosa* (Jacq.) R. Br. ex G. Don are reported as commercialised NTFPs in Benin, and they are mainly used for subsistence purposes (Assogbadjo et al., 2017).

Sampling design

An exploratory survey was first conducted in two localities, where the species or its parts are found in each phytodistrict based on the literature surveys. In each of these localities, 30 respondents (both male and female) from different age groups were asked whether they know and use the species. The proportion of positive responses was considered and used in the binomial approximation of the Dagnelie normal distribution (Dagnelie, 1998) to determine the sample size, that is, the number of people to survey by phytodistrict (Table 1):

$$n = \frac{U^2_{1-\alpha/2} \times p\,(1-p)}{d^2} \quad (1)$$

In Equation 1, n = sample size in the village; $U_{1-\alpha/2}$ = 1.96, is the value of the random normal variable for a probability value of α = 0.05 (1−α/2 = 0.975); p = proportion of individuals with knowledge of the species. The value considered for p is 0.5 and gives the maximum possible sample size with a margin of error d set at 0.08

Table 1. Localities surveyed by district in each phytodistrict.

Phytodistrict	Districts	Locality (number of respondents)
Bassila-South Borgou	Bassila	Aoro (54), Kprèkètè (39), Manigri centre (96), Modogui-Igbèrè (39)
Plateau	Adja-ouèrè	Igbo-Ikoko (18), Itchèdè-Toffo (12)
	Kétou	Ewè (22), Massafe (14), Odometa (13), Omou (21)
	Toffo	Toffo (44)
Pobe	Ifangni	Lagbé (14), Issobè (28), Sokou (26), Zian (22)
	Pobè	Adjégounlè (28), Agbele (26), Igbo-Edè (23), Issaba (23)
	Sakété	Dèguè (18), Igbo-Abikou (23), Ita-Akadi (26), Issalè-Eko (23)
Coastal	Abomey-Calavi	Abomey-Calavi (30)
	Cotonou	Cotonou (30)

Source: INSAE (2015).

considering the budget and operational constraints for the survey.

In total, 768 people were surveyed (60 people in the Coastal phytodistrict, 210 in Plateau, 270 in Pobe and 228 in Bassila-South Borgou). The respondents were selected and balanced by gender and age to ensure the full participation of women and young people in the surveys. The respondents were mainly uneducated (74.3%) and farmers (35.4%). The Nagot socio-linguistic group (56.4%) was the most surveyed. Three age categories were considered (<30 years for young people; ≥30 to <60 years for adults; and ≥60 years for old people). The distribution of respondents according to socio-demographic characteristics is presented in Appendix 1.

Data collection

Data were collected using individual interviews with the help of a local assistant translator. Interviews were conducted in the different localities with the consent of the head of the household or any person representing the household's authority at home or at the market where traders were interviewed. The following data were collected: (i) the socio-demographic characteristics of the respondent, (ii) the diverse uses of the species, (iii) the socio-economic importance of the species, (iv) whether there are taboos or not on the species, (v) the types of habitats where the species components are harvested, (vi) the perceived availability of the species, (vii) the estimated distance in km, travelled to harvest the species components at the time of data collection, and 30 years back in the past, and (viii) the potential substitute species. Socio-demographic data of the respondent included the respondent's age, educational level, gender, professional activity, and socio-linguistic group. In terms of the socio-economic importance of the species, we focused on all components used on the species and their market prices.

Data analysis

Ethnobotanical value of R. heudelotii trees

Analyses focused on the uses, use-value and commercial value of the species. The relative frequency of citation (RFC, %) was used to assess the salience of each specific use (Friedman et al., 1986).

$$FC_i = \frac{N_i}{N} \times 100 \quad (2)$$

In Equation 2, N_i is the number of respondents that reported the specific use i; N is the total number of respondents for the species. RFC was calculated for each use per phytodistrict (RFC).

To assess the overall use-value of the species, and test how it varied with phytodistrict and factors such as respondents' age, educational level, gender, professional activity, and socio-linguistic group, we calculated the use-value (UV) following Phillips and Gentry (1993).

$$UV_i = \frac{\sum U_{is}}{n_i} \quad (3)$$

The use-value was also calculated for kernels. In Equation 3, U_{is} is the number of specific uses mentioned by respondent i (varied from 0 to 6 (maximum U_{is}) for the whole plant and for the kernels from 0 to 3; n_i is the total number of interviews for species s with respondents i ($n_i = 1$).

The effect of the socio-demographic factors on UV of the species was tested using the Poisson generalised linear model. The full model, that is, the one including all main effects and possible interactions, was fitted first, and subsequently simplified using the likelihood ratio test. The UV was further compared among use-categories (cosmetics, handcraft, and medicine). Principal component analysis was used to describe the relationship between socio-linguistic groups and the use-categories and components.

The commercial value of kernels (as the main commercialised component of *R. heudelotii*) was expressed as the proportion of respondents who mentioned that the species has a market value (Lozano et al., 2014). The relationship between each socio-demographic factor and the commercial value was assessed using a Chi-square test. The currency exchange rate of 1 dollar (USD) to 554 FCFA (XOF) was applied (28/10/2020) for monetary conversion.

Availability and accessibility of R. heudelotii trees

The RFC was used to assess the local perception of the habitats of the species and its availability. The difference between the estimated distances travelled in the 30 past years compared to time

Table 2. Local names according to different socio-linguistic groups.

Species	Socio-linguistic group	Local names	Meanings
R. heudelotii	Fon	Apki, Akpèma, Apkopkotin	-
	Holli	Apkopko, Ayakorwor	-
		Erimando, Egui Guèlèdè	Eri means the head, Egui means tree, mando corresponds to a large giant animal found in the forest. Some masks carved with the image of the animal even if the representations dominated by female images
		Erimidun	Means that from the tree we can make sacred masks that bring good luck
		Kapki igbodo	Means that the leaves of the tree look like cassava leaves from swamp forests
	Nagot	Erimando	Means that *R. heudelotii* is the king of all the trees in the forest because it makes it possible to make the mask of Guèlèdè which has the power of a mother
	Yoruba	Akpokponi, Omodan	-

–, No meaning reported.

the data were collected was tested using a student *t* test as an indicator of changes in the species accessibility. Finally, Pearson correlation was used to test the link between the use-value and the estimated distance the respondent travels to get the species. This distance is an indicator of how much energy the respondent could invest to access the species and we expected that the higher the UV, the higher the distance the respondent could travel to have access to the species, hence a positive relationship between UV and this distance.

RESULTS

Ethnobotanical value of *R. heudelotii* trees

Local names and their meanings

Different local names were used to designate *R. heudelotii* depending on socio-linguistic groups (Table 2). However, similar designations were also used by some socio-linguistic groups (e.g., Erimando used by the Holli and Nagot). Likewise, within the same socio-cultural group, different designations were also used to designate the species, for example, Apki, Akpèma, and Apkopkotin used by the Fon. The meanings of the local names, in general, referred to the morphology of its components (e.g., the shape of its leaf), and to the role and uses of the species (e.g., Egui guèlèdè meaning tree used to craft the masks of Guèlèdè, an art and cultural Yoruba dance). Nagot socio-cultural group considered the species as the king of all the trees in the forest.

Uses of R. heudelotii

Eight (8) uses were enumerated for *R. heudelotii*, of which six were for medicine and one for cosmetic and handcraft respectively. The handcraft use was mostly observed in Pobe phytodistrict (e. g., to carve Guélèdè mask and wood statue by using stems), while the cosmetic uses were mostly reported in the Coastal phytodistrict where individuals of the species are rather absent. The seeds of *R. heudelotii* were used for their kernels. The kernels were used to tone and swell their buttocks and breasts and to treat females' infertility problems. Leaves and bark were also used to treat infants' walking difficulty, dysmenorrhea, cough, dizziness, and anemia (Table 3).

Gender, phytodistricts, professional, and socio-linguistic groups were found to significantly influence ($P < 0.05$) the species use. Particularly, the use-value was higher for men (1.15 ± 1.01), people from the Nagot (1.15 ± 1.08) and Holli (1.14 ± 0.55) socio-linguistic groups, people involved in the handcraft activities (1.59 ± 1.37), and people living in the Pobe phytodistrict (1.81 ± 1.05). No use was enumerated by people belonging to the Anii and Lokpa socio-linguistic groups in the Bassila and south Borgou phytodistricts (Figure 2a-d).

Relationships between socio-linguistic groups and use-categories and components

Results from the Principal Component Analysis (PCA) showed strong correlations ($|\text{correlation}| \geq 0.5$) between uses and sociolinguistic groups. More specifically, Fon socio-linguistic group used the kernel in cosmetics and medicine while the Nagot and Holli groups were mainly associated with the use of the species' stem for handcraft (Figure 3a, b). However, the other socio-linguistic groups such as Aïzo, Anii, and Lokpa showed a low relationship with the uses of *R. heudelotii* (Figure 3a, b).

Use and commercial values of R. heudelotii kernels

The kernel was mainly used for cosmetic and medicine.

Table 3. Uses of *R. heudelotii.*

Use-category (*Part*)	Specific use	Processing method	Form of use	Dose	Phytodistrict (RFC, %)				Mean (%)
					BaB	Pl	Po	Co	
Handcraft (*Stem*)	Craft	Carving Guélèdè mask and wood statue	Guélèdè mask and wood statue	Depends on the object to be carved	-	39.1	57.5	-	24.2
Cosmetic (*Kernel*)	Swell buttocks and breasts	Crush kernels, add a little plain water and shea butter, then mix well until you get a homogeneous paste	Body lotion	Pass over the buttocks or breasts and massage gently in circular motions from the bottom up until full penetration every evening for 3 months.	-	-	-	9.1	2.3
Medicine (*Kernel*)	Women infertility	Crush 6 kernels and 4 Guinea peppers (*Xylopia aethiopica* Dunal A. Rich.), add plain water (previously heated) to dilute the paste obtained	Liquid mixture	- Purge after menstruation until day 14 - The mixture can also be drunk.	-	-	-	7.7	1.9
Medicine (*leaf*)	Difficulty walking in infants	Boil green leaves (07 for female and 09 for male) in water	Bath water	Bath every morning and evening from birth until the day the child walks	-	0.2	1.3	-	0,4
	Dysmenorrhea	Boil the leaves and lemon in water	Herbal tea	Drink a bamboo glass every morning and evening during menstruation	-	-	0.4	-	0.1
	Cough	Boil young leaves in water	Herbal tea	Drink a bamboo glass morning, noon and evening for 3 days	-	-	0.4	-	0.1
	Dizziness	Crush the leaves and soak in water with a lemon, and bark of *Newbouldia laevis* (P.Beauv.) Seem.tree for 3 days	Bath water	Do head bath twice a day until satisfactory	-	-	0.2	-	0.1
Medicine (*bark*)	Anemia	Boil the *bark* in water	Herbal tea	Drink a bamboo glass morning, noon and evening until satisfactory	-	-	0.4	-	0.1
Total					-	39.1	60.4	16.8	29.1

Phytodistricts: BaB = Bassila - south Borgou, Co = Coastal; Pl = Plateau and Po = Pobe, – = No information reported.

There was a significant difference (P < 2.2e-16) in its use-value among use categories, with the highest use-value for cosmetics (0.62 ± 0.48), while the lowest for medicines (0.13 ± 0.12). In addition, gender, education, phytodistrict, and professional activities had significant effects on the use-value of the *R. heudelotii* kernels (P < 0.05). The highest use-value of *R. heudelotii* kernels was mainly observed in the following groups: women, Fon socio-linguistic group, people involved in the commercilization of the species, university education, secondary and primary educational levels (that is, educated people), and people who lived exclusively in the Coastal phytodistrict (Figure 4a-d).

The Kernels are sold in cities, such as Abomey-Calavi, Cotonou, Parakou, and Porto-Novo. The kernels were sold in 50–200 g plastic boxes or bags. The price of the kernels was 2000 XOF (3.61 USD) per 120 g. The price of the oil was 10,000 FCFA (18.05 USD) per litre. Most of the stakeholders in the commercilization of the kernels were women who imported the kernels from Cameroon and Cote d'Ivoire. Moreover, in the absence of this kernel, respondents reported that fenugreek (*Trigonella foenum-graecum* L.) kernels were used as a substitute for the same uses.

Availability and accessibility of *R. heudelotii*

R. heudelotii trees were generally found in forest ecosystems (Figure 5a). The species users

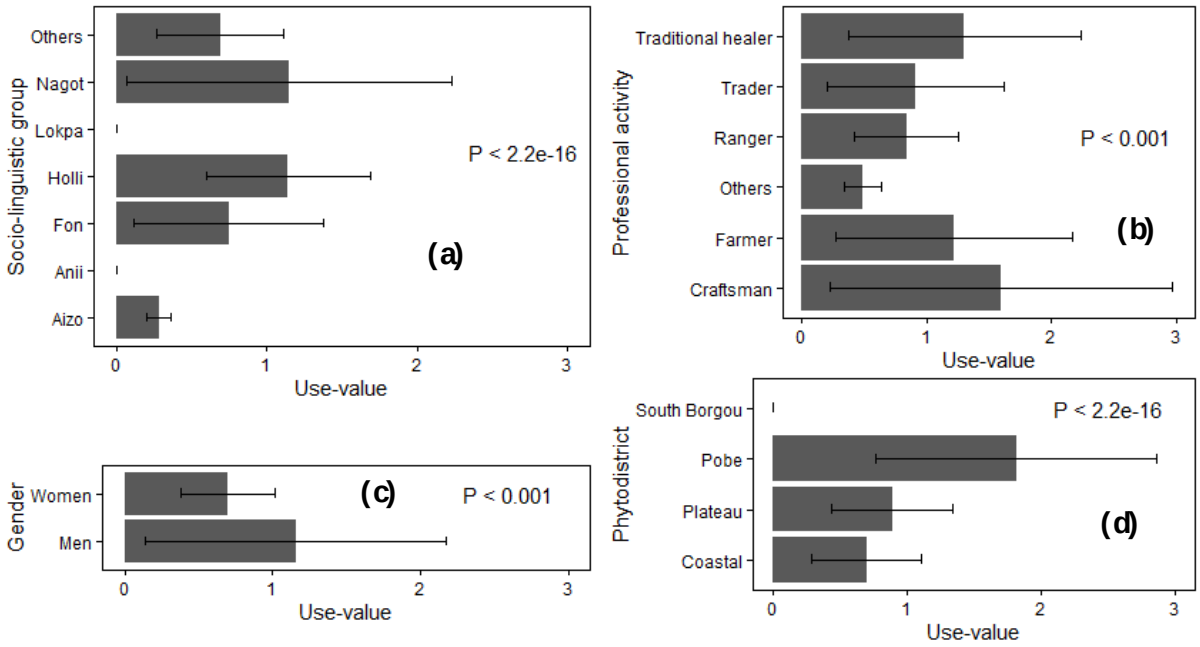

Figure 2. Relationship between the UV of *R. heudelotii* and respondents' socio-linguistic group (a), professional activity (b), gender (c) and phytodistrict (d); P = probability of significance. South Borgou = Bassila-South Borgou phytodistricts.

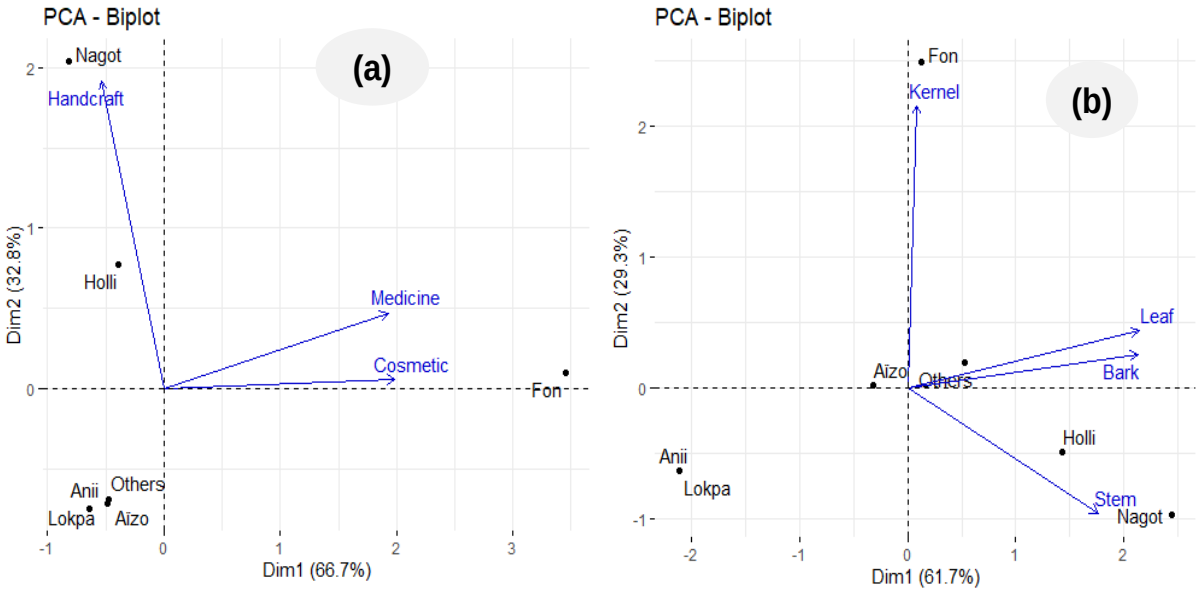

Figure 3. Graphical representation of the relationships between the socio-linguistic groups and the uses (a) and components (b) of *R. heudelotii.*

reported that they now travel twice longer distance (7.07 ± 0.52 km) than 30 years back in the past (3.60 ± 0.12 km), to harvest the parts of the species (Figure 5b, c). The estimated distance that the species users were likely to travel to collect the species was positively correlated with the use-value of *R. heudelotii* trees (Pearson correlation coefficient = 0.66, t = 24.619, df = 766, P < 2.2e-16), indicating that the higher the UV, the more the

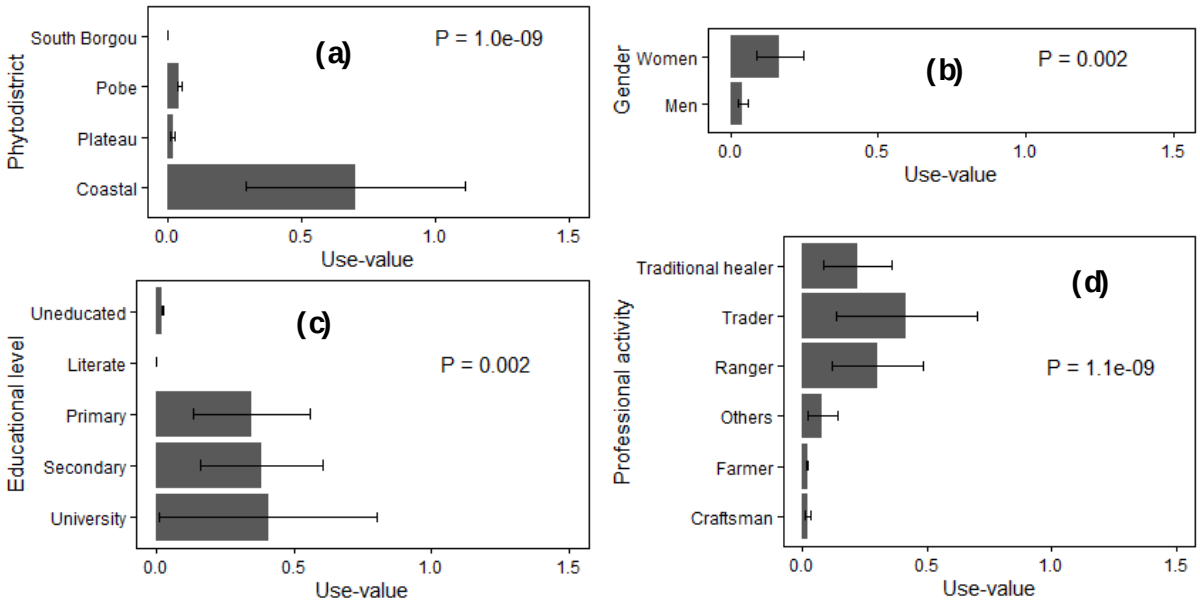

Figure 4. Relationship between the UV of kernels of *R. heudelotii* and respondents' phytodistrict (a), gender (b), educational level (c) and professional activity (d); P = probability of significance. South Borgou = Bassila-South Borgou phytodistricts.

species users are willing to travel longer distance to access the resource.

DISCUSSION

This study examined the ethnobotanical knowledge on the uses of *R. heudelotii,* and its socio-economic importance. The local populations used and named *R. heudelotii* under various designations. Its designation was different across socio-linguistic groups. The meanings of its local names were in reference to the morphology of its components or the cultural importance. The specificity of these names in the different local languages shows that the species is known by the different socio-linguistic groups surveyed. This observed specificity also suggests a long history of use of these species by the respondents (Assogbadjo et al., 2017). Nevertheless, most socio-linguistic groups were unable to give the meaning of the local names of the species. This likely resulted from the influence of modernization on folk lifestyles, which was then causing the ancestral knowledge erosion (Gaoue et al., 2017).

R. heudelotii is used for cosmetic, handcraft, and medicinal purposes, indicating relatively diverse the uses of the species. The diversity of the uses of this species is however relatively poor compared to that of other wild oil plants used in the same geographical areas, such as *V. paradoxa,* for which about 16 uses were reported (van der Vossen and Mkamilo, 2007). In addition, for this same species (*R. heudelotii*), more uses were cited in various other countries of West African, including Cameroon (Ezekwe et al., 2014), Côte d'Ivoire (Assanvo et al., 2015), and Nigeria (Ogbuagu et al., 2019) with an average of almost twenty uses reported. Such trends suggest that knowledge about the species is still rudimentary in Benin, and are evidence of the opportunities until so far unseized by local communities.

The most used components of the species are the stem, the leaves and the bark. In particular, the stem of *R. heudelotii* is used for Guèlèdè masks as also reported by Boko-Haya et al. (2017). Unfortunately, stem harvesting chops entire branches and destroys the whole plant (Yaoitcha et al., 2015), thus compromising the survival of individuals of the species. Given the importance of the species for local communities, their involvement in the definition of conservation strategies is essential because they will undoubtedly benefit from collective support and is essential in the process of perpetuating the various services it provides.

Knowledge about the stem, leaves, bark, and seeds of the species was found to vary according to the education, gender, phytodistricts, professional activities, and socio-linguistic groups, suggesting a possible spatial and ethnic specialisation in the use of these components of the species in Benin. In addition, Fon socio-linguistic group was found to be the main user of the kernel in cosmetic and medicine, while the Nagot and Holli groups were

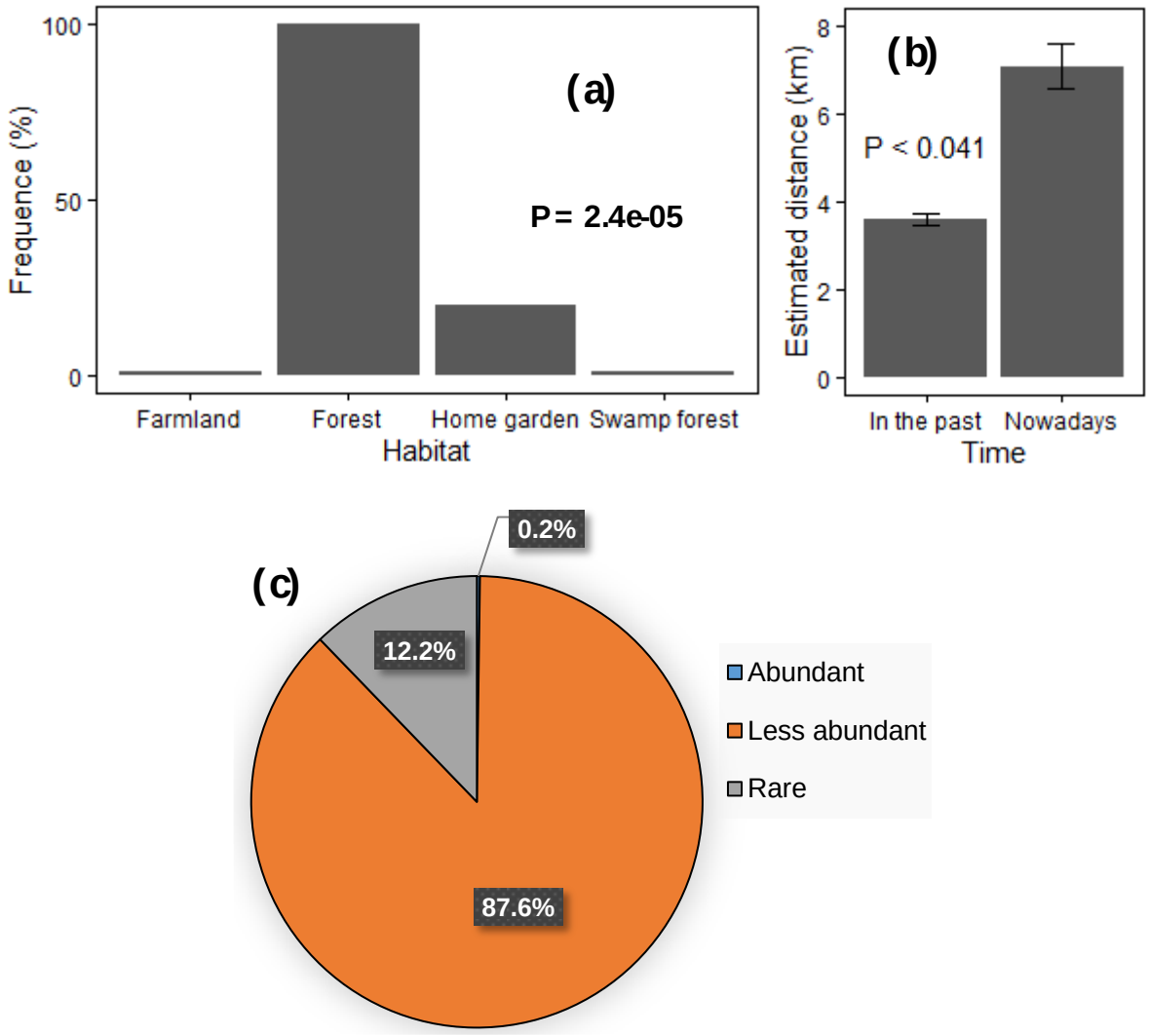

Figure 5. Habitat (a), estimated distance travelled to harvest the species components at the time of data collection (Nowadays), and 30 years back (in the past) (b), and perceived availability of its trees (c). P = probability of significance.

mainly associated with the use of the species' stem for handcraft. Other socio-linguistic groups such as Aïzo, Anii, and Lokpa showed a low relationship with the uses of the species' components. The specificities in the uses may be related to its abundance and distribution. Indeed, its availability at given times in various environments is a determining factor in the level and evolution of the knowledge of the uses. The cultural differences of the respondents may explain the different levels of knowledge recorded because, according to Assogbadjo et al. (2017), the nutritional habits of a population are fundamentally based on cultural norms. In fact, different communities may develop unique plant knowledge because they are exposed to diverse environmental conditions, ailments, and cultural practices (Avocévou-Ayisso et al., 2012). Ancestral knowledge of the plants' virtues was also transmitted from generation to generation and specific to the context and history of each group community (Assogbadjo et al., 2017).

Seeds of *R. heudelotii* have a commercial value, confirming the potential of the species in improving household income. However, the commercial value of the seeds in Benin is extremely low compared to their value in other countries in West Africa. For example, *R. heudelotii* seeds had about 50 times higher commercial value in Cameroon (Cosyns et al., 2011). This thus confirms that the seeds of the species are still undervalued in Benin.

Once again, the commercialisation of seeds and seed-linguistic and professional groups in the phytodistricts,

indicating that the use of the seeds of this species is also spatially, ethnically and gender-influenced. The commercialisation of the kernels and oil of *R. heudelotii* shows a certain socio-economic interest for local populations, in particular for women. Similar observations were reported by Assanvo et al. (2015), Ogbuagu et al. (2019), and Saad et al. (2019). Notably, respondents reported that the kernel of *R. heudelotii* used in Benin is imported from Cameroon and Côte d'Ivoire, despite its availability in the country. This could be because the tree has been considered sacred since time immemorial for its strictly cultural interest (Guèlèdè dance) for local communities: it is named 'the king of all the trees in the forest' by the Nagot socio-linguistic group. Guèlèdè masks carved from the stems of *R. heudelotii* are considered sacred objects and are not intended for sale. It should also be noted that the Guèlèdè dance was classified in 2008 as an oral and intangible heritage of humanity by UNESCO in order to avoid the loss of this traditional knowledge and to revitalise it (https://ich.unesco.org/en/RL/oral-heritage-of-gelede-00002).

Beyond the cultural restriction, the non-exploitation or under-exploitation of this resource, however locally available (see e.g. of *R. heudelotii* sheaths in Bassila-South Borgou, Pobe, and Plateau phytodistricts), could be explained by a poor knowledge of its virtues. This challenges the reliability of the oral mode of transmitting knowledge, making information vulnerable in the long term (Ouédraogo et al., 2013). These results showed that the knowledge that is retained over time is generally limited to what responds better to the environment, emerging trends, and the inherent needs of younger generations. Indeed, apart from the seeds, the other parts of plants (bark, leaves, roots, and stems) of this species were not yet subject to commercial exchanges either inside or outside the country.

R. heudelotii occurs naturally mostly in forest ecosystems with declining populations under the threat of anthropogenic pressures. The trees are mainly found in undisturbed or less disturbed areas. Moreover, findings confirmed that the higher the UV, the more ready folks are to brave long distances to harvest the parts they need, indicating how users are depending on the species, probably as there are not suitable substitutes in surrounding ecosystems. In fact, only one substitute of the species was reported by respondents (*Trigonella foenum-graecum* L.). This reinforces the need for more effort for the domestication of the species.

Conclusion

The findings of this study show that *R. heudelotii* has only 8 uses; stems are used for handcraft and its kernels for medicinal and cosmetic purposes. Its use and commercial values are associated with gender, phytodistrict, professional activity and socio-linguistic group. They contribute to household income and represent potential important business opportunities to be realized. Knowledge generated in this study clearly shows that the species potential is far from being well exploited in Benin. The organisation and promotion of this resources will not only boost the local economy, but will also improve household incomes and the fabric of society, and will eventually reduce the level of poverty in Benin.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

Table 1. Distribution of people surveyed by phyto-district for *Ricinodendron heudelotii.*

Phyto-district	Coastal (n = 60)	Plateau (n = 210)	Pobe (n = 270)	Bassila-South Borgou (n = 228)	Total (n = 768)	Relative frequency (%)
Gender						
Men	30	105	135	114	384	50
Women	30	105	135	114	384	50
Age category						
Young (age <30 years)	20	70	90	76	256	33.33
Adult (30≥ age <60 years)	20	70	90	76	256	33.33
Old person (≥60 years)	20	70	90	76	256	33.33
Socio-linguistic group						
Aïzo	13	17	-	-	30	3.9
Anii	-	-	-	31	31	4.0
Fon	39	16	4	-	59	7.7
Holli	-	60	79	-	139	18.1
Lokpa	-	-	-	23	23	3.0
Nagot	3	109	155	166	433	56.4
Others (Adja, Berba, Goun, Kotokoli, Mahi, Mina)	5	5	32	8	53	6.9
Educational level						
Uneducated	2	182	239	148	571	74.3
Literate	2	1	12	59	74	9.6
Primary	18	20	13	10	61	7.9
Secondary	17	3	4	6	30	3.9
University	21	4	2	5	32	4.2
Professional activity						
Craftsman	4	15	15	28	62	8.1
Farmer	2	76	122	72	272	35.4
Ranger	10	6	1	1	18	2.3
Trader	15	56	58	38	167	21.7
Traditional healer	-	11	9	5	25	3.3
Others (Driver, Housewife Security guard, Student, Teacher)	29	46	65	84	224	29.2

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Feeding pattern of forest elephants in the Nki National Park and its environs, East Region, Cameroon

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Forest elephants play a vital role as keystone species in forest ecosystems, but little information is known on their feeding pattern which is a key concern for its conservation. This study was carried out in Nki National Park and the specific objective was to identify cultivated and non-cultivated plants eaten by elephants. Eleven 2 km line transects, and reconnaissance walk of approximately 40.16 km were used to identify all feeding signs of elephants. Also, administration of semi-structured questionnaires to 107 participants in 9 villages around the park was used to collect data on Human-Elephant Conflict mainly on crop raiding to identify cultivated plants eaten by elephants. Analysis was done using descriptive statistics in Statistical Package for Social Science (SPSS) version 23. Results showed that 25 wild and 18 cultivated plants from 24 families were consumed by elephants in the park and along its peripheries with diet preference of fruits (62%) and least being stems (6%). The most abundantly consumed plant families were Poaceae (*Setaria palmifolia*), Sapotaceae (*Gambeya lacourtiana*), and least being Pandaceae (*Panda oleosa*) among other families. This shows that elephants have a very diverse diet requirement which is important in the management and conservation of this critically endangered species.

Key words: Feeding pattern, wild plants, cultivated plants, conservation, *Loxodonta cyclotis.*

INTRODUCTION

Population pressure, poverty, agricultural intensification and expansion, development of infrastructure, etc., have been marked as main threats to biodiversity in the tropics (Davidar et al., 2010; Bargali et al., 2018, 2019; Vibhuti et al., 2020; Padalia et al., 2022). Merely 7% of the earth's land surface is covered by tropical forests and harbour more than half of the world's species (Wilson, 1988) and are highly threatened by human activities (Htun et al., 2011; Baboo et al., 2017; Mourya et al., 2019). The aforementioned factors have reduced the natural resources for wild life and domestic life.

Forest elephants (*Loxodonta cyclotis* Matschie, 1900) consume all plants life forms and fruits make up a greater part of their diet with grass making a small proportion of their diet (Tchamba, 1996). Forest elephants rarely move far away from permanent drinking water, thus drinking water availability does not constrain their access to food resources, habitat selection, or long-distance movements (Powell, 1997). Forest elephants do not make large-scale migratory movements such as those exhibited in savannah elephants, this is confirmed by incipient data from telemetric studies (Powell, 1997), though, more recent telemetric studies showed that forest elephants may make movements of over 100 km when their range

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is not restricted by human activity. This is done using collars fitted with Global Positioning Systems (GPS).

Vegetation distribution and characteristics are important determinants of elephant density and distribution in African forests (Fay and Agnagna, 1991b; White, 1994a). Does drinking water availability drive the distribution and large-scale movements by forest elephants? Powell (1997) argued that the determinant of forest elephant distribution is brought about by ripe fruit availability and White (1994b) alluded that elephant may move as far as 50 km into the forest in search of super-abundant fruit patches. Forest elephants maintain a high fibre intake throughout the year consisting of leaf browse, wood, bark, roots, stems, and aquatic vegetation though fruit constitute a larger part of the diet, (White et al., 1993). Feeding ecology of African forest elephants precisely in Central Africa, has been less documented. Studies in Cameroon precisely in Santchou Forest Reserve (Tchamba and Seme, 1993), Bayang-Mbo and Korup forests (Powell, 1997) showed that different plant parts make up forest elephants' diet which include leaves, bark, wood, roots, and fruit. Despite the unavailability of quantitative data, fruits, terrestrial herbaceous vegetation (THV) and secondary woody growth, all make up very important components of forest elephant diet, at least seasonally, and may influence elephant abundance and distribution (Short, 1983).

Forest elephants also occur at high density in open canopy, including secondary forests in Central Africa (Barnes et al., 1995a, b; Powell, 1997), where the abundance of forest floor vegetation may be higher than the closed canopy forest types (Short, 1983; Barnes et al., 1991). The Marantaceae forest of the Lopé Reserve, Gabon has recorded the highest consistent density of forest elephants (3 individuals ha^{-1}) (White, 1994b), where Terrestrial Herbaceous Vegetation (THV) (Rogers and Williamson, 1987) is more abundant as compared to the herb layer. As compared to the scrub forests of Kibale, the Lopé Marantaceae forest is also in the late stage of forest succession toward closed canopy or mature forest (White and Tutin, 2001). An abundant source of herbaceous browse may also be found in swamp forest (Barnes et al., 1991), as they do for savannah elephants in East Africa (Western and Lindsay, 1984). In addition to leafy vegetation, fruit availability may also influence the density and distribution of forest elephants (Short, 1983; Merz, 1986; White, 1994c; Powell, 1997).

Among some of the most important plants consumed by forest elephants are *Anonidium mannii, Dudoscia* species, *Panda eleosa, Myrianthus arboreus,* and *Gambeya lacourtiana* (Blake, 2002). The flora of Nki National Park was surveyed and found to consist of about 831 plant species belonging to 111 families (Nkonmeneck, 1998) but no study has been done in the park to ascertain the plants consumed by elephants which led to this study. A full knowledge of elephant foraging patterns is important for understanding their habitat requirements and for assessing their habitat condition for effective management. The primary objective of this study was to establish the different varieties of both wild and cultivated plant species consumed by elephants in the Nki National Park and its surroundings.

MATERIALS AND METHODS

Description of study area

The Nki National Park (NNP) is situated between latitudes 2°05'N to 2°50'N and longitudes 14°05'E to 14°50'E. It covers a surface area of about 309,362 ha (3,093.62 km^2) (Nyenty, 2016). It is situated in the East Region of Cameroon between Ngoyla sub-division in the Upper-Nyong division, Moloundou sub-division in the Boumba-and-Ngoko and Salapoumbé divisions (Figure 1).

Floristic results of the NNP revealed by Nkonmeneck (1998) and Ekobo (1998) showed the presence of 8 different types of vegetation disseminated in an evergreen, mixed and semi-deciduous forest. These include mono dominant forests of *Gilbertiodendron dewevrei*, mixed forests of *G. dewevrei* and *Raphia regalis*, forests dominated by *R. regalis*, forest clearings and swampy grasslands with or without salt licks, swampy forests of *Raphia* species, forests of *Mapania* species, forests of *Baphia leptobotrys* forests with undergrowth dominated by the family of Marantaceae. The wildlife of this region is estimated at 34 species of which large mammals are made of 11 species of primates, 12 species of ungulates and sub-ungulates including elephants and 4 species of carnivores (Ekobo, 1998).

Data collection

Data was collected in Ikwa area in the Nki National Park on eleven 2 km transect and approximately 40.16 km recce walkways and in nine villages surrounding the Nki National Park from the 18th of March to the 28th of May 2021. For this length of time, the research team went to the field twice collecting information on elephant feeding pattern. During surveys along the transects and approximately 40.16 km recce in between transects, all 'fruit fall events' of succulent fruits and pods observed along each transect and recce were recorded and identified to species where possible. Any fruit fall case was described as the fruit fall from a single plant seen on the survey route. Also, large trees, understory vegetation and vegetation on forest clearings eaten by elephants were identified.

Information on cultivated plant species eaten by elephants was collected by using semi-structured questionnaires/interviews (Bargali et al., 2007, 2009; Pandey et al., 2011; Parihaar et al., 2015; Padalia et al., 2017; Bisht et al., 2021) in nine selected villages. A total of 107 village informants were selected to get the required information for the study. Informants/Respondents were selected from the age of 16 and above and the questionnaire was based on elephant occupancy, detectability, and human-elephant conflict most especially on crop raiding to identify the cultivated plants consumed by elephants. Before the administration of questionnaires to the villagers, a pretesting was done in one of the villages (Doumzock) which was not included in the nine selected villages. This was to ensure that locals understand the questions. The nine selected villages were Dimako, Lelene, Lamson, Ngoyla-village, Mabam-Baka, Mabam-Ndjem, Nkondong II, Djadom and Bareko II.

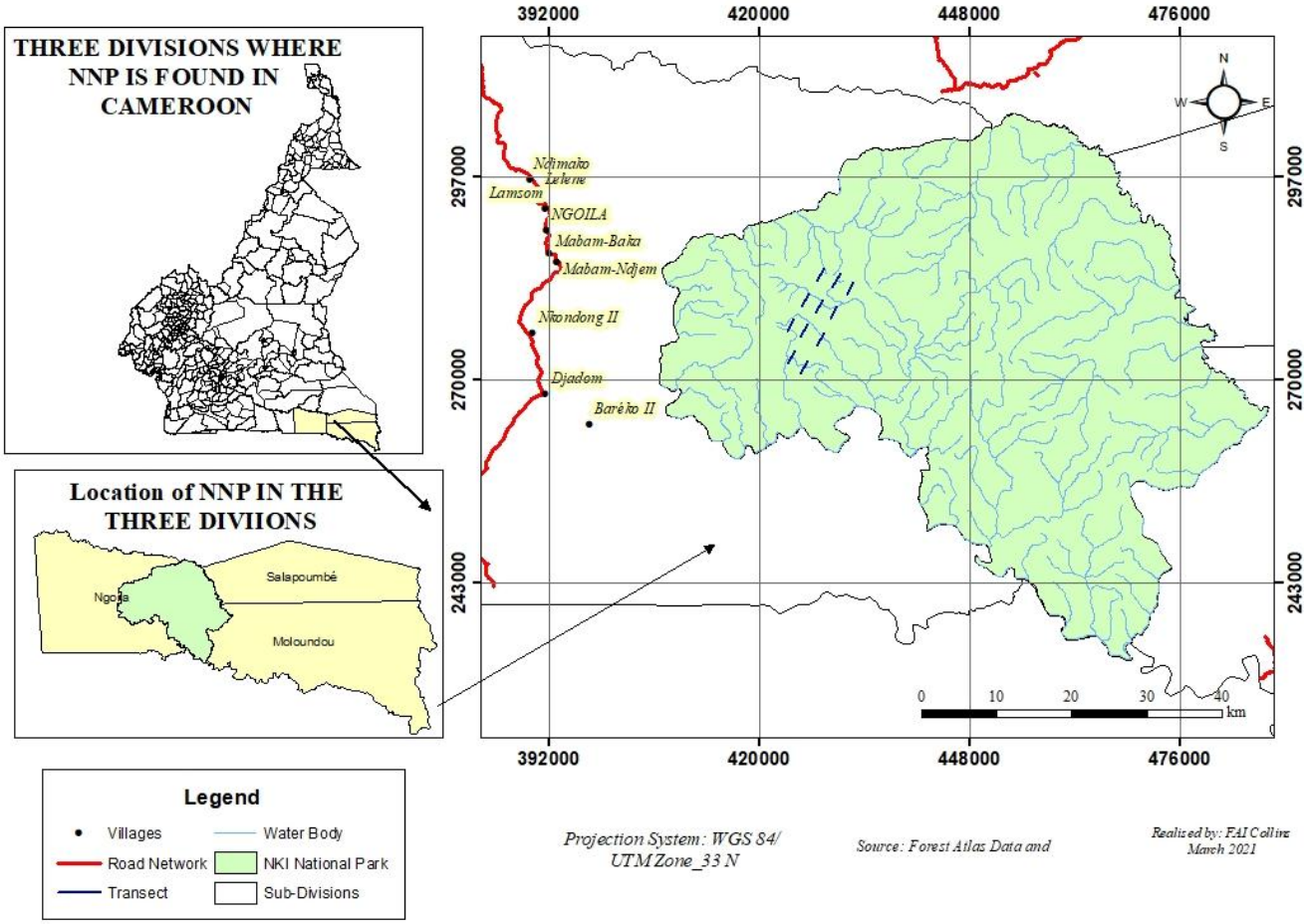

Figure 1. Map of Nki National Park (Njoka, 2021).

Plant identification

Plant identification was done in the field using morphological characters. Plant samples, videos and images of plant characters were recorded for later identification by Mr. Belinga Bana Jean Paul (botanist at WWF-Jengi Tridom in Ngoyla) and an inventory of these plants was made.

Data analysis

Inventory was made of the collected and identified plants showing their families, species and the part of the plant consumed by elephants. These plants were also grouped into monocots and dicots and descriptive statistics were used to compare various variables using Statistical Package for Social Sciences (SPSS) software version 23 and the results presented in three tables and four figures.

RESULTS

Species of plants eaten by elephants in the Nki National Park and its peripheries

During the survey on transects, recces and interviews, several species of wild and cultivated plants were recorded. 25 wild plants and 18 cultivated plants were identified to be fed upon by elephants in the Nki National Park. These plants were grouped into 24 families with different plant parts consumed: leaves, stems, bark, fruits, seeds, and pulp (Table 1).

Plant parts consumed by elephants

The identified plants species were grouped according to the different parts consumed by elephants; fruits and seeds, leaves, stems, bark, and whole plant (Table 2). From the identified plants eaten by elephants, the highest proportion of the plant part eaten were fruits and seeds (62%) and the least was stem (6.0%).

Forest elephant's diet composition by life form

Elephants fed more on trees which accounted for 56% of their food from plant life form, followed by monocotyledons with 23% of species and the least was fern with 2% (Figure 2).

Table 1. Plant species and parts fed upon by elephants.

Family	Scientific name	English name or commercial name	Plant part eaten
		Wild Plants	
Annonaceae	*Anonidium mannii*	Wild soursop /ebom	Fruit
	Xylopia athiopica	Okola	Fruit
Sapotaceae	*Gambeya lacourtiana*	Abam vrai	Fruit
	Omphalocarpum elatum	Navel fruit tree/mebememgono kosso	Fruit
	Baillonella toxisperma	Moabi	Fruits
	Autranella congolensis	Mukulungu tree	Fruit and bark
Combretaceae	*Terminalia ferdinandiana*	Kakadu plum/bush Plum	Fruit
Invirgiaceae	*Irvingia robur*	African mango	Fruit
	Irvingia gabonensis	Bush mango	Fruit
	Klainedoxa gabonensis	Eveuss	Fruits
Arecaceae	*Raphia monbuttorum*	Raffia	Pulp, young bamboos and nuts
Moraceae	*Myrianthus arboreus*	Giant yellow mulberry/monkey fruit	Fruits
Clusiaceae	*Garcinia kola*	Bitter kola	Bark and fruits
Pandaceae	*Panda oleosa*	afan(e)	Bark and fruits
Anisophyllaceae	*Poga oleosa*	African Brazil nut/Afo/ ovoga	Bark and fruits
Malvaceae	*Duboscia macrocarpa*	-	Fruits
Mimosaceae	*Tetrapleura tetraptera*	Aridan fruit/four corners (akpa)	Fruits
Poaceae	*Setaria barbata*	Corn grass	Whole plant
	Setaria palmifolia	Palmgrass	Whole plant
	Pennisetum purpureum	Elephant grass	Stem and leaves
Marantaceae	*Ataenidia conferta*	Emviali	Whole plant
	Haumania danckelmaniana	Sel	Whole plant
	Megaphrynium macrostachyum	Okoe	Whole plant
Meliaceae	*Lovoa trichiliodes*	Dibetou	Fruit
		Cultivated plants	
Curcubitaceae	*Cucumeropsis edulis*	Egusi/Ngon	Fruit and seeds
	Cucurbita pepo	Pumpkin	Whole plant
Poaceae	*Zea mays*	Maize	Whole plant
	Saccharum officinarum	Sugar cane	Whole plant
Musaceae	*Musa paradisiaca*	Banana	Pith, leaves and fruit
	Musa sapientum	Plantain	Pith, leaves, and fruits
Anacardiaceae	*Mangifera indica*	Mango	Fruit
Burseraceae	*Dacroydes edulis*	Plum	Fruit
Lauraceae	*Persea americana*	Pear	Fruit
Myrtaceae	*Psidium guajava*	Guava	Fruit
Arecaceae	*Elaeis guinensis*	Palm tree	Pulp and nuts
	Cocos nucifera	Coconuts	Leaves and nuts
Annonaceae	*Annona muricata*	Cultivated Soursop	Fruit

Table 1. Contd.

	Citrus latifolia	Lime fruit	Fruit
Rutaceae	*Citrus aurantifolia*	Lime fruit	Fruit
	Citrus sinensis	Orange fruit	Fruit
Bromeliaceae	*Ananas comosus*	Pineapple	Fruit
Caricaceae	*Carica papaya*	Paw-paw	Fruit
Total = 24	43		

Table 2. Proportions of plant parts eaten by elephants.

Plant part	Number	Percentage
Whole plant	8	16.0
Bark	4	8.0
Stem	3	6.0
Fruits and seeds	31	62.0
Leaves	4	8.0
Total	50	100.0

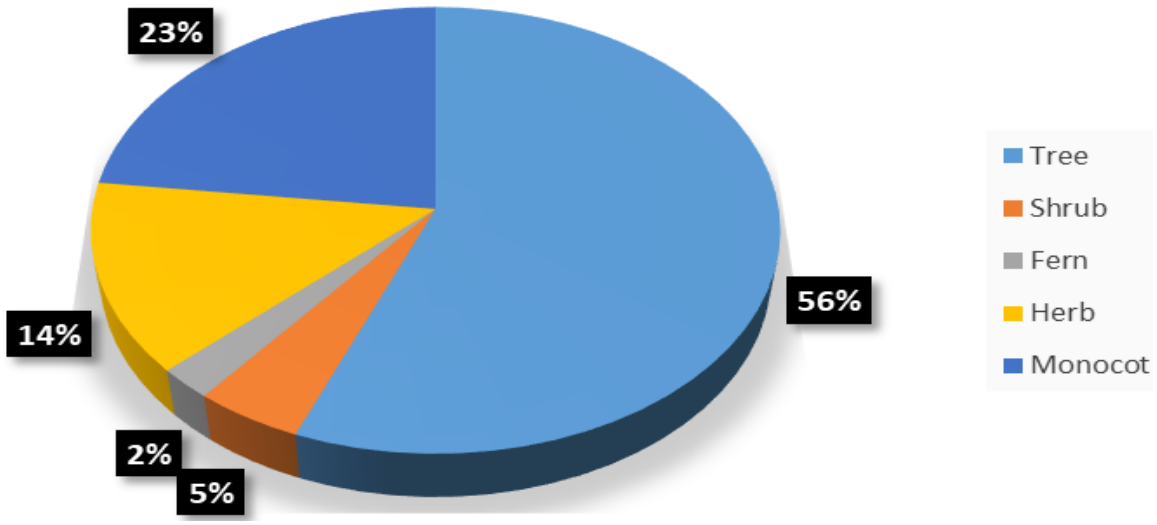

Figure 2. Forest elephant's diet composition by plant life form.

Monocotyledons and dicotyledons' percentage consumption by elephant

Plant species eaten by elephants were grouped into monocotyledons and dicotyledons for both wild and cultivated plant species and for the entire plant species collected (Table 3). Among the wild plants collected, 68.0% were dicots while 32.0% were monocots. Cultivated plants showed 44% dicots and 56% monocots but overall, 58% dicots and 42% monocots plants are consumed by elephants (Figure 3).

Plant species eaten by elephants classified according to family

The different plant species eaten by elephants were classified according to families to identify which family had the highest number of species eaten by elephants (Figure 4). Many families had the same number of plants that were consumed by elephants. Poaceae was the family with the most abundant plant species consumed by elephants, followed by Sapotaceae and lastly by Pandaceae among many other families. Many families

Table 3. Grouping of plants into monocots and dicots.

S/N	Monocotyledons	Dicotyledons
	Wild plants	
1	*Raphia monbuttorum*	*Anonidium mannii*
2	*Setaria barbata*	*Xylopia athiopica*
3	*Setaria palmifolia*	*Gambeya lacourtiana*
4	*Pennisetum purpureum*	*Omphalocarpum elatum*
5	*Ataenidia conferta*	*Baillonella toxisperma*
6	*Haumania danckelmaniana*	*Autranella congolensis*
7	*Megaphrynium macrostachyum*	*Terminalia ferdinandiana*
8	*Pteridium aquilinum*	*Irvingia robur*
9		*Irvingia gabonensis*
10		*Klainedoxa gabonensis*
11		*Myrianthus arboreus*
12		*Garcinia kola*
13		*Panda oleosa*
14		*Poga oleosa*
15		*Duboscia macrocarpa*
16		*Tetrapleura tetraptera*
17		*Lovoa trichiliodes*
Total	8	17
	Cultivated plants	
1	*Cucumeropsis edulis*	*Mangifera indica*
2	*Cucurbita pepo*	*Dacroydes edulis*
3	*Zea mays*	*Persea americana*
4	*Saccharum officinarum*	*Psidium guajava*
5	*Musa paradisiaca*	*Annona muricata*
6	*Musa sapientum*	*Citrus latifolia, Citrus aurantifolia*
7	*Elaeis guinensis*	*Citrus sinensis*
8	*Cocos nucifera*	
9	*Ananas comosus*	
10	*Carica papaya*	
Total	10	8
Grand total	18	25

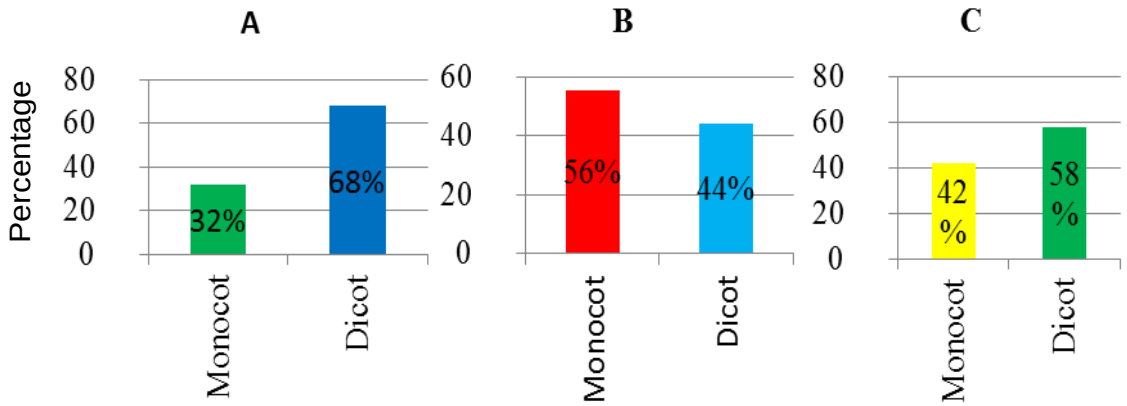

Figure 3. Proportions of monocotyledons and dicotyledons consume by elephants within wild plants (A), cultivated plants (B) and whole study (C).

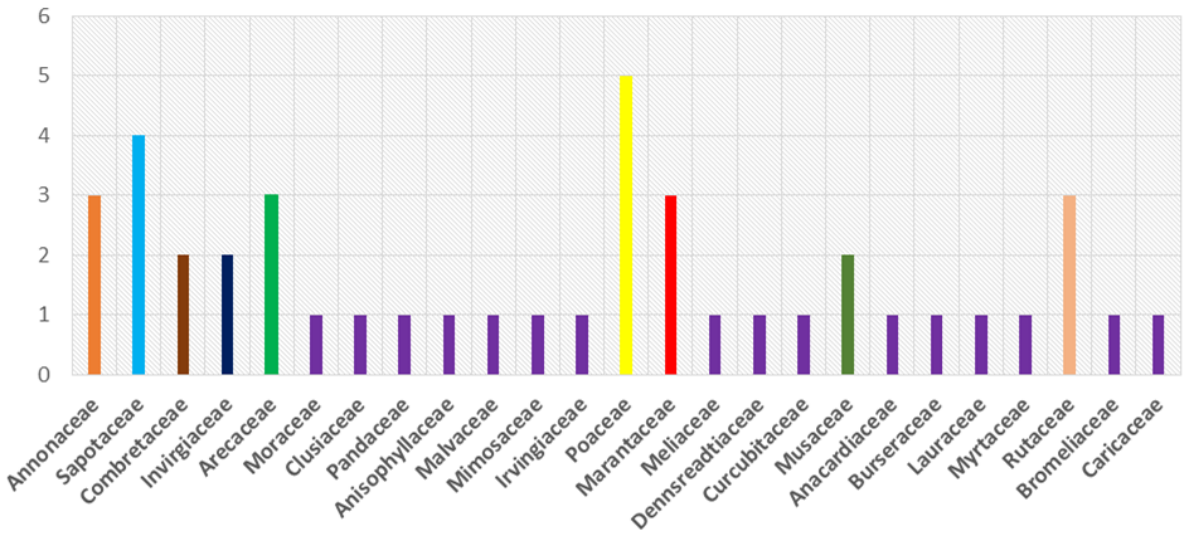

Figure 4. Proportions by family of plants consumed by elephants.

had the same number of plants that were consumed by elephants.

DISCUSSION

The flora of Nki National Park is diverse with about 831 plant species belonging to 111 families of which 544 are in the undergrowth and 287 have diameters greater than or equal to 10 cm (Nkonmeneck, 1998). Of this great diversity, this study recorded only 25 wild plants in the park and 18 cultivated plants along the peripheries of the park known to be eaten by elephants in this park. In the Santchou reserve, Tchamba and Seme (1993) identified only 39 plant species consumed by forest elephants out of which 17 were fruits. Blake (2002) recorded 351 different plant species from 73 families in Ndoki National Park. The comparatively large food list for elephants in the Ndoki National Park may have more to do with the focus and long duration of the study and not a difference in the forest elephant diet.

It is ascertained that forest elephants consume more fruits compared to savannah elephants (Alexandre, 1978; Gautier-Hion et al., 1985; Dudley et al., 1992; Tchamba and Seme, 1993; White et al., 1993; Feer, 1995; Powell, 1997). This study indicated that fruits accounted for the highest proportion (62%) of plant part consumed by elephants. This aligns with an extensive study on the role of forest elephants as seed dispersers in Bayang-Mbo and Korup forests Cameroon (Powell, 1997) who isolated 93 different species of germinating seedlings in elephant dung piles. This was further confirmed by the study of Blake (2002) in the Ndoki National Park where elephants consumed a minimum of 96 species of fruit from 35 families, and fruit was present in 94.4% of dung piles.

Overall, trees mostly dicots (58%) were the most heavily consumed plant life form. Grass was rarely eaten by elephants in the forest though the most abundant plant family (Poaceae) recorded were grasses, but their consumption rate was low. This same pattern was reported by Blake (2002) in the Ndoki National Park in neighboring Congo where forest elephants fed mostly on tree products than grasses. Information on food selection of forest elephants by life form is limited. Tchamba and Seme (1993) reported that in the Santchou reserve, elephants feed mostly by either grazing or stripping off fruit' which constituted 45 and 38% of their records, while only 6% of feeding observations were recorded of elephants eating leaves and twigs. The Santchou reserve has many vegetation types; savannah, swamp forest and farmland, and forest elephant rates of feeding may vary by vegetation type and these data may not reflect overall life form selection rates of elephants. Other published studies of forest elephant feeding ecology give no information on the relative frequency with which the different plant life forms are eaten but rather species lists by life form is used as an indicator of the importance of each plant species (Merz, 1981; Short, 1981; White et al., 1993). All these studies show that, in terms of number of species, small dicotyledonous trees are the most commonly eaten plant type. This present study shows 68% dicots and 32% monocots consumption of wild plants, a 56%:44% monocots and dicots consumption pattern of cultivated crops along the peripheries of the park and an overall 58% dicots and 42% monocots consumption rate of all identified plant species. Based on plant life forms, this study showed that trees (57%) were the most consumed, then monocots (23%), herbs (14%), shrubs (4%) and least consumed was ferns (2%). An abundant monocotyledon remains (excluding grasses) in

dung samples was found throughout the year in the Lopé Reserve (White et al., 1993), though neither Merz (1981) nor Short (1981) listed a single monocotyledon food species in their study sites, even though these species were present in the understory.

Across all plant life forms, fruits and seeds constituted 62% of all feeding events, though when elephants find themselves on cultivated land, most crops are consumed whole. Other studies have not focused on identifying the different cultivated plant species raided by elephants where human-elephant conflict is prevalent. This study identified 18 species of cultivated plants consumed by elephants on farmlands.

This study recorded Poaceae as the family with the most abundant plant species consumed by forest elephants though their proportion of consumption was very small. The Nki National Park is made of different vegetation types, and since feeding ecology of elephant is influenced by habitat type, grasses may compensate for low fruit availability in some habitat types or during seasonal decrease in fruit availability.

Conclusion

The findings of this study showed that forest elephants feed on a diverse diet of different plant species consisting of 25 wild plants and 18 cultivated plants with their diet preference mainly consisting of fruits in the Nki National Park and its surroundings. This knowledge on elephant feeding requirements is essential for the conservation of this Critically Endangered Species. Plant species such as *A. mannii*, *G. lacourtiana, Duboscia macrocarpa, Irvingia gabonensis* and *Baillonella toxisperma* among many others which are consumed maximally by elephants should be propagated/regenerated and managed *in-situ* at higher level/quantity so that elephants could not face any paucity of the food.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Ethnoecological knowledge allied to the management of wild medicinal plants in Ada'a District, East Shewa Zone of Oromia Regional State, Ethiopia

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This study assessed and documented ethnoecological knowledge of the indigenous people of Ada'a District that has important contribution in the conservation of wild medicinal plants. Both purposive and random sampling methods were used to collect appropriate data. Quantitative and qualitative ethnobotanical methods were used to analyze the ethnoecological data. A significance test on the indigenous knowledge variation of the average number of reported medicinal plants was assessed. Results indicated that a total of 112 wild medicinal plants belonging to 53 families were recorded. Moreover, the indigenous knowledge about the medicinality of the reported medicinal plants were found to be evenly known (P>0.05) by all informants regardless of their demographic characteristics (gender, age, level of education, marital status, and experiences). On top of this, it was found that the district has important traditional ecological knowledge that has a substantial contribution for the conservation of the medicinal plants in the wild. Therefore, we recommend that the district agricultural organization should synergize the existing traditional ecological knowledge with the conventional scientific approaches that are being promoted and implemented in the district for ensuring sustainable, integrated and long- term management of wild medicinal plants in the study area.

Key words: Ada'a District, ethnoecology, traditional ecological knowledge, Wild medicinal plants.

INTRODUCTION

Biodiversity is correlated with human cultural diversity (Cotton, 1996); and their links are of great concern to ethnobiology as this field of study emphasizes the relationship between indigenous people and the biota where they live (Kefalew and Sintayehu, 2018). To examine the different aspects of these interactions Ethnobiology has moved into a wider multidisciplinary approach (Asfaw and Wondimu, 2007).

One dimension of ethnobiology that focuses on studying the interaction of indigenous people and their ecosystems is ethnoecology (also called ecological ethnobotany) (Martin, 1995; Cotton, 1996). These relationships can be social, economic, symbolic, religious, commercial and/or artistic (Williams and Muchena, 1991; Balick and Cox, 1996). Ethnoecology stresses on documenting traditional ecological knowledge

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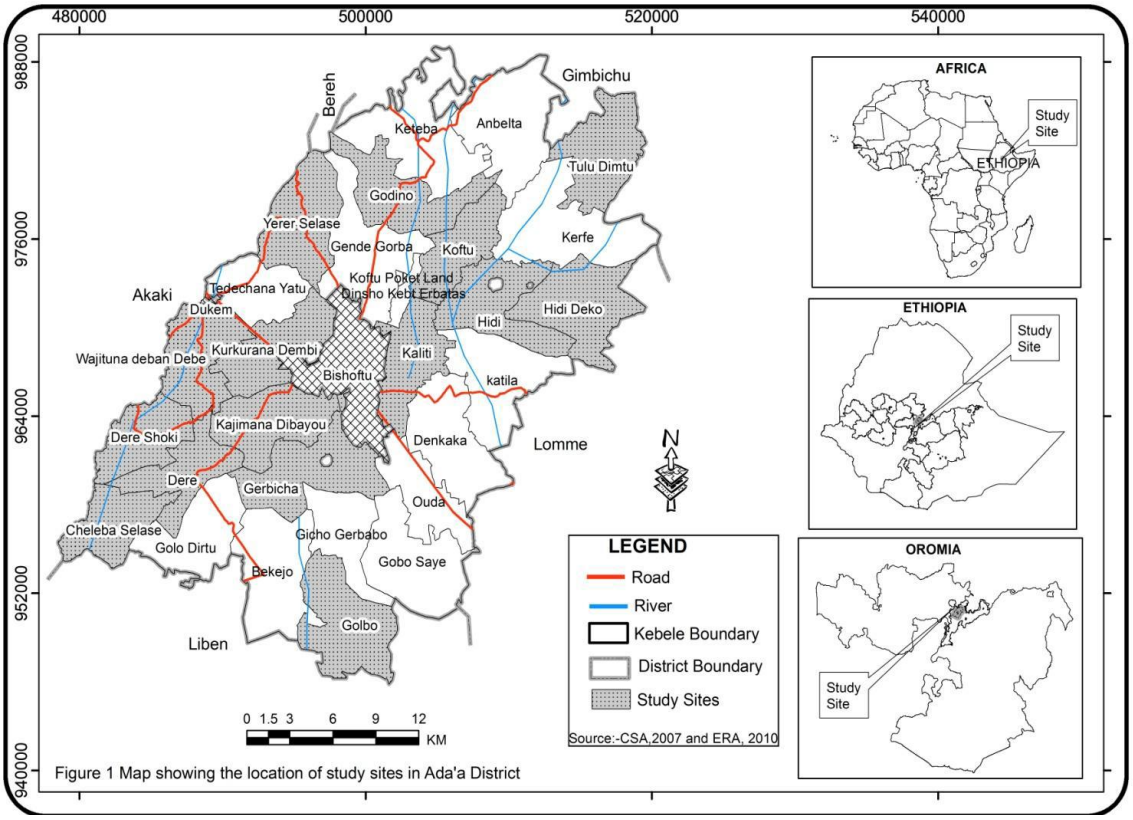

Figure 1. Location of the study sites in Ada'a District.

(TEK), which may include the culture and beliefs that have been handed down through generations by cultural transmission (Balick, 1996).

Ethnoecological knowledge can be applied in long term management and conservation strategies of biodiversity in general (Pedroso-Junior and Sato, 2005; Harisha et al., 2016) and wild medicinal plants in particular (Aumeeruddy and Ji, 2003; Ghimire et al., 2004). In supporting this fact, the International organizations such as the World Wildlife Fund (WWF) and UNESCO in their joint program titled 'The People and Plants Initiative' have been encouraging the role of traditional ecological knowledge (TEK) as well as integration of people's perception and practices in resource management at the local level (Cunningham, 2001). Moreover, the Convention for Biological Diversity (CBD), which has been ratified by 178 countries including Ethiopia on the Earth Summit in Rio de Janeiro, appreciates the role of indigenous knowledge in biodiversity conservation in general and wild medicinal plants in particular especially in its statements under Article 8j. Thus, identifying and promoting traditional ecological knowledge as a new model in environmental management is really a core section of applied ethnoecology and/or ethnobotany (Alexiades, 1996; Turner, 2000; Hamilton et al., 2003).

Despite the increasing recognition of the importance of TEK as a key tool to environmental management and conservation initiatives, such an approach has been poorly implemented around many parts of Ethiopia due to erosion of TEK (Demisse, 2001; Kibebew, 2001). This is also the case in the Ada'a District, East Shewa Zone of Oromia Regional State, Ethiopia which is negatively impacting the people's culture associated to biodiversity conservation and management practices of wild medicinal plants. Thus, this study is initiated to document existing TEK of the indigenous people of Ada'a District that could have important contribution in the conservation of wild medicinal plants.

MATERIALS AND METHODS

Study site

The study was conducted from 2015 to 2017 in Ada'a District, East Shewa Zone of Oromia Regional State, Ethiopia (Figure 1). The district is located in the dry evergreen Afromontane Forest Ecosystem of Ethiopia (Friis et al., 2011). The district is characterized by a monsoonal climate, which is marked by a wet summer (June-September) and a dry winter (February-May). The mean minimum annual temperature ranges from 9.4 to 13.7°C and the mean maximum annual temperature ranges from 24.2 to 29.2°C (EMA, 2015). The study site is characterized by unimodal rainfall with an annual mean precipitation of 73. 43 mm (calculated based on long term data from 2000 to 2015) ranging from 7. 3 to 209.8 mm. About 46.55% of the district is believed to be covered by natural forests (ADAO, 2016).

Ethnobotanical information

Ethics statement

All necessary permits for the described field studies were issued by the Administration Bureau of the district, East Shewa Zone of Oromia Regional State, Ethiopia following the directions in Cunningham (1996) and the Code of Ethics of the Society of Ethnobiology (International Society of Ethnobiology, 1998). Informed consent was also obtained from all informants following a standard ethnobotanical consent procedure.

Informant selection

Informants were representatives of the local/indigenous people of the district who could provide the ethnomedicinal/ethnoecological information. The age of the informants ranged from 18 to 85. Participants were chosen both systematically and randomly. Demographic data for the population of the district were in the ratio of 66:34 for men and women (ADAO, 2016). Keeping the same proportion, a total of 105 informants (69 males and 36 females) were selected from 15 kebeles (7 informants per kebele). Sixty of the total informants (4 per kebele) were randomly selected. This was done in various ways. Some of them were chosen by tossing a coin and using him/her as informant whenever head of the coin was up if he/she had volunteered to participate. Some others were chosen accidentally during random walks made to houses in the selected areas. The other 45 of the total informants (3 per kebele) were local experts (key informants) that were selected systematically based on recommendations from the local people, local authorities and development agents at each study sites. Their socio-demography is summarized in Table 1.

Semi-structured interview

A semi-structured checklist was prepared in advance to ensure informant consensus about the traditional ecological knowledge and medicinality of each herbal, following Cunningham (2001). The interviews were done on and around this checklist and some issues were raised depending on responses of informants. The language that has been used most frequently with the informants was Amharic (common language of the district). Oromiffa (local language of the district) was also used with the help of interpreters who had good knowledge of the local cultures and vegetation. The interviews were done with those born in, or have lived most of their lives in, the district.

Plant interview

This method (Gerique, 2006) was used to know the medicinality of each herbal collected from each study locality. In this method, medicinal plants were collected from the studied field area and brought back to the nearest village and presented to the randomly chosen informants to indicate wheather the species have medicinal qualities. When the freshly collected species were lost due to desiccation, pressed specimens were used during the interviews.

Group discussion

Group discussions, which were employed in each kebele, were used for cross-checking and verifying the information gathered via semi-structured interview and plant interview following Cotton (1996). The discussions were made with key informants, other traditional healers and the local people sometimes altogether or alone in their categories during the field study; and that information was recorded using a tape-recorder. Brief introduction was given to the groups so as to encourage them to discuss sincerely and frankly. The places and time for discussion were arranged based on the availability of the informants.

Methods of data collection on wild medicinal plants

Sampling design

Out of the 27 kebeles (the smallest administrative units) in the District, 15 of them (55.6%) (Chelebaselase, Dere, Dereshoki, Gerbicha, Godino, Golbo, Hidi, Hidideko, Kajimanadibayou, Kality, Koftu, Kurkuranadembi, Tuludimtu, Wajitunadebandebe, and Yererselase) were used for data collection. The selection of the 15 kebeles was made by purposive sampling method based on the availability of key informants identified with the assistance of local authorities and elders. The informants categorized the availability of wild medicinal vegetation of the district into six general habitat types, namely *Laffa Bosoona* (Forest land), *Laffa Mukke* (Wood lands), *Laffa Choroka* (Wet lands), which is in line with the definition given by Ramsar Convention Bureau (1997), *Laffa Merga* (Grass lands), *Laffa hori edu* (Grazing lands) and *Laffa ekiri* (Fallow land). Within each kebele, localities were identified based on these six habitats. This procedure gave a total of 95 localities from which 59 sampling units were selected by taking one locality for each habitat type in each kebele using the lottery method (Table 2). This stratification procedure gave 8 forest land localities, 15 woodlands, 7 wetlands, 11 grasslands, 15 grazing lands and 3 fallow lands. The selection of localities based on stratification by habitat type was chosen as it is the best representative sample for capturing the medicinal plant and ethnomedicinal knowledge in the district. It is noted that not every kebele was represented by each of the habitat types.

Plant identification

Medicinal plant species which were readily identifiable were recorded in the field. Those ethnomedicinal plants, which were difficult to identify in the field, were temporarily stored in a plastic bag; and then were pressed and brought to the National Herbarium (ETH) of Addis Ababa University (AAU) where they were dried, deep frozen and identified. The identifications were done first using keys of published volumes of Flora of Ethiopia and Eritrea (Gilbert, 1989; Demissew, 2006; Friis, 2006; Tadesse, 2004), and later supported with identification by comparisons with already authenticated dried specimen in the Herbarium. At last, all the medicinal plant species were confirmed with the help of taxonomic experts in AAU.

Data analysis

Descriptive statistical methods such as percentage frequency method of data analysis were employed to summarize some of the descriptive ethnobotanical data obtained from the interviews on reported medicinal plants and associated knowledge. Microsoft Excel spreadsheet software (Microsoft Corporation, 2010) was employed for organizing and analysing some ethnobotanical data. Inferential statistical analyses using two sample independent t-tests were performed to check whether there was a significant difference among the different parameters of informants (gender, age, literacy level, informant experience, marital status and living distance from health centre) for their knowledge about the medicinality of the reported medicinal plants. P-value was set at 0.05.

Table 1 . Socio-demographic data of the informants used in Ada'a District.

Informant parameter		Age		Sex		Education level		Informants		Distance (Km)		Marital status		Total
		Youngsters (Age between 18-30)	Elders (Age >30)	Male	Female	Literate	Illiterate	Key	Random	Lives in less than 10 Km	Lives in more than 10 Km	Married	Unmarried	
Age	Youngsters (Age between 18-30)	31												31
	Elders (Age >30)		74											74
Sex	Male	20	49											69
	Female	11	25											36
Education level	Literate	19	23	30	12									42
	Illiterate	12	51	39	24									63
Informants	Key	4	41	36	9	12	33							45
	Random	27	33	33	27	30	30							60
Distance (Km)	Lives in less than 10 Km	5	9	6	8	8	6	6	8					14
	Lives in more than 10 Km	26	65	63	28	36	57	39	52					91
Marital status	Married	12	19	25	6	18	13	2	29	9	22			31
	Unmarried	19	55	44	30	24	50	43	31	5	69			74
Total No. of informants		31	74	69	36	42	63	45	60	14	91	31	74	**105**

*Numbers in each cell refers to the number of informants; and distance is measured from Debre Zeit Town; Number in bold refers to the total number of informants used in the study, age category follows the report of Fantaw et al. (2018).

RESULTS

Ethnotaxonomy and composition of wild ethnomedicinal species

A total of 112 wild ethnomedicinal plants species (locally referred as *Qoricha uruffa* in Oromo language) (Table 3) were identified and documented from the study area. These species can be grouped into 97 genera and 53 families (Appendix 1). Of these medicinal plant species, 10 (9%) were endemic to Ethiopia (Table 4). Shrubs (locally called *Muke* or *Mukaa titika*/*xixina* in Oromo language) took the highest proportion whereas lianas (locally called *Hidda Jebata* in Oromo language) took the least proportion (Figure 2).

Statistical test on the ethnomedicinal knowledge of the local people

The questionnaire respondents represented a diverse array of people including farmers, women, literate, illiterate, youngsters, elders, married and unmarried. Among the 105 informants, 69 (65.7%) were male and 36 (34.3%) were females. The largest proportions of the respondents were elders (70.5%) above 30 years old (Table 5). Most respondents were not able to write and read (60%) whereas about 40% of the respondents were joined at least formal school of grade one and able to write or read. Among the respondents 86.7% of them dwell far away (> 5 Km) from the centre of health centres and/or Bishoftu town; whereas only few (13.3%) of them were living near (< 5 Km) to the Bishoftu town. Inferential statistical test of significance on average number of reported wild medicinal plants by the different groups of informants in Ada'a District is shown in Table 5.

Traditional knowledge on conservation of wild medicinal plants

Semi-structured interview carried out with the key informants revealed the presence of various local beliefs and cultural traditions that have conservation values of medicinal plants. Some of

Table 2. Total number of wild localities and number of sampling units in Ada'a District.

S/N	Kebele	Different categories of the wild environment in Ada'a District												Total	
		Forest land		Woodland		Wetland		Grassland		Grazing land		Fallow land			
		TNL	CNL	TNL	CNL	TNL	CNL	TNL	CNL	TNL	CNL	TNL	CNL	TNL	CNL
1	Chelebaselase	NR	NR	1	1	NR	NR	1	1	1	1	1 (BL)	-	4	3
2	Dere	NR	NR	2	1	NR	NR	2	1	1	1	1	1	6	4
3	Dereshoki	NR	NR	2	1	1	1	NR	NR	2	1	1 (BL)	-	6	3
4	Gerbicha	NR	NR	3	1	1	1	1	1	1	1	1 (BL)	-	7	4
5	Godino	1	1	2	1	NR	NR	1	1	1	1	1 (BL)	-	6	4
6	Golbo	1	1	2	1	NR	NR	1	1	1	1	1 (BL)	-	6	4
7	Hidi	NR	NR	2	1	NR	NR	1	1	1	1	1 (BL)	-	5	3
8	Hidideko	1	1	2	1	NR	NR	2	1	1	1	1 (BL)	-	7	4
9	Kality	1	1	2	1	1	1	1	1	1	1	1 (BL)	-	7	5
10	Kajimanadibayou	1	1	3	1	NR	NR	NR	NR	1	1	1	1	6	4
11	Koftu	NR	NR	3	1	1	1	NR	NR	1	1	1 (BL)	-	6	3
12	Kurkuranadembi	1	1	2	1	1	1	1	1	2	1	1 (BL)	-	8	5
13	Tuludimtu	1	1	2	1	1	1	NR	NR	1	1	1 (BL)	-	6	4
14	Wajitunadebandede	NR	NR	2	1	NR	NR	1	1	1	1	2	1	6	4
15	Yererselase	2	1	2	1	1	1	1	1	2	1	1 (BL)	-	9	5
Total number of localities		9	-	32	-	7	-	13	-	18	-	16	-	95	-
Total number of sampling units		-	8	-	15	-	7	-	11	-	15	-	3	-	59

TNL-total number of localities, CNL-Chosen number of localities, NR-not represented, BL-bare land.

them are shown in Table 6.

DISCUSSION

Diversity of plant species used medicinally

Results with regard to wild medicinal plant composition (locally called *Qoricha Urufa*) suggest that the district was once primarily a typical dry Afromontane Forest ecosystem of Ethiopia. This is due to the presence of remnant characteristic species for the vegetation type of dry evergreen Afromontane Forests (Demissew and Friis, 2009; Friis et al., 2011). These species include *Croton macrostachyus, Juniperus procera, Olea europaea* subsp*. cuspidata* locally called *Bekanisa*, *Gatira* and *Ejersa,* respectively; and are still retained in the existing landscape of the district as medicinal herbals. The local people use a taxonomically diverse group of wild medicinal plants, about 112 species in 97 genera and 53 families. The availability of diverse medicinal plant species in the wild were also reported from all corners of Ethiopia (Abebe, 1986; Abebe and Ayehu, 1993; Asfaw, 1997, 2001; Abebe, 2001; Asfaw and Tadesse, 2001; Bekele, 2007; Birhane et al., 2011; Assefa and Abebe, 2014; Tolossa et al., 2013; Kidane et al., 2014; Mesfin et al., 2014; Megersa et al., 2013; Belayneh and Bussa, 2014; Seifu et al., 2006; Chekole et al., 2015; Lulekal et al., 2008; Bussmann et al., 2011). This is attributed to the fact that wild habitats are the main storehouse of medicinally useful plants. Some of these medicinal plants were recorded to be economically important plants used for many other purposes in the district. For example, *Juniperus procera, Acacia albida, Croton macrostachyus, Olea europaea* subsp*. cuspidata,* and *Prunus africana* were some of the medicinal plants in the district with multiple purposes other than their medicinal values (Kefalew et al., 2015). Some of the medicinal plants identified in this study were reported elsewhere to have other use values other than their therapeutic quality. For

Table 3. Lists of wild medicinal plants collected from Ada'a District (T=tree, S=Shrub, H=herb, UT=used to treat, An=Animal, Hu=human, Bo=both).

S/N	Scientific Name	Family	Local Name (Oromifa/Amarigna)	Growth form	UT	Ailment treated (English/Amaric)	No. of citations
1	*Acacia abyssinica* Hochst. ex Benth.	Fabaceae	Laaftoo /Girar	T	An	Horse scabies (Yeferse ebitet)	3
2	*Acacia albida* Del.	Fabaceae	Garbii /Gerbi	T	An	Eye bruise (Bilz)	5
3	*Acacia seyal* Del.	Fabaceae	Wachoo /Wachu	T	Hu	Headache (Ras mitat)	3
					Hu	Stomach trouble (Yehod hemem)	11
4	*Achyranthes aspera* L.	Amaranthaceae	Derguu /Etse-tekeze	H	Hu	Abdominal pain in woman after birth (Kurtet)	5
					Hu	RH case (Shotelay)	4
5	*Acmella caulirhiza* Del.	Asteraceae	Guticha	H	Hu	Loose tooth	7
6	*Agave sisalana* Perrine ex Engel.	Agavaceae	Qachaa /Qacha	T	An	Tick	3
7	*Ageratum houstanianum* Mill	Asteraceae	Q/Merzi /Yemerz Medanit/	H	Hu	Poisoning (Merzenet)	5
					Hu	Stomach trouble	8
8	*Ajuga integerifolia* Buch. Ham.	Lamiaceae	Harmmaguusa /Aqorarache/	H	Hu	Cold (Bired)	3
					Hu	Gout (Rihi)	4
					Hu	Hypertension (Dem bizat)	6
9	*Aloe macrocarpa* Tod.	Aloaceae	Argiisa /Ret	H	Hu	Intestinal parasite	3
					Bo	Swelling (Ebach)	3
10	*Alternanthera pungens* Kunth.	Amaranthaceae	*****	H	Hu	Sudden illness (Dingetegna)	3
					Hu	Whooping Cough (Tektik)	6
11	*Artemisia abyssinica* Schtz. Bip. ex Rich	Asteraceae	Tiroo /Chikugne	H	Hu	Stomach trouble	12
					Hu	Eye itching (Ayenen masakek)	9
12	*Asparagus africanus* Lam.	Asparagaceae	Seriiti /Seriti	S	Hu	Amobiasis (Ameba)	7
13	*Asparagus racemosus* Wild.	Asparagaceae	Seriiti / Seriti	S	Hu	Amobiasis	9
14	*Asplenium monanthes* L.	Aspleniaceae	*****	H	Hu	Woumb itching (Mehatsenen masakek)	2
15	*Bersama abyssinica* Fresen.	Melianthaceae	Loliichisa /Azamir	T	An	Horse Scabies (Bech'h)	4
16	*Bidens pilosa* L.	Asteraceae	Chogogitii /Chogogit	H	Hu	Devil sickness (Lekefet)	5
17	*Brucea antidysenterica* J. F. Mill.	Simaroubaceae	Qumegno /Abalo	S	Hu	Evil eye (Buda)	9
					An	Colic (yehod hemem)	6
18	*Buddlejia polystachya* Fresen.	Buddlejiaceae	Qawissa /Anfar	T	An	Leech (Alekit)	12
19	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	Ceekaa /Digita	S	Hu	Scabies (Ekek)	3
					An	Pubic hair louse (Qemanjer)	3
20	*Capparis tomentosa* Lam.	Capparidaceae	Goora /Gumero	CL	Hu	Wound (Kusil)	9

Table 3. Contd.

21	*Carissa spinarium* (Vahl.) Forssk. ex Endl.	Apocynaceae	Agamsa /Agam	S	Hu	Intestinal worms	3
					Hu	Evil eyes	2
22	*Centella asiatica* (L.) Urban.	Apiaceae	*****	H	Hu	Bleeding	4
23	*Clausena anisata* (Wild.) Benth.	Rutaceae	Ulumaa /Limich	S	Hu	toothache	7
					Bo	Wound	4
24	*Clematis simensis* Fresen.	Ranunculaceae	Fiitii /Enderifa	Ll	Hu	Evil eye	4
					Hu	Wart (Kintarot)	4
25	*Clerodendrum myricoides* (Hochst) Vatke	Lamiaceae	Maraasisaa /misirich	S	Hu	Diarrhae	4
26	*Colocasia esculenta* (L.) Schott	Araceae	Godaree /Godore	H	Hu	Swelling	4
27	*Croton macrostachyus* Del.	Euphorbiaceae	Bakaniisaa /Bisana	T	Hu	Febril illness (Megagna)	6
					Hu	Tinea nigra (Kuakucha)	5
28	*Cucumis dipsaceus* Ehrenb.	Cucurbitaceae	Buqee seexanaa /Yesetan kil/	CL	Hu	Depression (Eje seb)	8
29	*Cucumis ficifolius* A. Rich.	Cucurbitaceae	Holoo /Yemidir enbuay	CL	Hu	Abdominal pain (Kuretet)	14
30	*Cyathula cylindrica* Moq.	Amaranthaceae	Derguu/ Yemogn fikir	H	Hu	Stomachache (Yehod hemem)	4
31	*Cyphostemma adenocaule* (Steud. ex .A. Rich.) Descoings ex Wild & Drummond	Vitaceae	Melas golgul	CL	An	Blackleg	7
					Bo	Swelling	3
					Hu	Snake bite	4
32	*Datura stramonium* L.	Solanaceae	Atsefaris/Astenagir	H	Hu	For Intellegency (Letimret)	5
33	*Dodonaea angustifolia* L. f.	Sapindaceae	Etacha /Kitkita	S	An	Wound	3
34	*Dombeya torrida* (J. F. Gmel) Bamps	Sterculiaceae	Daanisa /Wolkefa	T	Hu	Antidot for snake bites	3
35	*Dregea schimperi* (Decne.) Bullock	Asclepiadaceae	Hida /Yeregna missa	Ll	Hu	Eczema (Chiffea)	4
36	*Ekebergia capensis* Sparrm.	Meliaceae	Somboo /Sombo	T	Hu	Syphilis (Kitign)	6
37	*Eleusine floccifolia Forssk*.	Poaceae	Coqorsa /Akerma	H	Hu	Snake bit	3
					Hu	Poisoning	4
38	*Embelia schimperi* Vatke	Myrsinaceae	Hanquu /Enqoqo	S	Hu	Tape worm (Kosso)	8
39	*Erica arborea*	Ericaceae		S	An	Eye disease	2
40	*Euclea racemosa* subsp. *schimperi*	Ebenaceae	Me'essaa /Dedeho	S	Hu	Tonsillitis (Entil siwored)	5
41	*Euphorbia abyssinica* J. F. Gmel.	Euphorbiaceae	Adamii /Kulkual	T	Hu	Haemorrhage	6
42	*Euphorbia ampliphylla*	Euphorbiaceae	Adamii /Kulkual	T	Hu	Haemorrhage	6
43	*Ferula communis* L.	Apiaceae	Dog	H	Hu	Cough	6
44	*Ficus sur* Forssk.	Moraceae	Harbuu/Sholla	T	Hu	Wart on hand(Kintarot)	3
					An	Swelling	2

Table 3. Contd.

45	*Foeniculum vulgare* Mill.	Apiaceae	Insilaalee /Ensilal	H	Hu	Urinary Retention (Shinet leklekelew)	6
					Hu	Stomach trouble	5
46	*Fuerstia africana* Th. Fries	Lamiaceae	Eje Admek	H	Hu	General malaise (Mich)	10
					An	Cattle eye disease	13
47	*Gamphocarpus abyssinicus* Decne.	Asclepiadaceae	Rebu Hunda	H	An	Blackleg (Aba gorba)	9
48	*Grewia ferruginea* Hochst ex . A . Rich.	Tiliaceae	Dhoqonuu /Lenquata	S	Hu	Taeniasis (Kosso)	4
49	*Guizotia scabra* (Vis) Chiov.	Asteraceae	Adaa /Mech	H	Hu	Epilospy (Yemitel beshita)	2
50	*Heteromorpha trifoliata* (Wendel.) Eckl. & Zeyh.	Apiaceae	Demehee /Yejib merkuze	S	Hu	Warding of Sorcery Stealing (Selabi)	5
51	*Hygrophila schulli* (Hamilt.) M. R. & S. M. Almeida	Acanthaceae	Q/Mearzi	H	Bo	poisoning	3
52	*Hypericum quartinianum* A. Rich.	Hypericaceae	Muke fonii	S	Hu	Jaundice (Yewof beshita)	4
53	*Hypericum revolutum* Vahl	Hypericaceae	Hindhee /Ameja	S	An	Eye disease	3
54	*Impatiens rothii* Hook. f.	Balsaminaceae	Buri /Gesherit	H	Hu	Wounds on hand	2
55	*Impatiens tinctoria* A. Rich. Subsp. *abyssinica* (Hook. f.) Grey-Wilson	Balsaminaceae	Ensosilla	S	Hu	Wound on palm	2
56	*Inula confertiflora* A. Rich.	Asteraceae	Mognoree /Weynageft	S	An	Eye disease	3
					Bo	Rabies (Yehebid wusha beshita)	2
57	*Jasminum grandiflorum* L.	Oleaceae	Qamaxee /Tembelel	S	Hu	Evil eye	3
					Hu	Toothache (Yeters himem)	3
58	*Juniperus procera* Endle	Cupressaceae	Gaatiraa /Yehabesha Tid	T	Hu	Demon possesesion (Ganen)	4
59	*Kalanchoe petitiana* A. Rich.	Crassulaceae	Bosoqee /Endahula	H	Bo	Swelling	24
60	*Lagenaria siceraria* (Molina) Standl.	Cucurbitaceae	Buqqee /Kil	H	Hu	Impotency (Sinfet wosib)	3
61	*Laggera tomentosa* (Sch. Bip. ex A. Rich.) Oliv. & Hiern	Asteraceae	Keskeso	H	Hu	Flu (Gunfan)	3
62	*Leonotis raineriana* Vis.	Lamiaceae	Bokkoluu dimma / Ras kimir /	S	An	Leech	15
					Hu	General malaise (Mich)	10
63	*Leucas martinicensis* (Jacq.) R. Br.	Lamiaceae	Bokkoluu adii / Ras kimir	S	Hu	General malaise (Mich)	8
64	*Lippia adoensis* Hochst. ex Walp.	Verbenaceae	Kusaayee /Kese	S	Hu	Stomach pain (Cheguara)	3
65	*Maesa lanceolata* Forssk.	Myrsinaceae	Abbayyii /Kelewa	S	Bo	Swelling	5
66	*Malva venticillata* L.	Malvaceae	Liitii /Lit	H	An	Swelling	2
67	*Myrica salicifolia* A. Rich.	Myricaceae	Kataba /Shinet	T	Hu	Ascariasis	4
68	*Myrsine africana* L.	Myrsinaceae	Qacama /Kechem	S	Hu	Taeniasis	5

Table 3. Contd.

					An	Worms in donkey	4
69	*Ocimum gratissimum* L.	Lamiaceae	Q/Michii /Mech medanit	H	Hu	General malaise	15
70	*Ocimum lamiifolium* Hochst. ex Benth.	Lamiaceae	Demakessie	S	Hu	General malaise	24
71	*Olea europaea* L. subsp. *cuspidata* (Wall. ex G. Don) Cif.	Oleaceae	Ejersa /Weyra	T	Hu	QOROQOR	4
72	*Olinia rochetiana* A. Juss.	Oliniaceae	Dalecho	S	Hu	Snake bit	2
					Hu	Toothache	4
73	*Osyris quadripartita* Decn.	Santalaceae	Waatoo /Qeret	S	Hu	Eczema	3
74	*Otostegia integrifolia* Benth.	Lamiaceae	Tungiitii /Tungit	S	Hu	Fibril illness (Megagna)	12
75	*Pavetta abyssinica* Fresen.	Rubiaceae	Muke-buniti	S	Hu	Poison	2
					An	Animal diarrhoea	3
76	*Pentas schimperiana* (A. Rich.) Vatke	Rubiaceae	Dasie	S	An	Eye disease	11
77	*Phytolacca dodecandra* L' Herit	Phytolaccaceae	Handoode /Endod	S	An	BECHE'H	10
					Hu	Wart on hand	9
78	*Plantago lanceolata* L.	Plantaginaceae	Qorxobbii /Yehaheya Kote/	H	An	Intestinal parasite	4
79	*Plantago major* L.	Plantaginaceae	Qorxobbii /Yekura wesife/	H	Hu	Poisoning	3
					Hu	Haemorroides	3
80	*Premna schimperi* Engl	Lamiaceae	Urgessa /Chchoho	S	Hu	Eye disease	4
81	*Protea gaguedi* J. F. G.	Proteaceae	Dasie	S	An	Animal jaundice	11
82	*Prunus africana* (Hook. f.) Kalms	Rosaceae	Hoomii /Tikur Enchet	T	Hu	Swelling	4
					Hu	Sudden illness (Dingetegna)	6
					An	Blackleg	2
					An	Anthrax (Abasenga)	2
83	*Pterolobium stellatum* (Forssk.) Brenan	Fabaceae	Harengeemmaa/ Kontir	S	Hu	Rhumantic pain (Kurtimat)	5
84	Rhus glutinosa	Anacardiaceae		S	Hu	Epistaxis (Neser)	2
85	Rhus retinorrhoea	Anacardiaceae	Tilem	S	An	Anthrax (Abasenga)	4
86	*Rhus vulgaris* Meikle	Anacardiaceae	Dabobechaa/ Kimmo	S	An	Diarrhoea	3
87	*Ricinus communis* L.	Euphorbiaceae	Qoboo/ Gulo	T	Hu	Dandruff (Forofor)	6
88	*Rosa abyssinica* Lindley	Rosaceae	Gora /Kega	S	An	Invoking sprit (Aganent)	7
89	*Rubia cordifolia* L.	Rubiaceae	Enchiberii/ Enchibir	H	Hu	Wound	13
					Hu	Cough	6
					Hu	Cough	7
					An	Cataract (Bemora yete-shefene ayen)	5

Table 3. Contd.

90	*Rubus steudnerS.*	Rosaceae	Agogota	H	Hu	Stabbing pain (Wugat)	2
					Hu	Cough	2
91	*Rumex abyssinicus* Jacq.	Polygonaceae	Meqmeqo	H	Hu	Eye bruise	5
					An	Blackleg	2
					An	Scabies (Ekek)	2
92	*Rumex nepalensis*Spreng.	Polygonaceae	Shuultii /Tulet	H	An	Colic (Yehod himem)	3
					An	Blackleg	6
					Hu	Stomach pain (Cheguara)	3
					Hu	Stabbing pain (Wugat)	3
					B	Urinary retention	4
93	*Rumex nervesus* Vahl	Polygonaceae	Dhangaggoo /Embuacho /	S	Hu	Delay in drying circumcision	5
94	Salix mucronata	Salicaceae	Alaletu/ Ahaya	T	Hu	MIKEGNA-SHEREGNA	6
95	*Salvia nilotica* Jacq.	Lamiaceae	Hulegebe	H	Hu	Wound	3
96	*Sida schimperiana* Hochst. ex A. Rich.	Malvaceae	Chefreg	H	An	Rabies	2
					An	Preventing bitch birth	2
97	*Snowdenia polystachya* (Fresen.) Pig.	Poaceae	Muja	H	Hu	Scabies (Ekek)	2
98	*Solanecio gigas* (Vatke.) C. Jeffrey	Asteraceae	Gommana osolee /Yeshikoko gomen/	S	Bo	Retained placenta	7
99	*Solanum anguivi* Lam.	Solanaceae	Hiddi Worabessa/Zerch Enbuay/	S	Hu	Intelligence	3
					Hu	Dandruff	2
					An	Rabies	3
100	*Solanum incanum* L.	Solanaceae	Hiddii /Yehabesha Embuay/	S	An	Tick bite	2
					An	Horse Scabies	2
					Hu	Wounds	2
101	*Solanum marginatum* Linn. f.	Solanaceae	Hiddii /Tileku Enbuay	S	Hu	Long stay menstruation	5
					An	Rabies	6
102	*Stephania abyssinica* (Dillon ex A. Rich.) W	Menispermaceae	Kalaala /Engochit	LI	An	Blackleg	5
					Hu	Unwanted pregenancy	3
					Hu	Wound	3
					Hu	Swelling	5

Table 3. Contd.

					Hu	Sudden illness	4
103	*Tagetes minuta* L.	Asteraceae	Tiro	S	An	KINKIN	4
104	*Thunbergia alata* Sims.	Acanthaceae	Hareg	CL	Hu	Cough	3
105	*Thymus schimperi* R.	Lamiaceae	Xoosanyii /Tosigne	S	Hu	Hypertension	8
106	*Urtica simensis* Steudel	Urticaceae	Dobii/ Sama	H	Hu	Gonorrheae (Chebit)	2
107	*Verbascum sinaiticum* Benth.	Scrophulariaceae	Guraa Haree / Yahaya joro/b	H	Hu	Nightmare	4
					An	Blackleg	2
108	*Verbena officinalis* L.	Verbenaceae	Atuch	H	Hu	Cough	4
					Hu	Tonsilities (Entil siwored)	5
					Hu	Warding off sorcery steeling	5
109	*Vernonia amygdalina* Del.	Asteraceae	Ebicha /Grawa	T	Hu	Malaria	5
					Hu	Abdominal pain	3
110	*Withania somnifera* (L.) Dunal.	Solanaceae	Gizaawaa /Gizawa	S	Hu	Daemon possesesion	6
111	Xanthium strumarium L.	Asteraceae	Yemogne Fikir	S	An	Leech	3
112	Zehneria scabra L.	Cucurbitaceae	Daaymii/ Areg resa	Ll	Hu	Deformed lips (Megagna)	6

example, *Cordia africana, C.macrostachyus, J. procera, Prunus africana, O. europea*, *Ekibergia capensis* were reported for the purpose of timber in different areas of Ethiopia (Lulekal et al., 2008; Mesfin et al., 2013). Similarly other medicinal species such as *Acacia abyssinica, Acacia albida, Acacia seyal* were also reported elsewhere for home garden agro-forestry purposes such as fencing and shading (Hailu and Asfaw; 2009; Awas and Demissew, 2009; Amberber et al., 2013; Abebe et al., 2013; Linger et al., 2014; Tefera et al., 2014); whereas, *Euphorbia ampliphyla, Euphorbia abyssinica, C. macrostachyus,* and *Vernonia amygdalina* were recorded for their purpose of beehive making and/or bee forage (Senbeta et al., 2013).

The findings of this study showed that shrubby herbals were the most dominant form of wild medicinal plants in the district followed by herbaceous forms. Similar findings were noted elsewhere in Ethiopia (Hunde et al., 2004; Yineger and Yewhalaw, 2007; Lulekal et al., 2008; Mesfin et al., 2009). This may be linked with the custom of the local people to use plants that are available almost all the time. In line with this fact, Martin (1995) and Cotton (1996) suggested that knowledge of medicinal plants directly emanates/originates from the type of the plants they are surrounded by. In this regard, shrubby herbals are the most available form of herbals in almost all year as they are tolerant to seasonal variation (Albuquerque, 2006) and might have had a high chance of being chosen by the local people of the study area. On the contrary, the ecological nature of herbaceous medicinal plants is normally an annual and more subjected to influences by small scale environmental variations than shrubs are. Moreover, apart from seasonal variation, grazing intensity in the study area might have contributed to the lesser number of herbaceous medicinal plants than shrubs (Kefalew, 2010).

This effect of grazing on herbaceous medicinal plants was also noted elsewhere (Adnan and Holscher, 2010). The rather fewer contribution of trees for therapeutic purposes in the district may be linked with the less abundance of tree species that resulted from previous over exploitation and habitat modification history of trees mainly for the purposes other than their medicinal values (Aba Geda *Tulema,* Pers. comm).

The plant families such as Asteraceae (11 species, 9.82%), Lamiaceae (11 species, 9.82%), Fabaceae (5 species, 4.46%), Solanaceae (5 species, 4.46%), Apiaceae (4 species, 3.57%),

Table 4. Lists of endemic wild medicinal plants encountered in Ada'a District.

S/N	Botanical Name	Habit	Family	Reference FEE
1	*Acacia abyssinica* subsp*. abyssinica*	Tree	Fabaceae	Hunde and Thulin (1989)
2	*Inula confertiflora*	Shrub/tree	Asteraceae	Tadesse (2004)
3	*Impatiens rothii*	Herb	Balsaminaceae	Tadesse (2004)
4	*Impatiens tinctoria* subsp. *abyssinica*	Herb	Balsaminaceae	Tadesse (2004)
5	*Jasminum stans*	Shrub	Oleaceae	Green (2003)
6	*Kalanchoe petitiana*	Herb	Crassulaceae	Gilbert (1989)
7	*Laggera tomentosa*	Shrub	Solanaceae	Friis (2006)
8	*Lippia adoensis*	Shrub	Verbenaceae	Demissew (2006)
9	*Otostegia integrifolia*	Shrub	Solanaceae	Friis (2006)
10	*Rhus glutinosa* subsp. *neoglutinosa*	Shrub	Anacardiaceae	Gilbert (1989)
11	*Solanecio gigas*	Shrub	Asteraceae	Tadesse (2004)
12	*Solanum marginatum*	Shrub	Solanaceae	Friis (2006)
13	*Thymus schimperi*	Herb	Lamiaceae	Ryding (2006)
14	*Urtica simensis*	Herb	Urticaceae	Friis (1989)

FEE: Flora of Ethiopia and Eriterea.

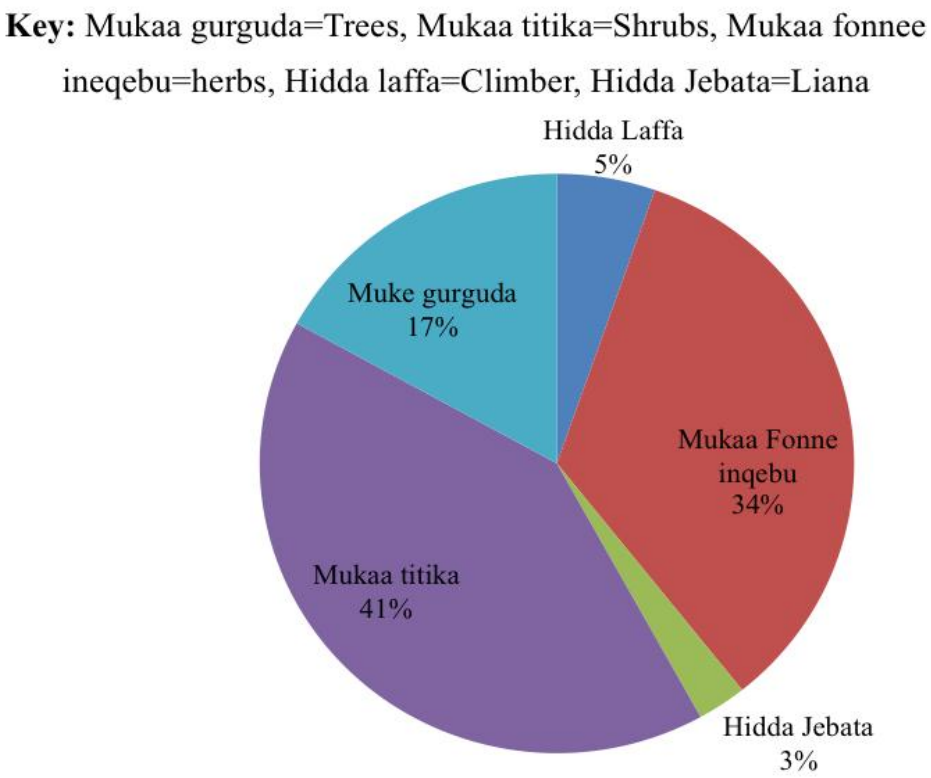

Figure 2. Growth form of wild medicinal plants in Ada'a District (note that growth forms are named using local language as recommended in ethnotaxonomy so as to give more weight for the voices of the local people).

Cucurbitaceae (4 species, 3.57%) and Euphorbiaceae (4 species, 3.57%) are found to be the most common plant families composed of wild medicinal plants in the District. This goes in agreement with most of the ethnomedicinal studies in Ethiopia (Giday, 2007; Giday et al., 2007, 2009, 2010; Giday and Teklehaymanot, 2013; Teklehaymanot and Giday, 2007; Adefa and Getaneh, 2013). This indicates the high contribution of these plant

Table 5. Average number of wild medicinal plants (AWMP) reported by different groups of informants.

Socio economic parameter	Informant groups	Number of informants (n)	Percentage	Total number of citations (N)	AWMP ± SD	t-value	P-value*
Gender	Male	69	65.7	351	34.07±20.47	-1.445	0.149
	Female	36	34.3	191	36.74±20.56		
Age	Youngsters	31	29.5	209	36.11±19.87	-0.985	0.325
	Elders	74	70.5	333	34.33±20.92		
Literacy level	Illiterate	63	60	181	35.03±21.00	-0.012	0.991
	Literate	42	40	361	35.01±20.31		
Informant category	Key	45	42.9	223	35.68±20.42	0.633	0.527
	General	60	57.1	319	34.55±20.62		
Marriage	Married	31	29.5	516	34.83±20.53	-0.925	0.355
	Unmarried	74	70.5	26	38.65±20.47		
Distance from health centre	Close to the health centre	14	13.3	42	44.50±18.29	-3.142	0.002*
	Far from the health centre	91	86.7	500	34.22±20.52		

*Indicates significant difference (P<0.05) between averages of the paired categories (note that the p-level reported with the t-test represents the probability of error involved in accepting research hypothesis about the existence of a difference).

families to most of the medicinal flora of the country, Ethiopia. The relatively high contribution of these families other than other families may originate from their high species richness in the Flora of Ethiopia and Eritrea (Kelbessa and Demissew, 2014). In line with this notion, Saqib et al. (2011) have found a strong positive correlation (r = 0.88) between the overall species richness of vegetation and the associated ethnomedicinal plant species richness in Pakistan. Moreover, critical observation on the finding of Giday (2001), Lulekal (2005), Yineger (2005), Giday (2007), Awas (2007), Lulekal (2014) and Regassa (2016) on the joint study of vegetation and ethnomedicinal plant diversity showed that the species richness of both the general vegetation and medicinal flora follow the same pattern and seem to be directly related. In line with this Erdelen et al. (1999) and Edwards (2001) concluded the presence of greater concentration of medicinal plant diversity at the areas where there is higher concentration of biological and cultural diversity.

The finding of this study showed that about 10% of the collected medicinal plants are endemic to Ethiopia, which follows almost the same proportion of endemism for the Flora of Ethiopia and Eriterea (Kelbessa and Demissew, 2014). This endemic medicinal flora in Ada'a District includes *Acacia abyssinica, Inula confertiflora*, *Impatiens rothii*, *Jasminum stans*, *Laggera tomentosa*, *Lippia adoensis*, *Otostegia integrifolia*, *Rhus glutinosa*, *Solanecio gigas*, *Solanum marginatum*, *Thymus schimperi and Urtica simensis* (Kelbessa et al., 1992; Friis, 1989; 2006; Giibert, 1989; Tadesse, 2000, 2004; Green, 2003; Vivero et al., 2005; Demissew, 2006; Ryding, 2006). Some of these medicinal species reported in this study were also reported elsewhere by Lulekal et al. (2013, 2014) for Ankober District in North Shewa Zone, Hunde et al. (2004) for Welechiti area in East Shewa Zone, and Amenu (2007) for Cheliya District in West Shewa Zone of Ethiopia.

Conservation implication of the indigenous ecological knowledge of Ada'a District

This study also found important belief and cultures of the local people that have important actions on the conservation of some of the wild medicinal plants. For instance, cutting plants that are of importance for religious purposes (e.g., *Acacia* spp., *Ficus* spp.) is considered as committing a curse since these plants and many others are respected for religious reasons. Thus, the local people protect and preserve the plant species that are strongly associated with beliefs and religion and hesitate to destroy them. This study also found that forests on the highland areas are protected as these areas are perceived to be a sacred area. This may be attributed with the tradition that the *Qallus'*, who are supposed to serve between the human and *Ayyanna* (spirit) and has a role equivalent to the role of Bishop in the Christian word and of Imam in the Muslim word, often build their *Gelma* (traditional Oromo ritual hall/church) on such high land areas. Hence, highland forests are believed to be a special place where the *Qallus'* live and

Table 6. Traditional ecological knowledge (TEK) of the people of Ada'a District which are having conservation implications of traditional medicinal plants in particular and ecology of the district at large.

S/N	Traditional knowledge	Description of the knowledge	Conservation implication
1	ADIBAR	ADIBAR is a term referring to the sacred plants in the district; and mainly applied to *Ficus* spp. *Acacia abyssinica*, *Olea europaea* subsp. *cuspidata*, *Cordia africana* are also regarded as place for ADIBAR festival. These are locally believed to be blessed trees and hence serve as a place where they believe; and not really what they believe. Thus, these plants are better protected by the local people as many people afraid of cutting them.	This culture contributes for the conservation of common umbrella species of the district.
2	BORENTICHA	BORENTICHA is supposed to be the spirit of a river; and makes the river and adjacent vegetation sacred. In this tradition, individuals are required to prepare traditional beer, Niger seed, and large local bread cooked only on one side and celebrates the *Borenticha* ritual at the river bed and/or other wet lands to appease the spirit of the river.	This tradition protects wet lands not to be naked
3	CAGINO days	In the tradition of the district some medicinal plants are only cut in Cagino days (selective days) if they need to be efficacious. For example, GIZAWA (*Withania somnifera*), TUNGIT (*Otostegia integrifolia*), SERITII (*Asparagus africanus*), YEAHEYA JORO (*Verbascum sinaiticum*), AGAM (*Carissa spinarium*), BISANA (*Croton macrostachyus*), and CHIFREG (*Sida schimperiana*) among many others are only cut on Wednesdays and/or Fridays. If cut in other days a devil sprite will attack while the healer is collecting.	This tradition avoids the frequent exploitation of medicinal plants; and has a role for sustainable utilization of these MPs
4	ENTUKEN	This tradition refers to a condition in which once the patient is healed (e.g *Sebeta Wakayo*, equivalent term for Jaundice) due to a particular plant part (such as *Acacia* sp.), then this healed person never cut that plant anywhere in the district. If he/she committed to cut the plant, then the disease is believed to reappear to him/her.	This tradition contributes for the conservation of some of such species that are very vital both ecologically and ethnobotanically.
5	ERECHA	ERECHA is a term refering to festival of shelters. It is the famous festival known in the district. It is thanks giving day. People hold flowers, fruits, grasses or other plants which are sign of God's gift and go to the lake or rivers to thanks him.	This tradition is helpful in conserving wet areas where plants are most frequently available.
6	GERBI ATETE:	GERBI ATETE refers to Gerbi (*Acacia albida*) whose main stem branched in to two from its base and hence it is a place for *Adibar*, or shelter for other cultural meetings. These plants are not most often cut by the indigenous people.	An important taboo of the area for the dominancy of the plant *Acacia albida* in the district
7	MELKA	MELKA refers to the area along streams or rivers where people passed by. It is a place where people give respect. Most frequently people put '*Erecha'* here while moving through it. Plants nearby Melka are not allowed to cut.	This tradition conserves wetland vegetation in general MPs in particular
8	ODAA NEBI	ODAA is a local term refering to *Ficus* spp. and NEBI is a local term referring to the acient Ayyanna of the Oromo; and equivalent to Jesus in the Christian word. Thus, *Odaa Nebi* is believed to be a *Ficus* species from Jesus. This is a known plant in the culture of '*Tulema Oromo'* where they produce laws of do's and not to do's. Otherwise the laws are believed to be unaccepted by '*Nebi'*.	This specific belief pays attention for the conservation of *Ficus* spp, which is an umbrella and keystone species in the district.
9	QALLUMAN EYEMEMME	This refers to the utilization of medicinal plants only by selected families who have divine power locally referred as *Qallu* in the community. But if other healers harvest the medicinal plant, it doesn't heal as it is believed to loss its efficacy.	This tradition reduces the level of exploitation
10	RAKOO	RAKOO is a term refering to a young man who hasn't got married; and according to the tradition *Rakoo* are not allowed to cut straight up growing trees.	The presence of more young people saves straight up growing trees
11	BOSSONA TULU GUBA	This refers to forests on top of the mountainous area. Usually this place is regarded as a place to worship God (*Waqayoo* in the local Oromo language) as their church (locally named as *Gelma*) is often bulid here.	This tradition conserves highland vegetation in general and MPs in particular

worship and therefore considered as sacred place where cutting of any plant is considered as sin. This study also found another traditional ecological knowledge which is very vital in the conservation of vegetation in general and medicinal plants in particular that are adjacent to water bodies and wet-lands. According to the culture of the study area, wet lands should not be expected to be "exposed" and need to be covered by vegetation as such places are areas to worship the spirit of the river or wet lands in general (locally called *Borenticha*). In line withthis, Martin (1995), Cotton (1996) and Cunningham (2001) have indicated the contributions of cultural and traditional beliefs in the conservation of plant species and ecosystems. Studies conducted elsewhere in Ethiopia have found related cultural beliefs and traditional practices, which contribute to the conservation of medicinal plants in particular, and biodiversity as a whole. For example, Tolosa (2007) listed out various local beliefs and cultural traditions used for the conservation of medicinal plants (MPs) in Gimbi District of Western Ethiopia. Tefera et al. (2015) similarly assessed the importance of local ecological knowledge associated with conservation of some plants on agricultural landscapes of Debark District in the Northern Ethiopia. Abbink (1995) explored medicinal plants that have ritual and conservation values for the Ethiopian southwest people. Mesfin (2007) also documented cultural and spiritual beliefs used for the conservation of MPs in Wonago District of the Southern Nations, Nationalities and Regional States of Ethiopia. Moreover, the Geda cultures of Oromo people of Ethiopia also have an important contribution in biodiversity conservation (Keller, 1995; Wemlinger, 2008; Mergo, 2014; Getahun, 2016), which creates a conducieve enviroment for wild medicinal plant conservation. Similarly, Wassie (2008) also noted the tradition of Ethiopian Orthodox Church (EOC) in the northern part of Ethiopia for the conservation of Biodiversity in general and hence medicinal plants, basically, due to the words in Genesis 2: 8-10 and 2:15 of the Holy Bible. Likewise, a number of rituals, ceremonies and customs related to sacred trees with medicinal value were documented elsewhere in the Middle East (Dafni, 2007) and north-eastern Brassil (Albuquerque et al., 2008).

Knowledge of informants about the medicinality of herbs

In ethnobotanical science an herb is a plant or plant part valued for its medicinal, aromatic or savoury qualities (Martin, 1995). Unlike many other studies that show significant variation of the knowledge of traditional medicinal plants among the genders of informants, ages of informants, educational status of informants, experiences of informants and marital status of informants (Teklehymanot, 2009; Lulekal et al., 2013, 2014), this study found that there was similar knowledge of traditional medicinal plants among these informant parameters. The similarity in the indigenous knowledge of herbals among traditional healers may be attributed to equal access of their family members to the existing indigenous knowledge regardless of age, gender, level of education and marital status. A similar observation was revealed by Yineger and Delenasaw (2007) in Sekoru District of southwest Ethiopia.

CONCLUSION AND RECOMMENDATION

This study documented 112 wild medicinal plants that can be grouped into 97 genera and 53 families. This study also found that there are traditional perspectives and cultural beliefs which would maintain the ecology of medicinal plant species. Thus, integrating the ethnoecological perspectives of the local/indigenous people would be helpful for better ecosystem management in general and wild medicinal plants in particular. Moreover, active formal and/or informal local institutions should be developed to sustain this traditional knowledge in the district.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Challenges for world natural heritage protection through coordinating a variety of values

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Designation of protected areas is an extremely effective means of "protecting" the natural environment and natural resources, and registration as a world natural heritage site is an extremely effective conservation policy for protecting its outstanding universal value. This paper introduces three cases such as Ha Long Bay, in Vietnam, Galapagos Islands and Shirakami-Sanchi in Japan which are the sites of world heritage. The paper presents the different values of stakeholders towards world natural heritage. In particular, the paper discusses how the universal values of world heritage and the values of stakeholders including local communities affect the protection of world heritage. Then, based on the recognition of the different values, future issues and perspectives regarding the coordination of interests among stakeholders are discussed. In today's world, where there are different values, sometimes conflicts among stakeholders happen with each other and it is of course needed to respect and mutually understand these different values. On the other hand, the international framework, the World Heritage Convention, is a global standard with outstanding universal value, although its characteristics are diverse. For registered sites, the global "external" endorsement should require local communities at the sites to comply with new global standards. At the same time, external global standards will force new changes on the ground in registered sites. It is important to think how to overcome conflicts between different values and to create new values through interaction between external and local values.

Key words: World heritage, universal outstanding value, Ha Long Bay, Galapagos Islands, Shirakami-Sanchi, different values.

INTRODUCTION

It is generally said that regulating or restricting use of natural resources and land use under certain legal frameworks is most effective way for the purpose of protection and conservation. In this line, designation of protected areas is an extremely effective means of "protecting" the natural environment and natural resources. For example, forests and people are tightly associated in the developing countries. The forest vegetation is highly threatened by human activities (Htun et al., 2011). Millions of people reside within or close to protected areas (PAs) and harvest forest products (Davidar et al., 2010) which changed the forest composition, structure (Bhuyan et al., 2003) and reduced the species diversity by restricting size of forest patches

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(Krishna et al., 2014) and alters the soil microbial activities (Bargali et al., 2018, 2019; Manral et al., 2020; Padalia et al., 2022) and nutrient cycling (Bargali and Singh, 1991). Continued increase in the human population together with livestock populations, the pressure on these forests in terms of intensive livestock grazing, fuel wood and timber harvesting for their energy and income generation are mounting and consequently resulting into the reduced carrying capacity of these forests (Sagar and Singh, 2004; Baboo et al., 2017). The PAs maintain and promote the population of native species, community composition, conserve the genetic diversity of all native species and permits the sustainable flow of natural goods and services to fulfill the requirements of the local peoples (Singh et al., 2014). Nevertheless, modules of PAs which have already been degraded may need rehabilitative measures to restore them to their natural state (Singh et al., 2014).

IUCN (2008) clearly defines protected area as geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values. Protected areas – national parks, wilderness areas, community conserved areas, nature reserves and so on – are a mainstay of biodiversity conservation, while also contributing to people's livelihoods, particularly at the local level. Their role in helping mitigate and adapt to climate change is also increasingly recognized (IUCN, 2008). Among protected areas, world natural heritage is one of powerful systems in terms of strict and legal protection of natural resource. The World Heritage Convention is one of the most successful international instruments to recognize the most exceptional natural places in the world, characterized by their outstanding biodiversity, ecosystems, geology or superb natural phenomena (UNESCO, 2021a). World natural heritage shall have natural features consisting of physical and biological formations or groups of such formations, which are of Outstanding Universal Value (Hereafter referred to as OUV) from the aesthetic or scientific point of view. Also the heritage are geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of OUV from the point of view of science or conservation. As stated, world natural heritage shall have OUV. The value means natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of the heritage is of the highest importance to the international community as a whole (UNESCO, 2021).

In the meantime, heritage shapes our present identity and provides insight for our future. Heritage includes a range of activities in the areas of stewardship, preservation, research, education and engagement. Within this context these activities must exhibit sensitivity to: 1) the indigenous natural environment, 2) the impact of the interaction between human activity and natural environments, and 3) differing perspectives regarding objects, ideas, places and traditions (Massey, 2012). Value-led conflicts between administrative management and local communities at world heritage site including world cultural heritage are reported (Jiancheng et al., 2019). It is not easy to draw the line of protected area (where to protect). This is because there are a wide variety of stakeholders involved in the use of natural resources and land. In particular, in areas where the use of land and resources in protected areas are strictly regulated, such as world natural heritage sites, conflicts often arise over the use of resources and the administration of protection, which makes it a challenge to harmonize and balance the environment and development including tourism, agriculture, fishery, to name a few, and to build consensus among various stakeholders. Lack of local community involvement in the management of world heritage sites was identified, and it was pointed out that local communities' participation could indeed contribute to sustainability of world heritage sites (Lekaota, 2018).

Today, conservation is understood to encompass any action designated to maintain the cultural significance of a heritage object or place, and is a process that starts at the moment a place is attributed cultural values and singled out protection. A variety of values of the heritage are attributed, not intrinsic; mutable, not static; multiple and often incommensurable or in conflict – can challenge established conservation principles. The nature of cultural values has serious implications for the impact of conservation on the values of a place, the universality of conservation principles, and the protection of the heritage for future generations (Marta, 2013).

Heritage as an identifiable discourse garnered more public attention in the 1960s and 1970s, as subaltern identity politics become a specific public issue. Increasingly assertive indigenous claims about their ability to control and assert their own identity coincided with the identification of material culture as 'heritage', and its regulation and management by a body of expertise and technical and legal processes. This confluence of events and processes had a significant political impact for indigenous political and cultural claims and aspirations. Meanwhile, globalization has seen an increase in the assertion of local and community identity claims that are expressed and disseminated through a broadening range of media. Heritage did become a useful discourse through which to make sense of, regulate and ultimately control the increasing public emergence of local and competing claims to a range of cultural, social, historical and other identities and experiences (Smith, 2006). At the same time, the designation of world heritage site brings about economic, socio-cultural, physical and attitudinal changes. Both positive and negative changes

for local communities in/around the heritage site after world heritage site listing are identified. There are three main factors behind these changes: the extensive and rapid tourism development after the inscription; the high level of appeal of a heritage status for domestic tourists; and local people's attitudes towards conservation of the cultural environment and the heritage status (Takamitsu, 2011).

Heritage is valued in myriad and sometimes conflicting ways. These different means of valuing influence negotiations among various stakeholders and thus shape conservation decision making. Given the increasing needs and calls to protect and preserve heritage, conservation professionals are challenged to revise, rethink, and strengthen previous methods as well as the philosophical underpinnings. Research on questions of values (their importance, their multiplicity, conflicts between them), pursued across disciplinary and professional lines, is essential for this task (Erica, 2000).

This paper presents three case studies on the different values of stakeholders towards world natural heritage. In particular, the paper discusses how the universal values of world heritage and the values of stakeholders affect the protection of world heritage. Then, based on the recognition of the different values, future issues and perspectives regarding the coordination of interests among stakeholders are discussed.

Case Study 1: Ha Long Bay, Vietnam

Brief synthesis and OUV

Ha Long Bay, located in the Gulf of Tonkin, within Quang Ninh Province, in the northeast of Vietnam, is 165 km from the capital of Ha Noi. Covering an area of 43,400 ha and including over 1600 islands and islets, most of which are uninhabited and unaffected by humans, it forms a spectacular seascape of limestone pillars and is an ideal model of a mature Karst landscape developed during a warm and wet tropical climate. The property's exceptional scenic beauty is complemented by its great biological interest. Ha long Bay was registered as a world natural heritage site by UNESCO in 1994.

The outstanding value of the property is centered around the drowned limestone karst landforms, displaying spectacular pillars with a variety of coastal erosional features such as arches and caves which form a majestic natural scenery. The repeated regression and transgression of the sea on the limestone karst over geological time has produced a mature landscape of clusters of conical peaks and isolated towers which were modified by sea invasion, adding an extra element to the process of lateral undercutting of the limestone towers and islands (UNESCO, 2021b)

The area is the most famous tourism spot in Vietnam, where a number of tourists from both home and abroad. Increasing visitor numbers and associated impacts continue to impact on the management of the property. Development pressures associated with growing tourist numbers continue to be an issue for government authorities and an appropriate balance between conservation and development, while difficult to maintain, is important to ensure the protection of the natural values of the property.

Ha long area is one of the foremost coal mining area in Vietnam and plays a key role of regional traffic system which has been functioned as a main industrial development zone in northern Vietnam. Urbanization is progressed with rapid industrialization by development of coal mining area, cement and brick factories, and power plant around the Ha long Bay. Under the situation, the following has become pollution sources and environmental issues to be solved in Ha long Bay: wastewater and solid waste from mining areas and factories, domestic wastewater by urbanization, increase of tourist facilities, deforestation of the mangrove, sediment deposition at ocean area, deregulated landfill, and wastewater and oil flow from ships and boats.

Survey on willingness to pay for environment

Japan International Cooperation Agency (JICA) implemented the study on environmental management for Ha Long Bay in 1999 and as a part of the study, questionnaire survey on willingness to pay for environmental value was carried out by JICA and Quang Ninh Province (JICA, 1999). The survey was designed to collect opinions for assessing willingness of local residents, national and international tourists to pay for the environment protection of Ha Long Bay. The survey for collection of opinions of tourists and local residents could be used as basic data of assessment of the benefits coming from activity for protection of environmental quality of Ha Long Bay.

RESULTS OF THE SURVEY

Tables 1 and 2 are the result of the survey on willingness to pay. Targets included local residents, national and international tourists. The sample size is 215 (0.1% of the total population in the study area), 145 (0.1% of all travelers: as of 1997), and 145 (0.1% of all travelers: as of 1997), respectively. The interviewer introduced to interviewees general environment aspects of Ha Long bay and clearly describes 3 images of pollution level in Ha Long bay that could happen in future including very polluted (Image A), no changed (Image B) and better water quality than now (Image C). The results were compiled in the form of interviews about how much people are willing to pay as a percentage of their annual income.

Table 1. Willingness to pay for environment of ha long bay.

	Image A (%)	Image B (%)	Image C (%)
(Foreign tourists)			
No contribution	35	26	21
≤0.1%	19	20	15
0.1 -0.5%	22	30	26
0.5 - 1.0%	10	8	13
≥1%	14	17	24
(National tourists)			
No contribution	**52**	25	16
≤0.1%	23	26	28
0.1 -0.5%	17	30	28
0.5 - 1.0%	6	9	12
≥1%	**1**	10	17
(Local residents)			
No contribution	18	16	11
≤0.1%	20	21	20
0.1 -0.5%	41	41	45
0.5 – 1.0%	20	20	20
≥1%	1	2	6

Table 2. Average willingness to pay (WTP) of tourists and local residents for the environmental management plan.

Items	Units	Foreign tourists	Vietnamese tourists	Local residents
(1) Average WTP for non-use value	US$/Household/year	6.2	1.2	0.3
Item(1)/Item(4)=	US $/person/year	1.8	0.3	0.1
(2) Average WTP for use value	US$/Household/year	12.5	1	1.1
Item(2)/Item(4)=	US $/person/year	3.6	0.2	0.3
(3) Average WTP in total Item(1)×Item(5) + Item(2)×Item(6)				
Item(3)/Item(4)=	US$/Household/year	10.9	1.4	0.4
	US $/person/year	3.1	0.3	0.1
(4) Average Household members	person/household	3.5	4.6	4.2
(5) Ratio expressing WTP for non-use value	%	14	21	53
(6) Ratio expressing WTP for use value	%	61	53	30
(7) Total ratio expressing WTP either for non-use or use value =Item(5) + Item(6)	%	75	74	83

Table 1 shows that there are no significant differences for three images in the willingness of local residents to pay for the conservation of Halong Bay's environmental conditions, while there are significant differences in the willingness of tourists, especially Vietnamese tourists, to travel to Halong Bay. Many (52%) are not willing to pay at all if the environment gets worse, while the percentage of those willing to pay more than 1% of their income if the environment gets better has increased sharply (from 1 to 17%). This trend also applies to foreign tourists, although the rate of increase in numbers differs.

Table 2 was compiled to assess the economic and financial relevance of the environmental management plan. The figure shows that most of the tourists (foreign and domestic in Vietnam) are interested in the use value of the environment of Halong Bay, while about half (53%) of the local residents are interested in the non-use value. In the interviews with local residents of this survey, there were many opinions about the landscape of Ha long Bay, such as that tourism is threatening the landscape of Ha long Bay and that the landscape of Ha long Bay should be properly protected. In addition, opinions touching on

the history of Ha long Bay were also confirmed. In general, the Vietnamese have an ancient religious connotation to the caste landscape regarding the origins of Vietnam. Ha long means "descending dragon," and it is also the site where legend has it that when Vietnam was once invaded by an enemy nation, a dragon soaring through the heavens descended and turned into a rock. This is where the mystique of Ha long Bay lies. The difference in values between tourists who use Ha long Bay as a tourist resource and locals who find meaning in non-use values such as Vietnamese legends and origins can be seen.

Case Study 2: Galapagos Islands

Brief synthesis and OUV

The Galapagos Islands, a natural laboratory of evolution, is known as the place that gave rise to Darwin's origin of the species evolution theory. It was among the first sites inscribed on the UNESCO World Heritage List in 1978.

Despite the Islands' outstanding and precious biological features, there are grave concerns over the future of their unique ecosystem. Invasive or introduced species control, tourism and artisanal fisheries regulations must be enforced as soon as possible. The relationships among stakeholders such as Government, the National Park Service, the Darwin Research Station, and the local community must be improved in order to preserve the integrity of the Islands' seriously threatened biological and cultural diversity.

A few particularly serious problems include invasive species and introduced agriculture. In order to combat these problems, the Special Law for the Galapagos was enacted in March 1998. Through enactment of this law, important progress has been made in fisheries, tourism and quarantine regulations. It is also said that since mid-2001 there has been little progress. For example, industrial and medical waste was discarded without any treatment. It was burned in a field (albeit outside protected area and far from local residents) (JICA, 2001). This report also indicated that toxic waste like dioxin was a byproduct of this burning and occurred easily. This could have a considerable negative impact on the Islands' ecosystem.

Local communities' awareness of natural heritage

The relationships between management authorities and local communities underpin the success of natural heritage conservation. The three tables below are collected from Galapagos authority, which aimed to analyze the situation outside the protected area with special focus on the local communities. These results served to formulate a JICA technical cooperation project.

Table 3 shows that immigrant control is regarded as the most important issue for environmental conservation. A report published by the Ecuadorian Government revealed that the annual population growth rate on the Islands was around 6.4%. The rough number of immigrants from other countries or areas such as the main land accounted for 65% of the entire population on the Islands. Strong attention was paid to the fact that rapid population growth was not derived from births on the Islands, but from the immigrants.

A great number of immigrants are people who sought jobs on the Islands, particularly in the fishery. Local long-term community members think of immigrants as the main source of illegal human activities and the carrier of invasive species. They also feel that the immigrants put a heavy burden on environmental capacity and have a huge overall negative impact on the Islands.

Interestingly, but not surprisingly, Table 4 indicates local people have no intention of leaving the Island in order to protect the rare ecosystem, despite the recognition that immigration is the main threat to the Islands' future environmental well-being. Table 4 also reveals that as a whole, environmental awareness of the local community is very high.

From Table 5, it can be interpreted that government regulations and laws did not seem to give enough consideration to local people. Local management authorities appear to believe that local communities are important for protection of the Islands, but local communities were not satisfied with the fact that around 97% of the entire Island was designated as a protected area, thus restricting their access to natural resource use.

Physical distance among protected area, heritage site and local community

As mentioned above, around 97% of the terrestrial area in the Galapagos Islands was designated as a protected area. This means that local people are allowed to use natural resources on only 3% of the Islands. This strict situation of protection of the Islands' precious ecosystem and regulation of human access enhances the value of Galapagos from the positive and tangible point of view. From the local people's point of view, however, it is often recognized that designation of the Islands as a natural heritage site and enactment of the special law forces local residents to restrict their access to natural resources. As a result of the regulation, especially regarding artisanal fishing, strict protection has become a fundamental cause of social conflict. In other words, the balance between severe or rigorous ecosystem protection and sustainable natural resources use is not enforced. It will be necessary, however, to enforce laws while at the same time maintain a sensitive balance between protection and sustainable use. This is crucial to preserving the Islands' global assets for future

Table 3. Which do you think is the most important issue for conservation among the following five items?

Item	Proportion by choice (%)
Control of immigrant numbers from main island/other countries	33.2
Control of invasive species	24.2
Regulation of natural resource use	18.9
Protection of the flora	14.0
Protection of the fauna	9.2
All five items above	0.4
Total	99.9

Table 4. Indicator of approval against the environment legal control.

Do you agree with the following control or regulations?	1997	1998	1999
Ban on shark capture	70.6	77.6	70.5
Closed season establishment for fishery	70.1	76.7	79.6
Ban on sand extraction from coastal area	79.1	90.4	90.4
Ban on cutting-down of native trees	64.9	77.6	78.5
Inspection implementation	69.9	77.3	74.2
Immigration control against new families	27.4	32.7	37.5
Control of tourist numbers	48.9	42.4	32.6
Ban on sea cucumber capture	60.4	62.8	37.3

Note: the number indicates the percentage that local people agree to the given questions.

generations of inhabitants and visitors.

Necessity of comprehensive framework with the consideration of intangible value

The biological value (tangible value) of the Galapagos is definitely the basis of the protection/conservation from the global and biological point of view. However, among most visitors and some residents of the islands there is an unquestionable sense of awe and holiness (intangible value) in the Islands' biology. It is also considered to be a biologically sacred place. It has been featured in books and films for decades, which reveals the reverence that scientists have held for the Islands ever since Darwin's discoveries years ago. The Galapagos is one of the world's best known heritage sites, and at the same time it is also an undeniable fact that local people consider the Galapagos as their own asset (as shown in Tables 3 to 5).

The Galapagos is an omnibus of international communities. These communities have begun in earnest to design and construct for the Islands a new framework in a comprehensive manner. This framework places great and equal emphasis on both tangible and intangible values. As mentioned, tangible values such as locally-rooted culture and life style are very important factors in protection/conservation of the Islands' natural environment. It is admirable that the international community and the Galapagos authorities in charge of managing the environment have concentrated and focused their activities on biological and cultural aspects of conservation.

In the case of the Galapagos, as in all protected areas, it is necessary to value local society, local culture and identity as fundamental factors for conservation. Also, it is important to recognize that it takes time, indeed generations, for cultural values to develop among newly established residents. In the Galapagos where there are many immigrants, it is very difficult to identify local society and cultural identity among the newcomers. It could take years to develop a deep cultural identity and society among new settlers. A lack of attachment to the Islands' cultural and biological history, however, could lead to a corruption of society and culture. This in turn could lead to the collapse of the environment or ecosystem in the long run. In this context, it is necessary to put more emphasis on intangible values of Galapagos Islands.

Despite the efforts by Galapagos authorities and international communities to involve local community from the beginning stage in designing and implementing the law and regulations, the local community is at a loss of what to do about the wave of migration and outside

Table 5. The level of local communities' awareness of the Galapagos' special law.

Do you agree with the following opinions?	MD	ED	NAD	DA	MA	NS/NR
Special law is effective for environmental conservation.	1.5	4.3	10.1	**68.5**	14.1	1.5
Special law affects negative indirect impacts to local people.	3.4	**45.3**	21.2	24.0	4.9	1.3
Government attaches importance to fauna rather than local people	2.9	16.6	24.2	**40.8**	14.2	1.2
There is not enough space for local people to live and use natural resources, with huge spatial space for conservation.	1.8	23.1	14.2	**48.1**	12.5	0.3
	Agree ⟺ Disagree					Don't know or no response

The above classification indicates as follows: MD; Not agree at all; ED; Not agree; NAD; Neither agree nor disagree; DA; Agree; MA; Agree absolutely; NS/NR; Don't know or no response.

pressures. International communities are just facing the need to address this unsettled condition by increasing preservation of tangible values. Thus, it is needed to work with newcomers, as well as the long term residents, to instill a sense of guardianship of the Islands. This is the only effective way to be taken by international conservation bodies to leave the Galapagos Islands to future generations.

Case Study 3: Shirakami-Sanchi, Japan

Brief synthesis and OUV

Shirakami-Sanchi contains a large pristine, non-fragmented beech forest. Planted forests of timber trees, such as Japanese cedar, have replaced many of the beech forests in northern Japan while within the boundaries of the property the unmodified beech forests are densely and continuously distributed. The area is largely a wilderness with no access trails or man-made facilities. The property includes all elements necessary to maintain the ecosystem function of beech forests and the area of the property, 16,971 ha in total, is of an adequate size to ensure the long-term existence of the beech forest ecosystem. Further to the strict legal protections, almost no logging of beech trees has been carried out in the property due to lack of access to the central part and precipitous topography of the property. Also, tourism activities are limited mainly to the areas near the boundary or the surrounding areas of the property. Consequently, the property preserves this extensive area of pristine forest with little human intervention.

The local offices of the relevant ministries and prefectural governments involved in management of the property established the Shirakami-Sanchi World Heritage Area Liaison Committee in 1995 to promote conservation management of the property in collaboration and cooperation with the local community. The Committee coordinates the management of the property including information sharing, awareness raising, instructions to visitors, and maintenance of facilities. (UNESCO, 2021c).

Differences between World Natural Heritage values and community values

Tonosaki (2014) analyzed differences and disagreement between world Natural heritage values and community values of Shirakami-Sanchi. Sites with outstanding and universal values based on the criteria for inscription are placed on the world heritage list as natural heritage. But she pointed out that there may be a discrepancy between the natural values recognized at the time of inscription on the World Heritage List and the values recognized by local communities.

The value of Shirakami-Sanchi is not limited to the beech trees, ecosystems, and wilderness registered as a world heritage site, but also includes a wide range of other natural, cultural, and historical values. However, with the registration of the Shirakami-Sanchi as a world heritage site, perspectives have focused on the value of the site, and only the value recognized as a world heritage site has come to be the focus of attention (Figure 1). Before it was registered as a world heritage site, Shirakami-Sanchi was valued not only for its beech trees, but also for the nature and culture that centered on them. After it was registered as a world heritage site in 1993, however, the values changed to strictly protect the wilderness and not allow human intrusion. The World Heritage management plan covers 16,971 ha in the world heritage area, and focused on the primary beech forest which was evaluated for world heritage status, and the ecosystem which was a criterion for world heritage listing. This led to a lack of recognition of historical and cultural values, as well as values from a holistic view, and the value of Shirakami-Sanchi was narrowed to that of pristine nature, which deviated from the community's concept of Shirakami-Sanchi as a place in harmony with nature, and this is where the value discrepancy occurred. In this way, the community's perception of the value of Shirakami-Sanchi is missing, and by focusing on the value of being registered as a world heritage site, the community and Shirakami-Sanchi have become more and more psychologically distant. This also poses the danger of making it difficult for communities to become proactively involved in the protection of world heritage sites.

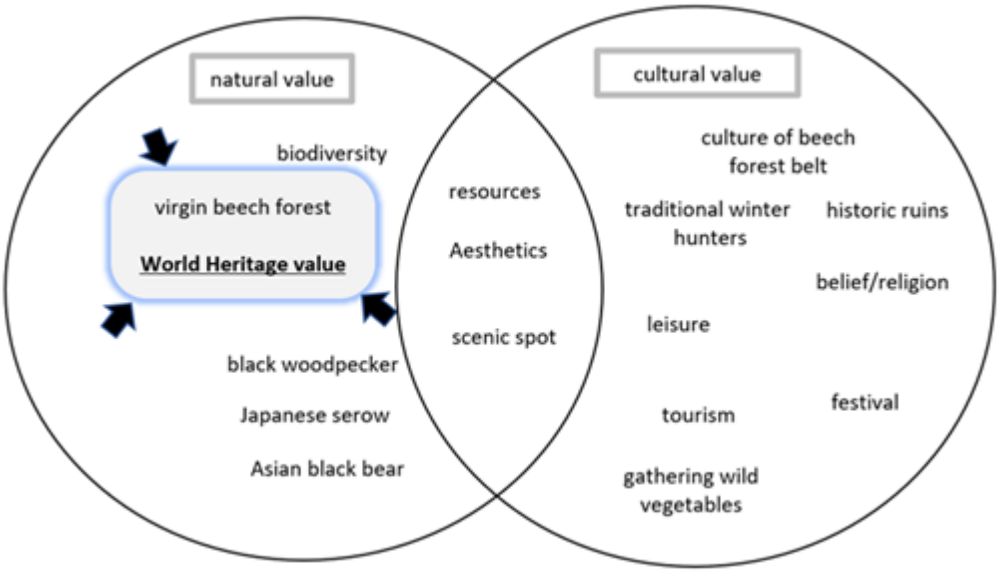

Figure 1. Shirakami Sanchi's intrinsic value and world heritage value.
Based on Tosaki (2014), partially modified and provisionally translated by the author.

DISCUSSION

As outlined in the case studies, there is a difference in values related to heritage between the outside and inside of a world heritage area. This is the difference between values that have been handed down from generation to generation and have a deep relationship with the traditions and history that existed in the area before it was inscribed on the world heritage list, and new world-class values that have come from outside. Here, discussions on the future prospects for protecting world heritage sites for future generations are made, while maintaining and evolving the sense of values that have been handed down from generation to generation in the heritage sites since ancient times, recognizing these differences in values.

How should world heritage confront external values that differ from OUV?

As can be seen from the case of Ha long Bay, Vietnam, domestic tourists have a different sense of value from foreign tourists than do OUVs of World Heritage sites. It is an external value system that is different from OUV, and such external value system is fluid and not fixed. In other words, it is a sense of value as a temporary tourism resource. If the world's last remaining regions are in tune with these values, it is possible to achieve economic benefits, but on the other hand, there is a concern that promoting tourism in pursuit of economic benefits will also lead to environmental problems such as garbage problems. If this happens, the value of world heritage sites to outside tourists will decline and they will lose their value as tourism resources. Such a structure is unsustainable and one-sided, and it is necessary to develop policies and specific mechanisms to ensure that economic benefits and world heritage protection are compatible so that the priority is not placed on economic benefits only.

How different local values in/around world heritage site can be reconciled?

In order to protect the Galapagos Islands which is a global sacred site, government authorities and the international community will continue to make thorough conservation measures, including strict restrictions on outsiders as a top priority policy. Local communities, who are often left behind by the international boom, are likely to be dissatisfied with the services provided by park authority and government agencies, but will support measures to limit the number of immigrants out of a sense of urgency to protect their own lives. Even if local communities do not necessarily value the Galapagos Islands as an "international and global sanctuary," in order to protect themselves in the international boom, they may need to be more in tune with the global values of the Galapagos Islands as considered by government authorities, researchers, and international aid organizations. Although they have different values, if the government, international community and the local communities want the same results at the end, the sustainable protection of the Galapagos Islands using this reality may be able to proceed successfully.

How conflicts between different values can be overcome?

The case of Shirakami-Sanchi argues for the necessity of integrating the OUV of the world heritage site with the sense of values unique to the local area. As already mentioned, the external factor of world heritage registration has a great impact on local values. As long as there is interaction and contact with the outside world, there may be no values that will remain unchanged forever. We must carefully continue the traditions and values that have been handed down from generation to generation by the community living in the site, and develop them while cultivating the future. In order to build consensus among stakeholders, mutual understanding among people with different opinions, positions, and values is necessary. When different values collide, it should be possible to unravel them based on field practice and attempt to reconstruct values by setting a new axis for how values should be, such as resource values, spiritual values, and academic values. New values are created in the intersection of global and local values, and the developmental succession of these values contributes to the protection of OUV of the world heritage.

How to create new values through interaction between external and local values?

As earlier discussed, here more discussion on the creation of new value is made. If local communities living in the world heritage site believe that the local environment and natural resources are their own and important to be protected for future generations, then efforts are needed to nurture their values and perspectives. External support may be acceptable, but considering the sustainability of the initiative, support that encourages community-based development is desirable. On the other hand, the international community has a great cause to protect the OUV of world heritage sites, and a framework of new incentives and external support might be needed for this purpose. Relationships with urban areas are also important for world heritage protection. As in tourism, the values of those who "use" world heritage sites are not constant or universal. Urban "outsiders" take a temporary interest in the external environment and natural resources, but when they no longer find value in them due to environmental destruction or pollution, for example, their interest fades and they turn to others. In the meantime, exchanges with urban areas not only bring economic benefits, but also help local community to rediscover their own culture and traditions or discover something new. Interaction with the outside world will contribute to "raising the level of awareness" of world heritage, including information disclosure, and as a result, not only the OUV but also the unique traditional values of the region will become visible. As a result, new values can be added to traditional values. Interaction with the outside world contributes to the evolution of the region's unique values, flexibly adapting them to the times. This has important implications for the protection of the OUV of world heritage.

Does world heritage protection contribute to community empowerment?

As a practical matter, it is difficult to protect world heritage without the understanding and cooperation of local community. The protection of world heritage sites rooted in the local community is closely related to various values rooted in local cultural context. Among them, the maintenance and inheritance of intangible values or non-material values is extremely important for the protection of world heritage. The intangible values or non-material values include spiritual values, rituals, belief, and oral traditions. It is also widely recognized that natural heritage sites have cultural, historical and religious significance for local communities and can create a sense of awe. Moreover, the existence of heritage is also recognized as a basis of cultural diversity and is crucial to social cohesion. Local communities living around or in natural heritage sites are usually aware of biological and cultural values. Cultural ties that link people to the natural world remain strong in many communities living close to biodiversity. Cultural institutions enforce norms of practice through compliance mechanisms that depend on continued belief in, or attachment to, traditions and values (Ostrom, 1990) and can be more effective than externally imposed sanctions (Colding and Folkes, 2001).

Though local communities recognize the importance of tourism as a mean of income generation for local economy development, globalization and other human pressures could be a risk of threatening natural heritage sites that have been protected by international framework for several decades and often by communities for centuries. More seriously, such globalization and economic development are not only because of the fear of destruction of the world natural heritage, but also because it is forcing a change in the local people's sense of value towards the world heritage. This teaches us the importance of recognizing that such a change in values will be a major threat to the future protection of world natural heritage.

Value-arguments based on science and economic rationalism increasingly overshadow the aesthetic and ethical arguments that originally inspired the conservation movement (Paul and Susan, 2003). There should be no discomfort in finding a certain justification for the local communities, who are the guardians of the region's history and culture to own them and continue to protect them. It is also an idea that relies on common sense

regardless of logic, and is considered to be innate in all people's reasoning, and therefore has a persistent and strong resilience (even to criticism). In case where there are significant international, political and economic influences, the logic of this external common sense can redefine local common sense, and in the process of mutual influence with the community, the concept of common sense of the local community who are often socially vulnerable can be weakened.

Mark et al. (2018) pointed out a values-based approach is essential to promoting world heritage protection for indigenous peoples and local communities that have long maintained traditional values. Cultural norms are the important determinant of the relationship between people and nature, and through the medium of cultural institutions and traditions, it may be possible to promote nature conservation more effectively than external uniform standards, such as the World Heritage Convention, and in some cases, some regulations and restrictions.

The conservation of the local natural environment through the cultural aspects of the local residents and their relationship with nature might make the conservation activities inherent to the residents, create legitimacy and motivation for the conservation, and also ensure that the conservation of the natural environment is carried out in a sustainable manner. This is different from the story that conservation of the natural environment is a priority for local residents. The objectives of the World Heritage Convention and local community may differ. However, inscription on the world heritage list could also contribute to the international community's recognition of the cultural values of the region and the traditional rights of the local people. As a result, it is expected that the international community's support for respecting andmaintaining the identities of local communities could strengthen the cohesion among them and enhance their ability and resilience to flexibly adapt to internal and external social, economic, and environmental changes.

Future perspective

Tonosaki pointed out future perspective for protection of Shirakami Sanshi. In the case of Shirakami Sanchi, the question is who will take the lead in protecting the world heritage site. One of the world's largest distributions of pristine natural beech forests, virtually untouched by human influence, is one of the characteristics of the Shirakami Sanchi, and is a universal value as a world natural heritage site. On the other hand, the reality is that people are using the natural resources in the surrounding area, and the protection of the world heritage site as a whole requires a balance with human activities. The values that communities originally envisioned for Shirakami-Sanchi, such as local beliefs, festivals, and harvesting of wild plants, need to be reaffirmed as important values of Shirakami-Sanchi. In order to utilize this cultural perspective in the protection of world heritage sites, a mechanism for communities to proactively participate in the protection of world heritage sites is needed. It is a system that integrates the universal values of world heritage with the values that communities have had. According to Tonosaki, one way to achieve this is to establish areas where sustainable human activities are allowed. It is necessary to pursue measures to maintain the diverse values of Shirakami-Sanchi as a natural heritage and pass them on to future generations.

In the meantime, Ping (2008) identified that the social quality of living heritage sites is sensitive to various changes in land use: spatial morphology and spatial operation, and indicated the necessity of bottom-up, community-based approach to retain high social quality of the living heritage sites in the long run. Globalization is having a major impact on world natural heritage sites, and local communities are under pressure to make significant changes. There is a growing need for efforts to maintain and develop the quality of life of local communities without compromising it. This is also in line with the current Sustainable Development Goals (SDGs). The International Council on Monuments and Sites (ICOMOS, 2021) has developed guidelines as World Heritage is the foundation for efforts to achieve the SDGs and further efforts are needed. Considering that heritage-based approaches can contribute to sustainable development in more ways than conventionally assumed, the guideline engorges a call to mobilize:

1) the knowledge and resources transmitted through heritage to achieve the well-being of People (SDGs 1, 2, 3, 4, 5, 6,11);
2) a ‘Culture-Nature’ approach and landscape-based solutions to achieve the well-being of the Planet (SDGs 6, 7, 11,13, 14, 15);
3) the shared resources embodied in heritage to achieve Prosperity of communities
(SDGs 5, 8, 9, 11, 12, 14);
4) the connecting power of heritage for social cohesion and dialogue to achieve
Peace within and among societies (SDGs10, 11, 16); and
5) the shared medium of heritage and its connections with all aspects of human life to create Partnerships (SDGs 11, 17).

Each goal of the SDGs is interrelated. It is very important to take a cross-sectional perspective as described above. It will be even more important to accumulate empirical findings that the conservation and protection of world heritage sites contribute to the achievement of the SDGs.

Conclusion

In today's world, where there are different values, there

are many times when these values become apparent and sometimes conflicts among stakeholders happen with each other. There are naturally a wide variety of values on the planet, and we need to respect and mutually understand these different values. On the other hand, the international framework, the World Heritage Convention, is a global standard with OUV, although its characteristics are diverse. For registered sites, the global "external" endorsement should require them to comply with new global standards. At the same time, external global standards will force new changes on the ground in registered sites. Environmental problems are anthropogenic and a product of values. The values that have traditionally persisted in a region will change and evolve while adapting to values that come from outside, not necessarily pandering to values from outside. It is something that does not happen over a long period of time.

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CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Patterns of mammalian roadkill in the Serengeti ecosystem, northern Tanzania

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Roads that traverse through protected areas if not well managed can have adverse impact on wildlife such as road-kills which is of global conservation concern. Though mammalian road-kills have been reported in different protected areas worldwide, very little information on the problem is available in the Serengeti ecosystem. This study employed both cross sectional observation and opportunistic encounter methods to determine the patterns of mammalian road-kills along the existing gravel road networks in the area. The results indicated that 29 mammals with encounter rates of 0.016 animals/kilometer including herbivores (75.9%), carnivores (13.8%) and omnivores (10.3%) were found killed more frequently on good roads, probably because of over speeding behavior by drivers. Mammals with small body sizes (<10.0 kg, 44.8%) predominantly Cape hares (*Lepus capensis,* 31.0%) and Thomson gazelle (*Eudorcas thomsonii*, 27.6%) were most frequently killed probably because they are less avoided by motorists than larger mammals; and also, smaller mammals move slowly in crossing the roads than larger mammals, which increases the chances of being hit by vehicles. Cape hares and Thomson gazelles are more abundant species in the Serengeti and their behavior of foraging on road verges and frequently crossing roads to access resources in the area is additional risk. The study findings recommend for high penalties to over speeding drivers and placing wildlife warning signs on the roadside, and education to drivers to change behaviour and reduce road-kills.

Key words: Small body-size, impact, mammals, protected areas, roads, tourism.

INTRODUCTION

Road traversing protected areas facilitate transportation of goods and services to promote tourism and other benefits to conservation (Machado et al., 2015), but if not well managed can create some negative impacts such as wildlife roadkills, which is a leading source of vertebrate mortality worldwide (Arévalo et al., 2017; Meza-Joya et al., 2019; Lala et al., 2021; Lyamuya et al., 2021) that need to be considered beside the benefits that tourism can bring (revenues, jobs, economic support for conservation, poverty reductions, etc) in different protected areas. However, few reports have focused on wildlife-vehicle collisions, which often have resulted in mortality of different wildlife species in many protected areas worldwide (Drews, 1995; D'Amico et al., 2015; Braz

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and Franc, 2016). Also, it had been previously found that roadkill is a serious threat to animal populations, and has the potential to drive threatened populations to extinction (Cook and Blumstein, 2013). Wildlife-vehicle collisions are reported to be the primary cause of death for Cape hare (*Lepus capensis*) among mammals and helmeted guinea fowl (*Numida meleagris*) among avifauna (Lyamuya et al., 2021). The dominance of mammals as a major roadkill taxon has also been recorded in several other studies and their difference across studies may be related to local patterns in vertebrate diversity (Lala et al., 2021). In a different study elsewhere it was found that small to medium-sized mammals, which was mostly represented by dik-dik, suffered the greatest roadkill mortality because most of the small to medium-sized mammals are nocturnal species that are easily blinded by strong vehicle headlight and this could have caused high collision incidences (Lala et al., 2021). Therefore, wildlife roadkill is one of the most obvious impacts of roads on wildlife (Barthelmess, 2014).

In order to determine mortality on wildlife population caused by roadkill, counts have been used across seasons and years in protected areas (Behera and Borah, 2010; Braz and Franc, 2016). Several studies on roadkill in Tanzania have reported on the occurrence of dead animals on the roads (Kioko et al., 2015a,b; Lyamuya et al., 2016, 2021; Njovu et al., 2019; Nkwabi et al., 2018), however, none has indicated the influence of body sizes and diet preference of mammalian species.

Therefore, this study aimed at bridging this gap by documenting the patterns of mammalian roadkill of different body sizes among different mammal species in the Serengeti ecosystem. Body size and diet preference have been reported as important variables to explore patterns in interspecies variation in roadkill frequency and how it affects the probability of roadkill (Ford and Fahrig, 2007). The present study therefore hypothesized that mammalian herbivores would have higher roadkill frequency due to their larger home range and higher population density compared to carnivores (Barthelmess and Brooks, 2010; Green-Barber and Old, 2019). Secondly, small sized mammals (<10.0 kg) would be killed more often than larger mammals because the latter are actively avoided by motorists than smaller mammals; and larger animals move more quickly than smaller animals, so they spend less time crossing a road, which reduces the chance of being hit by vehicles (Ford and Fahrig, 2007). Thirdly, mammalian roadkill would be occurring more frequently on good roads probably because of over speeding behavior by drivers as they are attracted to drive fast on such roads.

MATERIALS AND METHODS

Study area

This study was conducted in the Serengeti ecosystem, which has several protected areas under different management categories including Serengeti National Park (SNP), Ngorongoro Conservation Area (NCA), Maswa Game Reserve (MGR), Loliondo Game Controlled Area (LGCA) and Ikorongo-Grumeti Game Reserves (IGGRs) in Tanzania, and Maasai-Mara National Reserve in South-western Kenya (Nkwabi et al., 2018), and lies between 1°15' to 3°30' S and 34°34' to 36°E (Nkwabi et al., 2018). However, the study focused on the main roads passing through NCA and SNP, which are parts of the Serengeti ecosystem, and was conducted between March and August 2015 (Figure 1).

The ecosystem harbors about 70 mammal species and more than 600 avifauna species and supports one of the largest herds of migrating ungulates and highest concentrations of large predators in the world (Lyamuya et al., 2021). High diversity of animal species is a function of diverse habitats ranging from riverine forests, swamps, kopjes, open grasslands and woodlands. For example, in the south-eastern part of the area is open grassland, the northern part is largely wooded, and the western region is a mix of open and wooded grassland with riverine forest. The open grassland zone receives rainfall typically below 600 mm per year (Lyamuya et al., 2021). In addition, the area receives bimodal rainfall, short rain (November-December) and torrential rain (March-May) seasons. However, in some years inter-annual variations are inevitable especially due to climate variability. The woodland area is occasionally interspersed with patches of tall open grasslands and receives an annual maximum rainfall of 1100 mm (Lyamuya et al., 2021). In general, the Serengeti woodlands are mainly composed of *Vachellia, Balanites* and *Commiphora* species with broad leaved species such as *Terminalia*, *Euclea* and *Croton* as sub-dominates (Bukombe et al., 2018; Lyamuya et al., 2021). The woodlands are dominated by the intermediate grasslands and the topography is highly variable, with catena effects having important influences on woody species (Lyamuya et al., 2021).

Survey plan

During the study, a 200 km stretch of gravel road network passing through the Serengeti ecosystem was surveyed for five consecutive days for each study period in 2015 during wet (March-April, 2015) and dry (July-August, 2015) seasons to document the magnitude, patterns and composition of wildlife roadkill. Two sampling periods were conducted daily: the morning period (07:30-11:30 h) as the forward direction and the afternoon (14:00-18:00 h) as the backward direction along the same transect. The survey was performed along five transects each encompassed 40 km in length and included five main gravel roads transect: Naabi-Olduvai, Seronera-Naabi, Seronera-Fortikoma, Seronera-Ndabaka, and Seronera-Lobo (Figure 1). Each of the 40 km surveyed transect was divided into 1 km length segments for sampling and in total there were 40 sampling segments. Each transect/road was randomly selected and driven twice a day (morning and afternoon hours) and therefore making a total of 80 km drive per transect per day. Due to limited resources, each transect was driven four times (two times during the dry season and two times during the wet season), resulting in a total distance of 1600 km after pooling together all surveyed road transects into one data set.

Data collection

In this survey, it was assumed that each kilometer of road segment surveyed was independent from each other; e.g., a 40 km road surveyed twice has equal sampling effort to an 80 km road surveyed once. At the beginning of a transect sampling period, the vehicle odometer was set to zero. Then a researcher started to record on the roadkill data sheet the transect name, GPS location, time, transect length, road width, date, season, and the names of

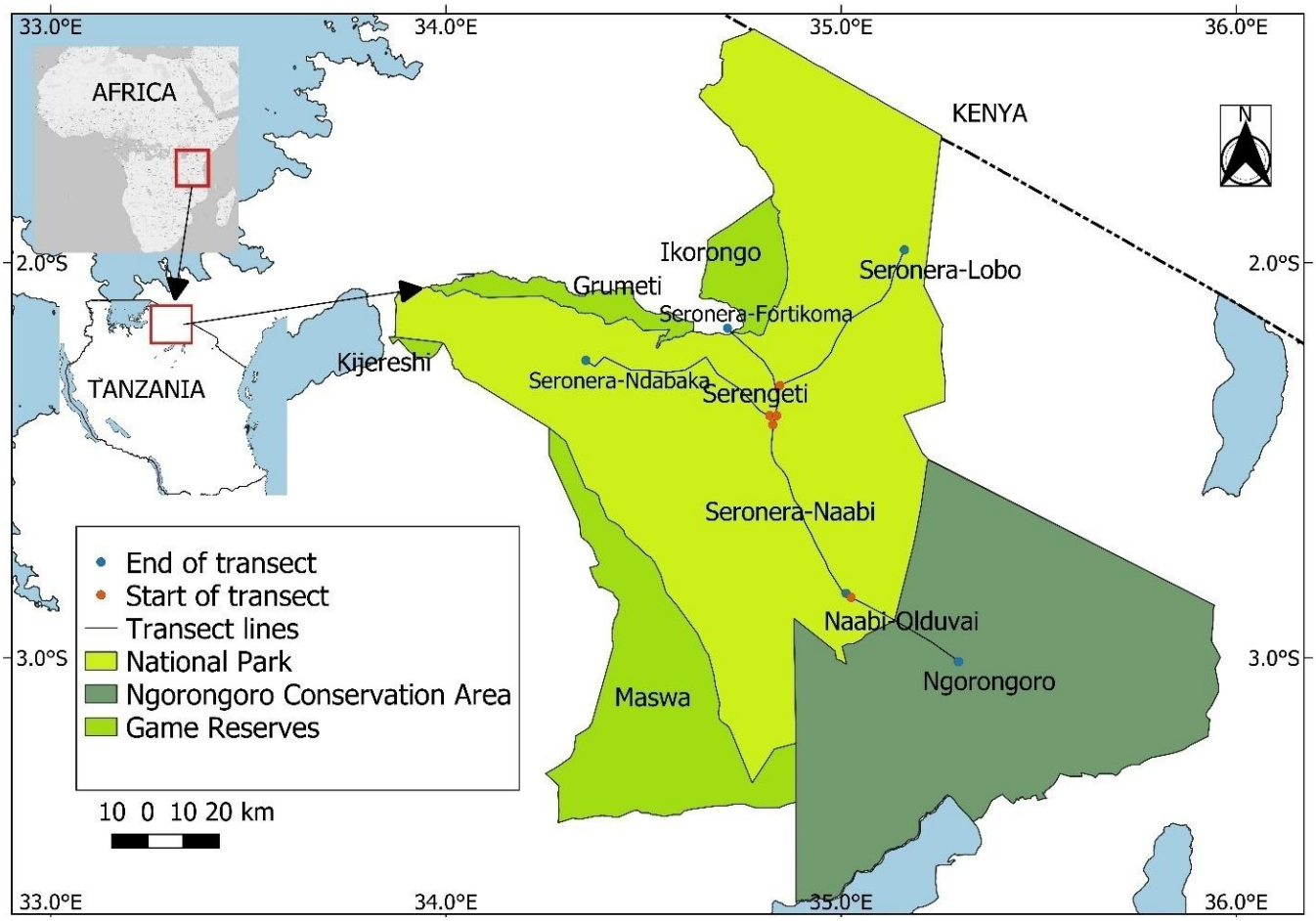

Figure 1. Map of the Serengeti ecosystem showing our study area and transects along the main roads.

the recorders. Thereafter, the vehicle was driven at a speed of approximately 20 km/h or below, as recommended by Collinson et al. (2014) and Teixeira et al. (2017). The four observers in the car were facing forward and made observations on either side of the road, in order to locate any carcass or injured animal. At the point of carcass or injured sighting, each encountered carcass or injured animal species was firstly identified, then other data recorded included GPS location, road width (how wide is the road at the roadkill site and was measured by using a tape measure), time of sighting, condition of the carcass/injured animal(s)(fresh = recent killed, still bleeding and have not started to smell bad/old=long time killed, have started to smell bad), the number of animals (killed/injured), estimated age classes (adults, sub-adults, or juveniles), sex (male/female), time of the day (morning/afternoon hours), road conditions (good = the road is regularly graded, with no potholes and few loose stones or bad = the road has not been graded for a long time and has several potholes and many loose stones) habitat types (general physiognomy vegetation type around the roadkill that is, grassland (>90% of the area is dominated by grass species), woodland (>90% of the area is dominated by tree species), bushland (>90% of the area is dominated by shrub species), wooded grassland (<20% of the area is dominated by trees species), were all recorded in a standard datasheet. Moreover, when the observers spotted any car driving towards the team, they stopped and recorded its speed (km/hr) using velocity speed gun (Model: 101911, Bushnell) and type of vehicle that was encountered (private, tourist, public, or government) and also counted them. After collecting all of the required data, the carcass was removed from the road to avoid double counting. We also used opportunistic encounter methods in addition to the transect method in order to record all the missing data out of data collection days to maximize the number and species of roadkill in the area.

Data analyses

Statistical Package for Social Science (SPSS, version 16.0) software was used for analyzing the data. The data were analyzed using the Pearson's chi-square goodness-of-fit test using Exact Tests with Monte Carlo confidence level (that is, sig. 2 sided). The Exact Tests enabled us to make reliable inferences because our data were small, sparse, heavily tied, or unbalanced and poorly distributed. Also, Exact Tests enabled us to obtain an accurate p value without relying on assumptions that may not be met by our data. Therefore, Pearson's chi-square goodness-of-fit test using Exact Tests with Monte Carlo confidence level (that is, sig. 2 sided) were used to determine whether the distribution of cases (e.g., mammalian roadkill) in a single categorical variable (e.g., " body sizes ", consisting of three groups: " small < 10.0 kg ", “medium 10.0 - 20.0 kg” and " large > 20.0 kg ", “dietary category”, consisting of three groups: “herbivores”, “carnivores” and “omnivores”, “taxonomic group”, consisting of two groups: “families” and

"orders", "seasons", consisting of two groups: "dry" and "wet", "session", consisting of two groups: "morning" and "afternoon", and "road conditions", consisting of two groups: "good" and "poor"), follows hypothesized distribution (e.g., a distribution that is "hypothesized", such as the mammalian herbivores would have hi\\192.168.1.30\all operations\BIOLOGICAL SCIENCES DATA\IJBC\DOWNLOADS\2021\3. March\IJBC-07.03.21-1480\Review\from author 2gher roadkill frequency due to their larger home range compared to smaller animals, and higher population density compared to carnivores (Green-Barber and Old, 2019), small sized mammals (< 10.0 kg) would be killed more often than larger animals because the latter are more actively avoided by motorists than smaller animals; and larger animals move more quickly than smaller animals, so they spend less time crossing a road, which reduces the chance of being hit by a vehicle (Ford and Fahrig, 2007). Mammalian roadkill would be occurring more frequently on good roads probably because of over speeding behavior by drivers as they are attracted to drive fast on such roads. However, the proportion of cases expected in each group of the categorical variable can be equal or unequal (e.g., we anticipated an "unequal" proportion of mammalian roadkill based on their dietary category). Additionally, to calculate the rate of mammalian roadkill per kilometer, we divided the number of road-kills by the total distance driven in kilometers during the study period. All tests reported at level of $P < 0.05$ were considered statistically significant.

RESULTS

Our results revealed that different mammal species were impacted by road accidents, representing 29 individual species occurring at a rate of 1.56 individual mammal per 80 km belonging to 13 mammalian species from 7 mammalian orders (Table 1) were recorded in the area. Moreover, mammal species found killed belonged to different orders with more individual mammal species recorded killed belonged to the order artiodactyla (n = 11, 37.9%) and lagomorpha (n = 9, 31.0%). Thomson gazelles was more affected among artiodactyla (n = 8, 27.6%) and Cape hares was more affected among lagomorphs (n = 9, 31.0%) compared to other orders encountered in the roadkill in the area including carnivora (n = 4, 13.8%), rodentia (n = 2, 6.9%), primates (n = 1, 3.4%), perissodactyla (n = 1, 3.4%) and certiodactyla (n = 1, 3.4%) and their differences were statistically significant ($\chi^2 = 1.74$, df = 72, $p < 0.001$) with the 99% confidence interval for p = (0.000, 0.000). The Monte Carlo estimate of 0.000 for the exact p value was based on 10,000 random samples from the reference set, using a starting seed of 624387341.

Furthermore, mammals' roadkill differed significantly between families they belong ($\chi^2 = 2.030$, df = 84, $p < 0.001$) with the 99% confidence interval for p = (0.000, 0.000), with more individuals coming from the bovidea family (n = 11, 37.9%) followed by families leporidae (n = 9, 31.0%), canidae (n = 4, 13.8%), sciuridae (n = 1, 3.4%), cercopithecidae (n = 1, 3.4%), suidae (n = 1, 3.4%), equidae (n = 1, 3.4%) and hystricidae (n = 1, 3.4%) (Table 1). The Monte Carlo estimate of 0.000 for the exact P value was based on 10,000 random samples from the reference set, using a starting seed of 957002199.

Mammals' species found killed differed significantly in body size ($\chi^2 = 58$, df = 24, $p < 0.001$) with the 99% confidence interval for p = (0.000, 0.000), represented with more small body sized mammals (<10.0 kgs, n = 13, 44.8%) followed by medium (10.0- 20.0 kgs, n = 10, 34.5%) and large bodied sized mammals (>20.0 Kgs, n = 6, 20.7%). The Monte Carlo estimates of 0.000 for the exact p value was based on 10,000 random samples from the reference set, using a starting seed of 92208573. However, the Cape hares (n = 9, 31.0 %) small body sized and Thomson gazelles (n = 8, 27.6 %) medium body sized mammals were more frequently killed than other mammals' species in the area.

Though road-kills occurred more during the dry (62.1%) than wet (37.9%) seasons and again between the morning (69%) and afternoon (31%) hours in the area but their differences were not statistically significant ($\chi^2 = 13.9$, df = 12, p = 0.260) with the 99% confidence interval for p = (0.249, 0.271), and ($\chi^2 = 13.8$, df = 12, p = 0.498) with the 99% confidence interval for p = (0.486, 0.511), respectively. The Monte Carlo estimate of 0.260 and 0.498 for the exact p value was based on 10,000 random samples from the reference set, using a starting seed of 1993510611 respectively. Also, mammalian roadkill occurred most frequently on good condition roads (75.0%) than poor condition roads (25.0%) though their differences were not statistically significant (p = 0.136) with the 99% confidence interval for p = (0.127, 0.145) probably because of the over speeding by drivers as they are attracted to drive fast on such roads. The Monte Carlo estimate of 0.136 for the exact p value was based on 10,000 random samples from the reference set, using a starting seed of 475497203.

Additionally, mammal species found killed differed significantly among their dietary type ($\chi^2 = 58$, df = 24, $p < 0.001$) with the 99% confidence interval for p = (0.000, 0.000) whereby herbivores were more killed along the roads (n = 22, 75.9%) followed by carnivores (n = 4, 13.8%) and omnivores (n = 3, 10.3%). The Monte Carlo estimate of 0.000 for the exact p value was based on 10,000 random samples from the reference set, using a starting seed of 726961337.

DISCUSSION

This study recorded only 29 mammalian roadkills belonging to 13 species, 7 orders and 8 families in the area. This finding is in line with previous works which revealed that thousands of mammals were killed annually from vehicle collisions, making the issue an important one for if we are to achieve sustainable conservation (Canova and Balestrieri, 2018; Smith-Patten and Patten, 2008). Previous studies have also shown that roads and traffic impact wildlife directly in several negative ways,

Table 1. Mammal species found killed along roads in the Serengeti ecosystem.

Common name	Family	Scientific name	Diet	Body mass	Total killed	% killed
Thomson gazelles	Bovidae	*Eudorcas thomsonii*	H	M	8	27.6
Cape hares	Leporidae	*Lepus capensis*	H	S	9	31.0
Black backed jackals	Canidae	*Canis mesomelas*	C	S	1	3.4
Bat eared fox	Canidae	*Otocyon megalotis*	C	S	1	3.4
Spotted hyaenas	Canidae	*Crocuta crocuta*	C	L	1	3.4
Dikdik	Bovidae	*Madoqua kirkii*	H	S	1	3.4
Wildebeests	Bovidae	*Connochaetes taurinus*	H	L	2	6.9
Zebra	Equidae	*Equus burchelli*	H	L	1	3.4
Cheetah	Canidae	*Acinonyx jubatus*	C	L	1	3.4
Olive baboon	Cercopithecidae	*Papio anubis*	O	M	1	3.4
Warthog	Suidae	*Phacochoerus africanus*	H	L	1	3.4
Squirrels	Sciuridae	*Sciurus carolinensis*	O	S	1	3.4
Crested porcupine	Hystricidae	*Hystrix cristata*	O	M	1	3.4
Total					**29**	**100**

Diet (H = herbivore, C = carnivore, O = omnivore) and body mass (S = < 10.0 kg, M = 10.0 - 20.0 kg, L = >20.0 kg) were determined from Barthelmess and Brooks (2010).

such as decreasing habitat quality, facilitating the introduction and spread of exotic species (Machado et al, 2015; Teixeira et al., 2017; Bukombe et al., 2018), acting as barriers by forming habitat fragmentation, reducing genetic diversity and increasing wildlife mortality due to wildlife-vehicle collisions (Meza-Joya et al., 2019). Additionally, the current study has shown that herbivores were the most affected group (75.9%), followed by carnivores (13.8%) and omnivores (10.3%) in the area. This observation supports our first prediction that mammalian herbivores have a higher roadkill frequency than carnivores or omnivores and corroborates findings by Canova and Balestrieri (2018). The reason for the higher herbivore roadkill was probably the fact that more mammalian herbivores have large home ranges and occur at higher densities (Green-Barber and Old, 2019). Furthermore, mammalian herbivores are attracted to road sides by resources that are rare or limited in other areas, including water and green pasture as source of food (Freitas et al., 2015; Kiros et al., 2016; Green-Barber and Old, 2019) and therefore increase chances of being hit by vehicles.

We also found that, the Cape hares which are small body mammal sizes were more recorded killed than medium and large body size mammal species probably because they are less actively avoided by motorists than larger mammals; and also, smaller mammals move more slowly than larger mammals, so spending more time traversing across a road, which increases their chances of being hit by vehicles (Ford and Fahrig, 2007). Also, Cape hares are commonly abundant species (Caceres, 2011) and their behavior of frequently crossing roads to gain access to other resources (Green-Barber and Old, 2019) in the area. Additionally, since the Cape hares are nocturnal, they might have been hit by vehicles more frequently at night or early morning because of the reduced driver vision (Braz and Franc, 2016), which may shorten the time a driver has to react to an animal on the road, concurrent with high proportion of this species that is active at night (Chyna et al., 2019). Therefore, this finding supports our second hypothesis that small sized mammals (<10.0 kg) would be killed more often than larger animals because the latter are more actively avoided by motorists than smaller animals; and larger animals move more quickly than smaller animals, so they spend less time crossing a road, which reduces the chance of their being hit by vehicles (Ford and Fahrig, 2007) and also because of their frequency of crossing the roads and abundance in the area (Barthelmess and Brooks, 2010). This finding is again in support with the study by Gonzalez-Suarez et al. (2018) who pointed out that species with weights above 2-3 kgs had higher risk of being killed, although for mammals the risk decreased again for species above ~50 kgs due to the reason that divers can see them at a distance and slow down their vehicles.

In this study, also predators or scavengers such as bat eared fox, spotted hyaena, black backed jackals and cheetahs were recorded killed in the area. This was probably because they were scavenging roadkill carcasses on the road which attracted and expose them to a higher risk of mortality by vehicle collision (Freitas et al., 2015; Planillo et al., 2018). Previous study has also shown that some small mammals thrive in verges and reach dense populations and play the role of prey in the ecosystem and can influence carnivore habitat use by

attracting them close to roads and increase their mortality risk by vehicle collision (Planillo et al., 2018). This is in support of the previous finding by Smith-Patten and Patten, (2008) who revealed that roadkill is easy prey, albeit coming with a high risk of the scavenger becoming the scavenged. Furthermore, cheetah as an endangered species was hit by vehicle representing a species of conservation concern and therefore may be used as a flagship species (Freitas et al., 2015) for conservation in the area.

More mammalian roadkills were observed along good or smooth roads than along poor roads probably because of the failure of drivers to adhere to safe driving practices (Selvan et al., 2012). This finding support that of Santos et al. (2013), who reported that road characteristics and the quality of the surrounding habitat play a key role in shaping wildlife roadkill patterns. Generally, according to Santos et al. (2013), casualties will increase in good road sections with high traffic volume or low driver visibility, as well as where good or smooth roads cross high-quality habitats, although this effect is species-specific.

Furthermore, we also found that mammalian roadkills occurred more frequently in single than two or more individual carcasses. This finding is in consistent with the study by Collinson et al. (2015) who reported that roads pose a threat to the survival of individual animals and entire populations. Our encounter rates of 0.0156 animals /kilometer are considerably lower than those of the study reported by Njovu et al. (2019) of 0.04 and 0.02 animals/kilometer, which was conducted on tarmac road compared to our study which was conducted on the gravel roads.

Ultimately, the knowledge of mammalian roadkill patterns can inform managers to device strategies to reduce it in the area (Lyamuya et al., 2021; Kreling et al., 2019). This is because the study has shown that roadkill is currently a problem in the Serengeti ecosystem, therefore it should be controlled to prevent perpetual biodiversity loss in this area. This can be accomplished by obliging drivers to reduce speed and placing wildlife warning signs on the roadside to modifying drivers' behaviour (Collinson et al., 2019; Lyamuya et al., 2021) as well as adding steeper penalties for over speeding drivers on roadkill risk areas (Collinson et al., 2019; Lyamuya et al., 2021).

CONCLUSION AND RECOMMENDATIONS

This study, therefore, concludes that though roads are economically beneficial to tourism and other conservation activities in most protected areas worldwide and particularly in the Serengeti ecosystem, however when their usage are not well managed, they can adversely impact a variety of wildlife species such as causing mammalian roadkill. This is because about 29 mammals represented more with herbivores than carnivores and omnivores were recorded killed in the Serengeti ecosystem. Moreover, most of the mammalian raodkill were recorded on good condition roads probably because of the over speeding behavior by drivers as they are attracted to drive fast on such roads. Additionally, mammals with small body sizes predominantly Cape hares were most frequently killed probably because they are less actively avoided by motorists than larger mammals. Furthermore, mammalian roadkill differed between the orders and families they belong with more individuals from the order artiodactyla and families bovidea and leporidae which were represented more with the Thomson gazelles and Cape hares respectively. In order to reduce mammalian roadkill in the area this study recommends that drivers should adhere to the park speed limits of 50 km/h so that they can easily see more smaller mammals on the roads such as the Cape hares from far away and try to avoid them as they do for large mammals. To achieve this, we recommend for the park managers to enforce their park vehicles speed regulations by giving steeper penalties for over speeding drivers. Also, the park managers should install more of pictured wildlife warning signs on the roadside for modifying driver behaviour in reducing mammalian roadkill especially of smaller and more medium mammals in the area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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