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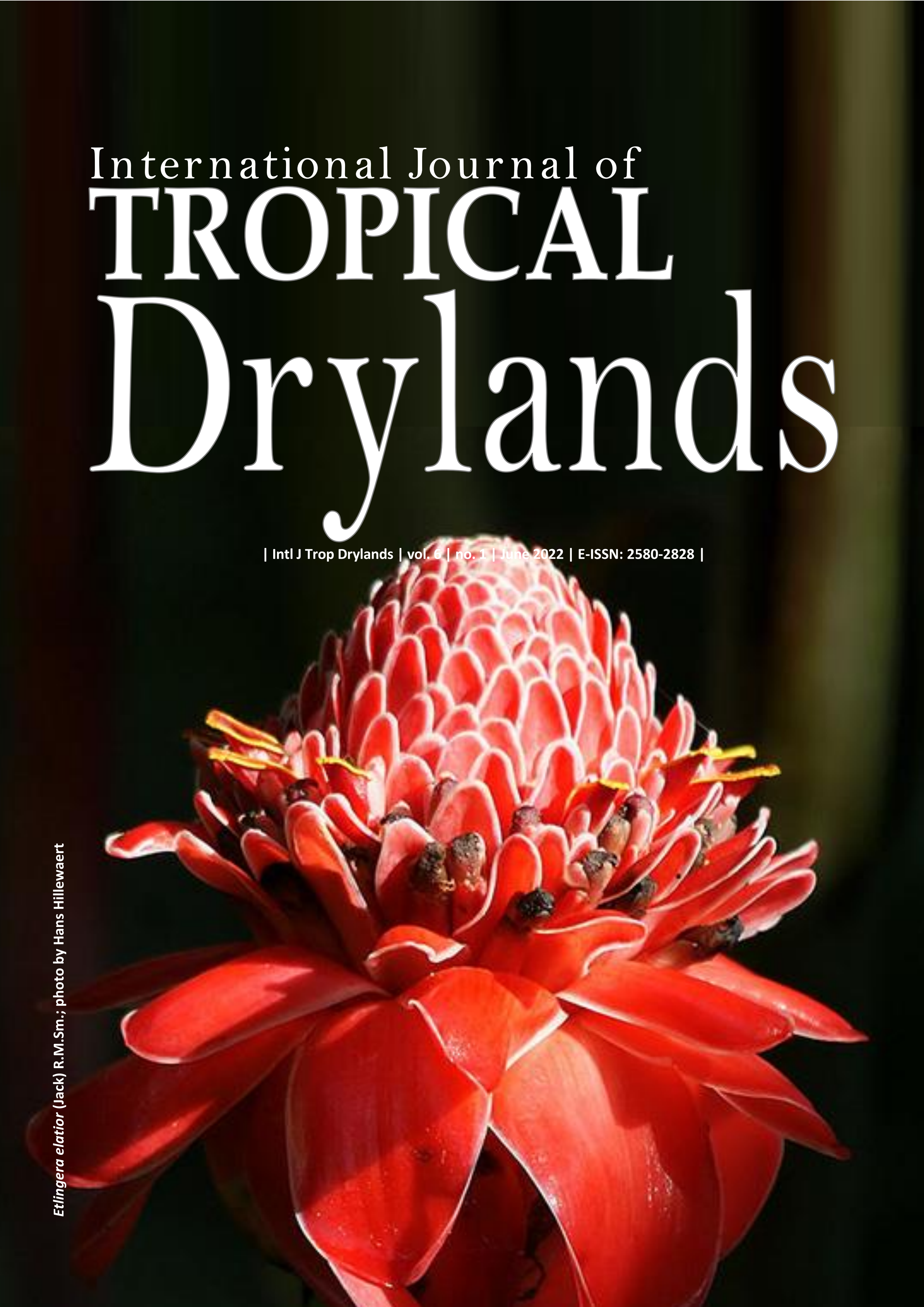

Etlingera elatior (Jack) R.M.Sm.; photo by Hans Hillewaert

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Figures and Tables of maximum of three pages should be clearly presented. Title of a picture is written down below the picture, while title of a table is written above the table. Colored figures can only be accepted if the information in the manuscript can lose without those images; chart is preferred to use black and white images. Author could consign any picture or photo for the front cover, although it does not print in the manuscript. All images property of others should be mentioned source. **There is no appendix**, all data or data analysis are incorporated into Results and Discussions. For broad data, it can be displayed on the website as a supplement.

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Rai MK, Carpinella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in book:
Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds) Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:
Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:
Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.) Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:
Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from internet:
Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. www.molecularsystemsbiology.com. DOI:10.1038/msb.2008.24

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Ethnobotanical study of the non-medicinal plant by village communities in the karst area of Pacitan, East Java, Indonesia

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Manuscript received: 10 January 2022. Revision accepted: 30 April 2022.

Abstract. *Cahyaningsih AP, Arifiani KN, Aprilia D, Nugroho ME, Setyawan AD. 2022. Ethnobotanical study of the non-medicinal plant by village communities in the karst area of Pacitan, East Java, Indonesia. Intl J Trop Drylands 6: 1-10.* The local community of Pacitan District, East Java Province, Indonesia, especially in the karst area in several villages of Tulakan Sub-district, has a yard and farm usually planted with many species of plants that have various benefits. These plants are edible, animal feed, spices, biopesticides, and plant growth hormones. However, the knowledge of the local community of Tulakan Sub-district regarding the various benefits of plants is only known from generation to generation, conveyed orally and in daily practice habits, so a study is needed to document this information. This study aims to reveal the knowledge of local communities and the diversity of non-medicinal plant species to meet communities' daily lives. The location of research was carried out in 2 villages located in Tulakan Sub-district, Pacitan District, East Java, Indonesia, namely Bungur Village and Tulakan Village. Data was collected through field surveys and direct interviews using the snowball sampling technique. A total of 40 respondents were interviewed, with details 14 male and 26 female. Respondents with the majority of high school educational backgrounds have around 46-55 years old. The inventory of non-medicinal plants amounted to 60 species of angiosperm plants from 43 families. The plants used consisted of 34 species for the edible plants, 20 for the fodder plants, 6 for herbs, 1 for biopesticide, and 1 for natural growth hormone. Based on the study results, it is known that local people use plants as edible plants with more diverse plant species compared to other uses.

Keywords: Edible plant, fooder plant, karst area, local knowledge, Pacitan

INTRODUCTION

Ethnobotany is one of the studies that learn about the relationship between humans and plants using traditional methods in the local community. In the diverse aspect of human life, local communities are used biodiversity around their residence. The history of human growth indicates that plants have an important function in the local community's cultural preservation (Sukmawati et al. 2013). Therefore, an ethnobotanical study is expected to become one factor that supports cultural sustainability in the utilization of plants. Local community knowledge also contributes to improving science and technology (Arsyad 2018) and provides scientific practices that can be further developed for future sustainable uses (Cao et al. 2020).

The community can use various types of plants for various purposes. Its uses are like plants that humans and livestock can eat in the form of vegetables or fruit. Local people are more interested in consuming edible plants that are wild or cultivated because the vegetables and fruit are still fresh, have good nutrition for health and daily needs, are protected from a polluted environment, and are free from the use of chemical fertilizers and pesticides. Especially for local people who live in rural mountainous areas with difficult access to transportation and far from the city center, to meet their daily food needs, people rely more on traditional markets, cultivate their crops, or utilize the diversity of plants in nature that grow wildly (Cao et al. 2020).

In rural areas, especially the karst mountains in East Java, Indonesia, most local communities own housing areas with large yards and utilize the karst areas for agroforestry. Rural communities generally plant various types of plants in the yard with various benefits. The large yard can be a habitat for plants to grow and maintain high biodiversity in residential areas (Yulianti et al. 2018). Plant diversity creates environmental preservation in an area, so the yard plays an important role in meeting the needs of daily life and providing a comfortable home (Mukarlina et al. 2014). On the other hand, local people also take advantage of plants that can grow in the karst area to meet their needs. The rural communities of Pacitan District, East Java, Indonesia, especially in the karst area, have yards and gardens, usually planted with many plants that have various benefits to meet their daily needs. Plant parts used include leaves, fruit, flowers, rhizomes, seeds, shoots, tubers, and roots. These plants are usually used as food and cooking spices, animal feed, natural pesticides, and natural plant growth stimulants for local communities that have livestock and work as farmers.

With the growing era, developments in modern agriculture and industry, and urbanization, it is feared that more or less will affect the village community in terms of meeting basic needs. Globalization which makes it easier to access mountainous and rural areas, can also change the habits of rural communities in terms of utilizing various plants for daily needs. Modernization that directly and indirectly occurs in the younger generation of rural communities can cause the transmission of local knowledge from the older generation to be hampered and will not always be guaranteed and even decrease (Ghanimi et al. 2022). Moreover, the knowledge of local communities regarding the various benefits of plants is only known from generation to generation and is conveyed orally.

Therefore, a study is needed to determine the knowledge of local communities regarding the use of plants in the present and to document the information. This study aims to reveal the knowledge of local communities and the diversity of non-medicinal plant species to meet people's daily lives in the village of Tulakan Sub-district, Pacitan, East Java, Indonesia.

MATERIALS AND METHODS

Study area

This research was conducted in two villages in the karst area of Southern Mountain, namely Bungur Village and Tulakan Village, Pacitan District, East Java, Indonesia (Figure 1). Bungur Village is located at the coordinates of -8° 10' 22.8", 111° 16' 37.2"E with a land area of 596,616 hectares with an altitude of 150 m to 450 m above sea level. The second location is Tulakan Village, located at the coordinates of 8°10'28.3"S, 111°15'47.1"E, with an altitude of 700 m asl., with a land area of 496.51 hectares (Fendi 2016; Tulakan Sub-district 2022).

Data collection and analysis

Information on non-medicinal plants used by local communities was collected from the two villages. Data were collected using survey techniques and open interviews using the snowball sampling method to obtain 40 informants. The interview technique was carried out with direct questions regarding the use of various non-medicinal plants, local names of plants used, plant parts used, and methods of using plants (Bhandary 2021). The conversations were recorded during the interview, and the information was well-written. As a result, the local name information of plants is identified and analyzed. The results of the interviews of non-medicinal plant list data and supporting information are presented in tables and graphs to combine information for easy understanding (Silalahi 2018) and analyzed using descriptive statistics in frequency and percentage (Purba and Silalahi 2021).

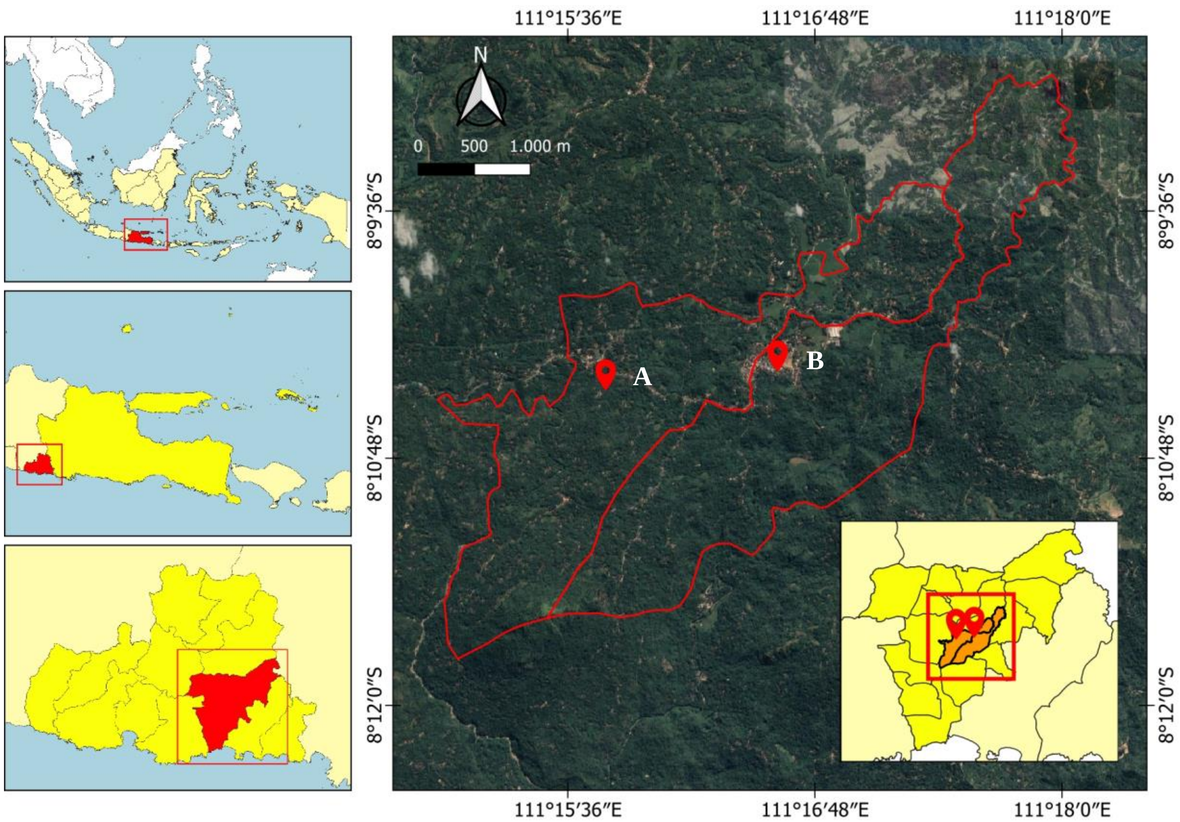

Figure 1. Map of the study area in the karst area of Tulakan Sub-district, Pacitan, East Java, Indonesia. A. Tulakan, B. Bungur

RESULTS AND DISCUSSION

A total of 40 sources were obtained as informants in this study, with details of 14 men and 26 women. The educational background consists of elementary school to college education, but most informants graduate from high school. The age range is 15-75 years, with the most being 46-55 years old and married. The village head became the first informant at each research location to collect information based on the snowball technique.

Based on the informant's demographic data (Table 1), it is known that the knowledge of local communities regarding the use of non-medicinal plants in the villages of Bungur and Tulakan is still well maintained from old to young age, even though information on plant use is only based on daily practice and becomes a habit of the residents. Furthermore, based on the results of the interviews, it is also known that information regarding the use of plants in the surrounding environment is passed down from parents to children within the household and is also taught by community leaders such as village heads to villagers or residents who have higher education to residents within the scope of one village. In addition, the daily practice of villagers who are always carried out also makes information about the use of plants can be maintained.

Purpose of use

The local community in Tulakan Sub-district utilizes non-medicinal plants for various purposes (Table 2). The most widely used by the community are edible plants, as much as 56.66%fodder plants, 33.33% natural pesticides, and plant growth regulators at 1.66%. From the study results, it is also known that several plants have multiple functions. For example, bananas used for food are also used for animal feed, and onions and garlic as herbs are also used as natural pesticides and plant growth stimulants. The diversity of non-medicinal plants in Bungur Village and Tulakan Village is still relatively high, where the plants used to consist of 60 species from 43 families.

Rural communities, especially in Java, Indonesia, are synonymous with settlements not yet crowded, large yards of houses, and raising livestock in the home area. The existence of a home yard and the maintenance of animals have made the village community continue to use plants to meet their daily needs. Using yard land for medicinal plants, food, horticulture, and others can meet family needs and increase household income if designed and planned properly (Ashari et al. 2012). The utilization of plants can be in the form of planting edible plants in the yard and fodder plants that can grow in areas around rural areas. Especially in karst mountainous areas, villagers also apply agroforestry to utilize forest areas to plant various food crops.

In addition, to using plants as edible and fodder plants, the people of Bungur and Tulakan Villages also use plants like herbs, natural pesticides, and plant growth stimulants. Although the number of species used is relatively small, this can be used as basic information to develop its application. On the other hand, the village community is still using, applying, and disseminating this information within the village scope.

Respondents in this study were mainly housewives, so the information obtained was more used as edible plants and herbs, while the male respondents mostly worked as farmers. Hence, they only understood using plants as fooders and natural pesticides. Most people in Bungur and Tulakan Villages only grow fruits, vegetables, and medicinal plants; although some care for ornamental plants, these plants are not taken from the original area of Tulakan village. Moreover, the community uses no plants for handicrafts, while none of the respondents conveyed it in detail for furniture.

Solanaceae is a plant family that acts as a food provider species. Based on ethnobotanical studies, 15 genera of Solanaceae are used as food worldwide (Samuels 2015).

Table 1. The demographic structure of informants

Parameter	Specification	Frequency
Gender	Male	14
	Female	26
Age	15-25	1
	26-35	4
	36-45	7
	46-55	12
	56-65	8
	>65	8
Education	Elementary School	9
	Junior High School	8
	Senior High School	15
	University	8
Marital status	Single	1
	Marriage	39

Table 2. Number of species, genera, and families used for non-medicinal purposes by communities of Bungur and Tulakan Villages, Tulakan Sub-district, Pacitan, East Java, Indonesia

Purposes	Number of species	Number of genera	Number of families	Percentage (%)
Edible plant	34	28	25	56,66
Fodder plant	20	17	9	33,33
Herbs	6	5	3	10
Plant growth	1	1	1	1,66
Pesticide	1	1	1	1,66

Plants used for edible plant

The people of Bungur and Tulakan Villages utilized 34 species of edible plants from 28 genera and 25 families (Table 3), with the highest utilization percentage compared to other uses. The majority of edible plants used by rural communities are planted in the house's yard, making them easier to maintain and use. Edible plants used by the majority of the community belong to the type of vegetable and fruit plants that can be eaten directly/raw, or cooked. However, based on the results of the interviews, it is known that the knowledge of the villagers about the edible plants used is only limited to plants that are often planted in the yard of the house and consumed every day, so only a little information is obtained about wild plants in the karst area which are still used by the community as edible plants.

Solanaceae family is the most widely used family group for edible plants by the people of Bungur and Tulakan Villages. The members of the Solanaceae family consisted of *Solanum nigrum* L., *Solanum melongena* L., *Solanum torvum* Sw., and *Solanum lycopersicum* L. All species of *Solanum* are harvested for cooking as vegetables. Family Solanaceae was also found in ethnobotanical studies in the Aizawl District of Mizoram, India, where Solanaceae plants can be found in home gardens, roadside, or wild plants in the area. Apart from being an edible plant whose fruit is useful as a source of protein and minerals, species such as *S. melongena* are also useful as medicinal plants (Ralte et al. 2021). However, the study results of non-medicinal plants in the villages of Bungur and Tulakan did not obtain information on using unique species as edible plants. That is also related to village areas located in tropical karst areas, so people prefer to grow food crops that are easy to grow on soil in their yards. Most of these plants are also found and used throughout Java, Indonesia. However, based on the research results, it is known that several plant species are used as edible, and not many other areas use them. These species include *Moringa oleifera* Lam. leaves, *Etlingera elatior* (Jack) R.M.Sm. flowers, *Anredera cordifolia* (Ten.) Steenis leaves and *Phytolacca acinosa* Roxb. leaves are processed into vegetables.

The *M. oleifera* leaves are more commonly consumed by the public as medicinal plants in extracts and capsules because of their phytochemical content and broad pharmacological benefits (Paikra et at. 2017; Bhattacharya et al. 2018). However, for the residents of Bungur and Tulakan Villages, most people consume the leaves as vegetables by boiling and processing them into soup. Based on Sallau et al. (2012), the boiling process of *M. oleifera* leaves can reduce the antinutrient content in the form of cyanide, oxalate, phytate, and trypsin inhibitors, so the process of boiling *M. oleifera* leaves will maximize the utilization of its nutrients. Apart from being a medicinal plant, actually the *M. oleifera* species has a high nutritional content; the leaves contain lots of minerals and vitamins (Sultana 2020; González-Burgos 2021), which also have been proven to be used to treat malnutrition (Gopalakrishnan et al. 2016). Therefore, for most people in Bungur and Tulakan, *M. oleifera* is one of the plants commonly consumed daily as a vegetable. This plant grows wild in rural areas or is planted in the house's yard.

The people of Bungur and Tulakan Villages also consume *E. elatior* flowers (Figure 2A) as food, cooked as vegetables. Based on several studies, *E. elatior* flowers, globally known as torch ginger, are used as ingredients in food, garnishes, salads, soups, appetizers, and desserts (Barash 1997). Traditionally it is also widely consumed by local Thai people for medicinal and nutritional purposes (Rachkeeree et al. 2018). It is also used in dishes by local Malaysians because it has a unique aroma and taste that can enhance food flavor (Wijekoon et al. 2011). The *E. elatior* flowers contain high levels of vitamins, fiber, fat, and protein (Nazikussabah et al. 2017), unsaturated fatty acids, amino acids, other mineral compounds, and low heavy metal contaminants (Juwita et al. 2018). Some of these nutritional characteristics can be used as information for human food and its potential in the food industry (Nazikussabah et al. 2017).

The *A. cordifolia* is a plant quite well known as a medicinal plant, but for the people of Bungur and Tulakan Villages, the leaves of this species are consumed daily as food by cooking. Globally, *A. cordifolia* is considered an unconventional food plant because the leaves and tubers can be eaten in various forms, such as for making bread (Alba et al. 2020). However, the people of southern China in coastal areas use *A. cordifolia* species as an edible plant also carried out by consuming young leaves and stems cooked in soup or with noodles. In addition, *A. cordifolia* leaves can be a source of dietary fiber, containing calcium, iron, and vitamin C (Xu et al. 2020).

The *P. acinosa*, a wild plant, is also consumed by local people in Bungur and Tulakan Villages as a cooked vegetable. Several other ethnobotanical studies have also revealed that *P. acinosa* species are classified as wild leafy vegetables and food plants that are rarely explored. Residents of the Nanda Devi Biosphere Reserve, India, consume the young leaves of *P. acinosa*, which are widely grown in forest borders by cooking (Misra et al. 2008). *P. acinosa*, as a wild plant, has a higher micronutrient and mineral content than commercial vegetables (Seal et al. 2017).

The diversity of non-medicinal plant species used by the local community in Bungur Village and Tulakan Village is still relatively high but lower compared to ethnobotanical studies from other regions in Indonesia. For example, Sunesi and Wiryono's (2007) research recorded 113 species of plants that grow in settlements and forests used by the community in Kandang Village, Kepahiang District, Bengkulu Province. Nahlunnisa et al. (2015) recorded 168 species used as food crops in Nyungcung Village, Malasari Village, Nanggung District, Bogor. Then, Iqbar et al. (2018) list 146 species used for various needs and obtained from settlements and forests in the Seulawah Valley, Aceh Province.

Table 3. Plants used for the edible plant by communities of Bungur and Tulakan Villages, Tulakan Sub-district, Pacitan, East Java, Indonesia

Scientific name	Family	Local name	Growth form	Parts used	Method of use
Moringa oleifera	Moringaceae	Kelor	Tree	Leaf	Cooked
Ipomoea aquatica	Convolvulaceae	Kangkung	Herbaceous	Leaf	Cooked
Ipomoea batatas	Convolvulaceae	Ubi jalar	Climber	Leaf, tuber	Cooked
Carica papaya	Caricaceae	Pepaya	Tree	Leaf, flower, fruit	Cooked, raw
Cosmos sp.	Asteraceae	Kenikir	Scrub	Leaf	Cooked
Gynura procumbens	Asteraceae	Sambung nyowo	Tree	Leaf	Cooked
Gnetum gnemon	Gnetaceae	Dongso/Melinjo	Tree	Leaf, fruit, seed	Cooked
Brassica rapa subsp. *chinensis*	Brassicaceae	Sawi	Scrub	Leaf	Cooked
Brassica oleracea	Brassicaceae	Kubis	Scrub	Leaf	Cooked, raw
Manihot esculenta	Euphorbiaceae	Singkong	Scrub	Leaf, tuber	Cooked
Amaranthus sp.	Amaranthaceae	Bayam	Herbaceous	Leaf	Cooked
Amaranthus tricolor	Amaranthaceae	Bayam merah	Herbaceous	Leaf	Cooked
Phytolacca acinosa	Phytolaccaceae	Bayam Belanda	Herbaceous	Leaf	Cooked
Ocimum basilicum	Lamiaceae	Kemangi	Scrub	Leaf, flower	Raw
Anredera cordifolia	Basellaceae	Binahong	Scrub	Leaf	Cooked
Etlingera elatior	Zingiberaceae	Kecombrang	Scrub	Flower	Cooked
Bambusa sp.	Poaceae	Rebung	Tree	Shoot	Cooked
Sechium edule	Cucurbitaceae	Manisah	Climber	Fruit	Cooked
Momordica charantia	Cucurbitaceae	Pare	Scrub	Fruit	Cooked
Morus alba	Moraceae	Murbei	Tree	Fruit	Raw
Vigna unguiculata	Fabaceae	Kacang panjang	Climber	Fruit	Cooked
Psophocarpus tetragonolobus	Fabaceae	Ciper/Kecipir	Climber	Fruit	Cooked
Musa paradisiaca	Musaceae	Pisang	Tree	Fruit	Raw
Solanum nigrum	Solanaceae	Leunca/ranti	Herbaceous	Fruit	Cooked
Solanum melongena	Solanaceae	Terong	Scrub	Fruit	Cooked
Solanum torvum	Solanaceae	Pokak/takokak	Scrub	Fruit	Cooked
Solanum lycopersicum	Solanaceae	Tomat	Scrub	Fruit	Cooked, raw
Nephelium lappaceum	Sapindaceae	Rambutan	Tree	Fruit	Raw
Mangivera indica	Anacardiaceae	Mangga	Tree	Fruit	Raw
Durio zibethinus	Malvaceae	Durian	Tree	Fruit	Raw
Psidium guajava	Myrtaceae	Jambu	Tree	Fruit	Raw
Annona muricata	Annonaceae	Sirsak	Tree	Fruit	Raw
Hylocereus polyrhizus	Cactaceae	Buah naga	Climber	Fruit	Raw
Daucus carota	Apiaceae	Wortel	Scrub	Root	Cooked, raw

Figure 2. Examples of edible plants in the villages of Bungur and Tulakan, Pacitan, East Java, Indonesia. A. *Etlingera elatior* flower. B. *Carica papaya*

Plants used for fodder

Most rural communities in Java, Indonesia, are no exception in Bungur and Tulakan, Pacitan, East Java, raising livestock by building cattle pens behind their houses. The livestock usually kept are cows, goats, chickens, and ducks. Villagers raise livestock to support daily food consumption for chickens and ducks or for future savings for cows and goats, usually sold at certain times. The daily lives of villagers who have livestock at home will also need to look for animal feed. The people of Bungur and Tulakan Villages who live in the karst area use the plants in their area to meet livestock needs. Table 4 shows which species are widely used by the community as animal feed. The people of Bungur and Tulakan Villages used plants as animal feed, with a total of 20 species from 9 families with a percentage of 33.33%, and became the second largest number after edible plants.

Rural communities most widely use Poaceae and Fabaceae families as animal feed. The majority of Poaceae family members used grass species consisting of *Brachiaria mutica* (Forssk.) Stapf, several cultivars of *Pennisetum purpureum* Schumach., *Setaria sphacelata* (Schumach.) Stapf & C.E.Hubb. ex Moss, and *Megathyrsus maximus* (Jacq.) B.K.Simon & S.W.L.Jacobs. This type of grass grows wild in rural areas, and residents search around houses, roadsides, and forest borders every day. This grass is used as animal feed for cows and goats, with preparations only being cut and then given directly to livestock. Meanwhile, from the Fabaceae family, residents use the leaves of *Leucaena leucocephala* (Lam.) de Wit, *Albizia chinensis* (Osbeck) Merr., *Gliricidia sepium* (Jacq.) Kunth, *Canavalia gladiata* (Jacq.) DC. as feed for cows and goats, which are given directly.

Some plant species are used for one type of livestock only. For example, species only given as feed for goats are *C. gladiata* leaves, *Manihot glaziovii* Müll.Arg., *Manihot esculenta* Crantz, *Gmelina arborea* Roxb. ex Sm., and *Carica papaya* L. leaves. The preparation of using leaves as goat feed is only taken from the leaves and given directly to livestock. The animal feed species only given to cows are dried straws from *Oryza sativa* L. For ducks, residents use crushed *Cucurbita* fruit and mostly use mashed rice seed husks for chickens. The crushed leaves of *Colocasia esculenta* (L.) Schott and mashed soybean seeds are used as feed for chickens and ducks.

Three cultivars of the P. purpureum species are used by the residents of Bungur and Tulakan Villages as feed for cattle and goats, namely the common elephant grass, *P. purpureum*, the dwarf elephant grass *P. purpureum* cv. Mott, and *P. purpureum* cv. Thailand. The difference between common elephant grass and dwarf grass is the size of the plant where common elephant grass has a height of 3-4 meters (Reksohadiprodjo 1994), while dwarf elephant grass is a such of grazing grass that has a height of 125 cm (Ako 2013). The use of the Poaceae family, especially *P. purpureum*, as animal feed is also known from several ethnobotanical studies, namely in Gumantar Village, North Lombok District (Jannaturrayyan et al. 2020) and in Toba Samosir by the Parmalim Batak community (Amrul et al. 2019). That shows that elephant grass is a species that is widely used as animal feed for rural communities in general. Village communities that use elephant grass a lot as animal feed can be related to the character of elephant grass, which has good adaptation during the dry season, especially in karst areas. In particular, dwarf elephant grass is easy and fast-growing (Rusdy 2016) with high nutritional content (Maleko et al. 2019). Therefore, it is suitable for ruminant feed for grazing and cutting, and transport systems (Sirait 2017).

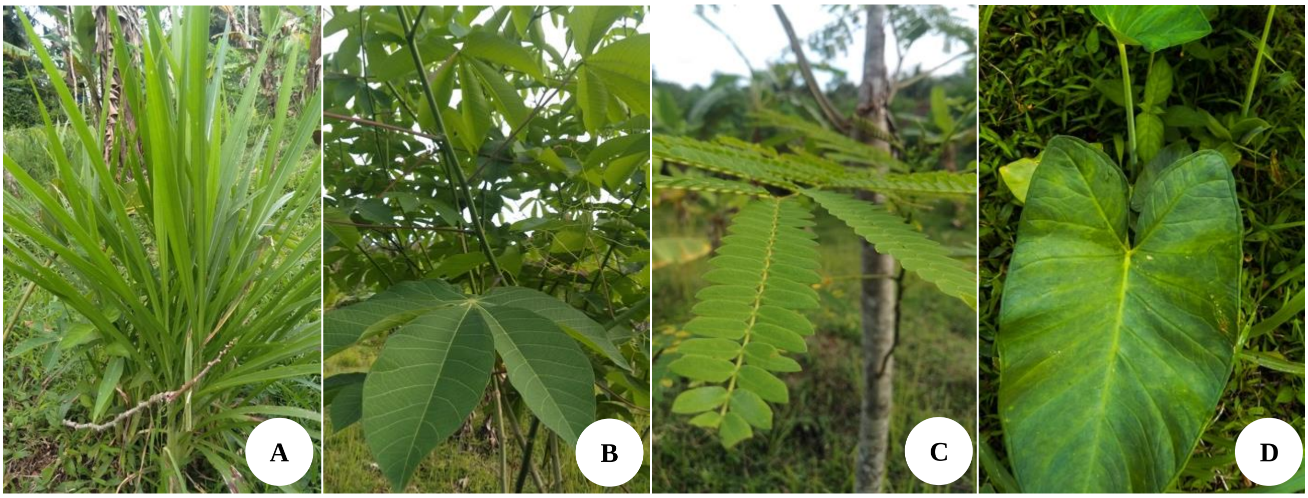

Figure 3. Some examples of species for fooder in the villages of Bungur and Tulakan, Tulakan Sub-district, Pacitan, East Java, Indonesia. A. *Pennisetum purpureum* cv. mott, B. *Manihot glaziovii*, C. *Albizia chinensis*, D. *Colocasia esculenta*

Table 4. Plants used for fodder by communities of Bungur and Tulakan Villages, Tulakan Sub-district, Pacitan, East Java, Indonesia

Scientific name	Family	Local name	Growth form	Parts used	Method of use	Livestock
Brachiaria mutica	Poaceae	Kolonjono	Scrub	Leaf	Cut, fed directly	Goat, cow
Pennisetum purpureum	Poaceae	Rumput gajah	Scrub	Leaf	Cut, fed directly	Goat, cow
Pennisetum purpureum cv. Mott	Poaceae	Rumput odot	Scrub	Leaf	Fed directly	Goat, cow
Pennisetum purpureum cv. Thailand	Poaceae	Rumput pakchong	Scrub	Leaf	Cut, fed directly	Goat, cow
Setaria sphacelata	Poaceae	Setaria	Scrub	Leaf	Fed directly	Goat, cow
Megathyrsus maximus	Poaceae	Rumput benggala	Scrub	Leaf	Fed directly	Goat, cow
Oryza sativa	Poaceae	Jerami	Herbaceous	Stem, seed coat	Dried, crushed, mashed	Cow, chicken
Leucaena leucocephala	Fabaceae	Mlanding/lamtaro	Tree	Leaf	Fed directly	Goat, cow
Albizia chinensis	Fabaceae	Sengon	Tree	Leaf	Fed directly	Goat, cow
Gliricidia sepium	Fabaceae	Gamal/sono	Tree	Leaf	Fed directly	Goat, cow
Canavalia gladiata	Fabaceae	Koro benguk	Climber	Leaf	Fed directly	Goat
Glycine max	Fabaceae	Kedelai	Climber	Seed	Mashed	Duck, chicken
Manihot glaziovii	Euphorbiaceae	Telo Jerman	Scrub	Leaf	Fed directly	Goat
Manihot esculenta	Euphorbiaceae	Singkong	Scrub	Leaf	Fed directly	Goat
Melia azedarach	Meliaceae	Mindi	Tree	Leaf	Fed directly	Goat, cow
Gmelina arborea	Verbenaceae	Gamar	Tree	Leaf	Fed directly	Goat
Colocasia esculenta	Araceae	Talas	Herbaceous	Leaf	Crushed	Duck, chicken
Artocapus heterophyllus	Moraceae	Nangka	Tree	Leaf	Fed directly	Goat, cow
Carica papaya	Caricaceae	Pepaya	Tree	Leaf	Fed directly	Goat
Cucurbita sp.	Cucurbitaceae	Waluh	Climber	Fruit	Crushed	Duck

The people of Bungur and Tulakan Villages also use a lot of plants from the Fabaceae family to feed cows and goats, especially *A. chinensis,* which has not been widely used by other regions. *Albizia* is a plant that is not well known as food (Karda and Spudiati 2006). In the areas of Bungur and Tulakan Villages, the people also plant a lot *of A. chinensis* trees in addition to their leaves for animal feed as well as for their wood needs which can be sold, so this species is also commonly found around roadsides or village markets which also sell *A. chinensis* seedlings. The *A. chinensis* can be used as animal feed because ruminants easily eat the leaves, and the wood can be used for building houses and furniture (Akkasaeng and Gutteridge 2016).

Apart from goats and cows, the people of Bungur and Tulakan Villages also raise chickens and ducks as livestock. Raising chickens and ducks for rural communities, especially in Java, is a habit despite having no specific purpose. Raising chickens and ducks in the village is usually used for eggs, meat, or sale at certain times. The people of Bungur and Tulakan Villages used fine rice bran, mashed soybean seeds, and crushed pumpkin. These chicken and duck feed ingredients have been widely used in various regions with many methods and advantages (Viet and Kien 2001; Kumar et al. 2014; Bakshi and Wadhwa 2017; Lourenco et al. 2019; Egorov et al. 2020). However, residents also use crushed taro leaves, which is not commonly practiced in other areas. Villagers take advantage of *C. esculenta* leaves because the plant grows wild in rural areas. Taro is an energy source that is less desirable than human food, so it can be developed as an alternative energy source for animal feed (Adejumo et al. 2013). Taro is also recommended as animal feed because of its nutrition in high protein content in leaves and stems (Setyawan et al. 2021).

Plants used for other purposes

The people of Bungur and Tulakan Villages also use plants for various other purposes, such as herbs, biopesticide, and plant growth regulators, by utilizing plants grown in their yards. Villagers mostly use the Zingiberaceae and Amaryllidaceae families for this purpose (Table 5). For seasoning, the herbs used are *Zingiber officinale* Roscoe, *Kaempferia galanga* L., *Curcuma longa* L., *Allium cepa* L., and *Allium sativum* L. Plants used for seasoning can be used fresh or dry mixed in dishes to add aroma and flavor. The parts of plants that contain phytochemicals produced by plants are part of the plant's metabolic process (Robi et al. 2019).

Species *A. cepa* and *A. sativum* also have a dual function where *A. cepa* is used as a natural plant growth regulator, and *A. sativum* is used for biopesticides. Natural growth regulators from shallots are usually applied when plants' vegetative propagation, such as grafts and stem cuttings, by applying grated shallot to the cut end of the stem where the potential roots will grow. As for pot plants, shallot filtrate is applied by soaking the grated shallots overnight, adding water, filtering, and then spraying on the plants. Shallots act like auxin to stimulate root and shoot growth during vegetative propagation. Several studies have also been conducted regarding the application of shallots as natural growth regulators; Susanti (2011) tested the shallot filtrate on *Syzygium aqueum* (Burm.fil.), Alston cuttings, Marfirani et al. (2014) on jasmine cuttings, Manurung et al. (2020) on *A. cordifolia*, Prameswari and Pratomo (2021) on cuttings of *Mucuna bracteata* D.C. ex Kurz. Based on some of these studies, it has been proven that onion filtrate can stimulate root growth because shallots contain the hormone auxin, vitamin B1, nicotinic acid, and *allin* compounds which turn into *allicin* compounds when onions are chopped or cut. The direct practice of using shallots as plant growth regulators, such as those carried out by the people of Bungur and Tulakan Villages, needs to be informed so that the general public can carry it out.

Local people also use garlic as a biopesticide to treat the plants they grow in their yards. That is related to all the plants they plant in their yards, which will be consumed along with their families to avoid using chemical pesticides. Residents make a concoction of garlic by mixing mashed garlic with water and dry tobacco with high nicotine content. This mixture can be used to eradicate caterpillars that usually attack vegetable and fruit crops. The use of garlic extract or juice has been widely studied globally. It has been shown to be effectively used as a natural pesticide to eradicate various pests, such as research by Li and Zhihui (2009) to control *Phytophthora capsici* (Leonian, 1922) in China, Magwenya et al. (2016) controlled for *Aphis gossypii* (Glover, 1877) in Zimbabwe, and Hardiansyah et al. (2020) to control rice-eating bird pests in Tonasa village, South Sulawesi, Indonesia. Based on the results of these ethnobotanical studies and references, the use of biopesticides such as garlic is expected to be further developed and applied more widely to reduce the use of chemical pesticides.

Parts and methods used

The use of plants by the people of Bungur and Tulakan Villages for non-medicinal plants consists of various parts and methods of use. The community primarily uses the leaves with 53.22% and mostly uses it as an edible and fooder plant. The fruit is the second largest part after the leaves, with 29.03%. Even with a small percentage, the community uses 6.45% of tubers, 4.48% of flowers, rhizomes, and seeds, and 1.61% of stems, shoots, and roots (Figure 4A).

Table 5. Non-medicinal plants are used for other purposes by communities of Bungur and Tulakan Villages, Tulakan Sub-district, Pacitan, East Java, Indonesia

Scientific name	Family	Local name	Growth form	Part used	Purposes	Method of use
Capsicum frutescens	Solanaceae	Cabai	Scrub	Fruit	Herbs	Cooked
Zingiber officinale	Zingiberaceae	Jahe	Herbaceous	Rhizome	Herbs	Cooked
Kaempferia galanga	Zingiberaceae	Kencur	Herbaceous	Rhizome	Herbs	Cooked
Curcuma longa	Zingiberaceae	Kunyit	Herbaceous	Rhizome	Herbs	Cooked
Allium cepa	Amaryllidaceae	Bawang merah	Herbaceous	Tuber	Herbs, natural plant growth regulator	Cooked, mashed
Allium sativum	Amaryllidaceae	Bawang putih	Herbaceous	Tuber	Herbs, biopesticide	Cooked, mashed

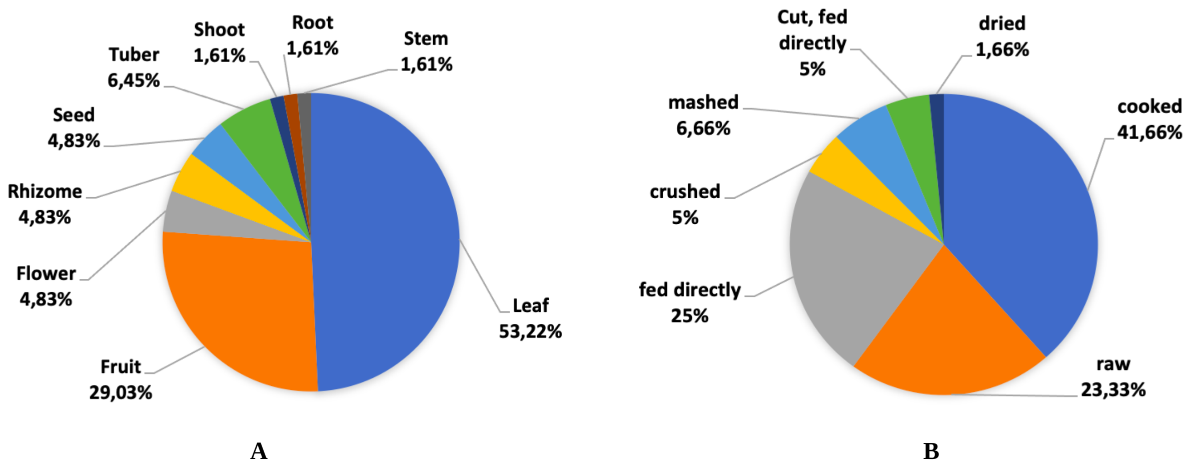

Figure 4. Percentage of plant parts and methods used by the community of Bungur and Tulakan Villages, Tulakan Sub-district, Pacitan, East Java, Indonesia. A. percentage of plant parts used, B. Percentage of methods used

Umartani and Nahdi (2021) research revealed that the people on the slopes of Mount Merapi and Merbabu used the leaves and fruit widely as edible plants. The same thing also happened in ethnobotany studies by ethnic groups in Jiangcheng County, Southwest China which mostly used leaves, fruit, and stems as edible plants (Cao et al. 2020). The most widely used method is cooking, where most residents cook it by boiling. The second most commonly used method is eating raw vegetables and fruit as edible plants. Plants used as animal feed are fed directly as much as 25%, while the method that requires cutting is only 5%. With a small percentage, the community uses the crushed method by 5% and mashed by 6.6%. The results of this study are the same as the ethnobotanical study in Nepal, with the category of using edible plants by cooking as vegetables for the highest percentage and eating raw methods for fruits (Uprety et al. 2012). Based on the percentage of parts and the method of use, it is known that the villagers prefer to use plants in a practical, easy, and quickly obtained way.

In conclusion, the people of Bungur and Tulakan Villages use plants for edible plants, fodder plants, herbs, biopesticides, and natural growth regulators. Village communities use plants for this purpose by planting in their yards or taking wild plants in rural areas. The leaves and fruit are the most widely used plant parts as edible plants and fodder plants. The method of use is mainly cooked and raw. The community's knowledge and diversity of species are still relatively high from the old to the young. Still, this knowledge may be further degraded if there is no knowledge teaching about the traditional use of plants in the village.

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REFERENCES

Adejumo IO, Babalola TO, Alabi OO. 2013. *Colocasia esculenta* (L.) Schott as an alternative energy source in animal nutrition. British J Appl Sci Technol 3 (4): 1276-1285. DOI: 10.9734/BJAST/2014/4945.

Akkasaeng R, Gutteridge RC. 2016. *Albizia chinensis*. In: Hanum IF, van der Maesen LJG (eds). PROSEA, Plant Resources of South-East Asia.

Ako A. 2013. Ilmu Ternak Perah Daerah Tropis. Institut Pertanian Bogor Press, Bogor. [Indonesian]

Alba TM, de Pelegrin CMG, Sobottka AM. 2020. Ethnobotany, ecology, pharmacology, and chemistry of *Anredera cordifolia* (Basellaceae): A review. Rodriguésia 71: e01042019. DOI: 10.1590/2175-7860202071060.

Amrul HMZN, Pasaribu N, Harahap RH, Aththorick TA. 2019. Ethnobotanical study of fodder plant species used by the Batak Parmalim Communities in Toba Samosir, Indonesia. IOP Conf Ser: Earth Environ Sci 305: 012089. DOI: 10.1088/1755-1315/305/1/012089.

Arsyad M. 2018. Studi etnobotani tumbuhan obat oleh masyarakat Desa Sidorejo Kecamatan Tamban Kabupaten Barito Kuala. J Insan Farmasi Indonesia 1 (1): 85-95. [Indonesian]

Ashari, Saptana, Purwantini TB. 2012. Potensi dan prospek pemanfaatan lahan pekarangan untuk mendukung ketahanan pangan. Forum Penelitian Agro Ekonomi 30 (1): 13-30. DOI: 10.21082/fae.v30n1.2012.13-30. [Indonesian]

Bakshi' MPS, Wadhwa M. 2017. Utilization of rice straw as livestock feed. Indian Farming 67 (7): 27-29.

Barash CW. 1997. Edible Flowers: Desserts and Drinks. Fulcrum Publishing, Colorado.

Bhandary MJ. 2021. Diversity of plants used for non-medicinal purposes by the traditional communities of Coastal Karnataka, India. Asian J Ethnobiol 4 (2): 106-114. DOI: 10.13057/asianjethnobiol/y040205.

Bhattacharya A, Tiwari P, Sahu PK, Kumar S. 2018. A review of the phytochemical and pharmacological characteristics of *Moringa oleifera*. J Pharm Bioallied Sci 10 (4): 181-191. DOI: 10.4103/JPBS.JPBS_126_18.

Cao Y, Li R, Zhou S, Song L, Quan R, Hu H. 2020. Ethnobotanical study on wild edible plants used by three trans-boundary ethnic groups in Jiangcheng County, Pu'er, Southwest China. J Ethnobiol Ethnomed 16: 66. DOI: 10.1186/s13002-020-00420-1.

Egorov I, Manukyan V, Lenkova T, Egorova T, Nikonov I. 2020. Use of full-fat soy flour in compound feeds for meat chickens of the initial lines and broiler chickens. Intl Trans J Engineer Manag Appl SciTechnol 11 (6): 1-8. DOI: 10.14456/ITJEMAST.2020.118.

Fendi. 2016. Profil Kecamatan Tulakan Kabupaten Pacitan Provinsi Jawa Timur. https://www.sindopos.com/2016/02/profil-kecamatan-tulakan-kabupaten.html [30 December 2021] [Indonesian]

Ghanimi R, Ouhammou A, Ahouach A, Cherkaoui M. Ethnobotanical study on wild edible plants traditionally used by Messiwa people, Morocco. J Ethnobiol Ethnomed 18: 16. DOI: 10.1186/s13002-022-00500-4.

González-Burgos E, Ureña-Vacas I, Sánchez M, Pilar Gómez-Serranillos MP. 2021. Nutritional value of *Moringa oleifera* Lam. leaf powder extracts and their neuroprotective effects via antioxidative and mitochondrial regulation. Nutrients 13 (7): 2203. DOI: 10.3390/nu13072203.

Gopalakrishnan L, Doriya K, Kumar DS. 2016. *Moringa oleifera*: A review on nutritive importance and its medicinal application. Food Sci Human Wellness 5: 49-56. DOI: 10.1016/j.fshw.2016.04.001.

Hardiansyah MY, Ridho AFA, Nurhidayat. 2020. The effect of garlic (*Allium sativum*) extract pesticides in repelling rice eating bird pests. Indones J Agric Res 3: 145-152. DOI: 10.32734/injar.v3i3.3947.

Iqbar I, Masykur M, Putri R. 2018. Tumbuhan berguna di lembah Seulawah, Provinsi Aceh. Prosiding Seminar Nasional Biotik 4 (1): 85-94. [Indonesian]

Jannaturrayyan S, Sukenti K, Rohyani IS, Sukiman. 2020. Ethnobotanical study on plants used by local people in Dusun Beleq, Gumantar Village, North Lombok District. Biosaintifika 12 (2): 203-212.

Juwita T, Puspitasari IM, Levita J. 2018. Torch ginger (*Etlingera elatior*): A review on its botanical aspects, phytoconstituents and pharmacological activities. Pak J Biol Sci 21: 151-165. DOI: 10.3923/pjbs.2018.151.165.

Karda IW, Spudiati. 2006. Relative palatability by sheep and goats of oven-dried *Calliandra*, *Albizia*, *Gliricidia*, and *Leucaena* leaves. Majalah Ilmiah Peternakan 9 (2): 1-10.

Kumar A, Singh VK, Narender, Kumar R. 2014. Utilization of paddy straw as animal feed. Forage Res 40 (3): 154-158.

Li S, Zhihui C. 2009. *Allium sativum* extract as a biopesticide affecting pepper blight. Intl J Veg Sci 15: 13-23. DOI: 10.1080/19315260802446377.

Lourenco JM, Rothrock Jr. MJ, Sanad YM, Callaway TR. 2019. The effects of feeding a soybean-based or a soy-free diet on the gut microbiome of pasture-raised chickens throughout their lifecycle. Front Sustain Food Syst 3: 36. DOI: 10.3389/fsufs.2019.00036.

Magwenya T, Svotwa E, Katsaruware RD. 2016. Evaluating the efficacy of garlic (*Allium sativum*) as a bio-pesticide for controlling cotton aphid (*Aphis gossypii*). Sci Agri 16 (2): 54-60. DOI: 10.15192/PSCP.SA.2016.16.2.5460.

Maleko D, Mwilawa A, Msalya G, Pasape L, Mtei K. 2019. Forage growth, yield and nutritional characteristics of four varieties of napier grass (*Pennisetum purpureum* Schumach) in the west Usambara highlands, Tanzania. Sci Afr 6: e00214. DOI: 10.1016/j.sciaf.2019.e00214.

Manurung GCT, Hasanah Y, Hanum C, Mawarni L. 2020. The role of bamboo shoot and shallot extracts combination as natural plant growth regulator on the growth of binahong (*Anredera cordifolia*

(Ten.) Steenis.) in Medan. IOP Conf Ser: Earth Environ Sci 454: 012169. DOI: 10.1088/1755-1315/454/1/012169.
Marfirani M, Rahayu YS, Ratnasari E. 2014. Effect of various concentration of onion filtrate and rootone-F on the "rato ebu" cuttings jasmine growth. Lentera Bio 3: 73-76.
Misra S, Maikhuri RK, Kala CP, Rao KS, Saxena KG. 2008. Wild leafy vegetables: A study of their subsistence dietetic support to the inhabitants of Nanda Devi Biosphere Reserve, India. J Ethnobiol Ethnomed 4: 15. DOI: 10.1186/1746-4269-4-15.
Mukarlina, Linda R, Nurlaila N. 2014. Keanekaragaman jenis tanaman pekarangan di desa Pahauman Kecamatan Sengah Temila Kabupaten Landak, Kalimantan Barat. Saintifika 1 (16): 51-46. [Indonesian]
Nahlunnisa H, Zuhud EAM, Prasetyo LB. 2015. Penyebaran spasial keanekaragaman tumbuhan pangan dan obat di Kampung Nyungcung, Desa Malasari, Kecamatan Nanggung, Bogor. Media Konservasi 20 (3): 187-196. DOI: 10.29244/medkon.20.3.%p. [Indonesian]
Nazikussabah, Zaharudin, Hazrulrizawati, Hamid, Dzulkaflee NF. 2017. Nutrient Content in Malaysia torch ginger flower (*Etlingera elatior*). 15th Asean Food Conference-Food Science and Technology 2017. 14-17 November 2017, Vietnam.
Paikra BK, Dhongade HKJ, Gidwani B. 2017. Phytochemistry and pharmacology of *Moringa oleifera* Lam. J Pharmacopunct 20 (3): 194-200. DOI: 10.3831/KPI.2017.20.022.
Prameswari S, Pratomo B. 2021. The effect of shallot extract and auxin-plant growth regulators on the growth of *Mucuna bracteata* D.C.. Agrinula Jurnal Agroteknologi dan Perkebunan 4 (2): 130-138. DOI: 10.36490/agri.v4i2.164. [Indonesian]
Purba EC, Silalahi M. 2021. Edible plants of the Batak Karo of Merdeka District, North Sumatra, Indonesia. Ethnobot Res Appl 22: 01. DOI: 10.32859/era.20.1.1-16.
Rachkeeree A, Kantadoung K, Suksathan R. 2018. Nutritional compositions and phytochemical properties of the edible flowers from selected Zingiberaceae found in Thailand. Front Nutr 5: 3. DOI: 10.3389/fnut.2018.00003.
Ralte L, Bhardwaj U, Singh YT. 2021. Traditionally used edible Solanaceae plants of Mizoram, India have high antioxidant and antimicrobial potential for effective phytopharmaceutical and nutraceutical formulations. Heliyon 7 (9): e07907. DOI: 10.1016/j.heliyon.2021.e07907.
Reksohadiprodjo S. 1994. Produksi Tanaman Hijau Makanan Ternak Tropik. BPFE, Yogyakarta. [Indonesian]
Robi Y, Kartikawati SM, Muflihati. 2019. Etnobotani rempah tradisional di desa Empoto Kabupaten Sanggau Kalimantan Barat. J Hutan Lestari 7 (1): 130-142. DOI: 10.26418/jhl.v7i1.31179. [Indonesian]
Rusdy M. 2016. Elephant grass as forage for ruminant animals. Livest Res Rural Dev 28: 4.
Sallau AB, Mada SB, Ibrahim S, Ibrahim U. 2012. Effect of boiling, simmering and blanching on the antinutritional content of *Moringa oleifera* leaves Intl J Food Nutr Saf 2: 1-6.
Samuels J. 2015. Biodiversity of food species of the Solanaceae family: A preliminary taxonomic inventory of subfamily Solanoideae. Resources 4 (2): 277-322. DOI: 10.3390/resources4020277.
Seal T, Pillai B, Chaudhuri K. 2017. Evaluation of nutritional potential of five unexplored wild edible plants consumed by the tribal people of Arunachal Pradesh State in India. J Food Nutr Res 5: 1-5. DOI: 10.12691/jfnr-5-1-1.
Setyawan HB, Yulianto R, Zelin O, Purnamasari L. 2021. Potential of three taro (*Colocasia esculenta* L.) cultivars as animal feed. ASEAN J Sci Technol Develop 38 (3): 97-102. DOI: 10.29037/ajstd.716.
Silalahi U. 2018. Metode Penelitian Sosial. Refika Aditama, Bandung. [Indonesian]
Sirait J. 2017. Dwarf elephant grass (*Pennisetum purpureum* cv. Mott) as forage for ruminant. Indonesian Bull Anim Vet Sci 27 (4): 167-176. DOI: 10.14334/wartazoa.v27i4.1569. [Indonesian]
Sukmawati N, Yuniati E, Pitopang R. 2013. Studi etnobotani tumbuhan obat pada masyarakat Suku Kaili Rai di Desa Toga Kecamatan Ampibabo Kabupaten Parigi Moutong Sulawesi Tengah. J Bio Celebes 2 (7): 9-14. [Indonesian]
Sultana S. 2020. Nutritional and functional properties of *Moringa oleifera*. Metabol Open 8: 100061. DOI: 10.1016/j.metop.2020.100061.
Sunesi I, Wiryono. 2007. Keanekaragaman jenis tumbuhan yang dimanfaatkan oleh penduduk desa yang tinggal di sekitar hutan lindung di Kabupaten Kepahiang, Provinsi Bengkulu. J Ilmu-Ilmu Pertanian Indonesia 432-439. [Indonesian]
Susanti E. 2011. Pengaruh Pemberian Berbagai Konsentrasi Filtrat Umbi Bawang Merah (*Allium ascolanicum* L.) dan Rootone-F terhadap Pertumbuhan Vegetatif Tanaman Jambu Air (*Syzygium aqueum* L.) dengan Cara Stek Batang. [Skripsi]. Universitas Negeri Surabaya, Surabaya. [Indonesian]
Tulakan Sub-district. 2022. Kecamatan Tulakan. https://tulakan.pacitankab.go.id. [30 December 2021] [Indonesian]
Umartani LA, Nahdi MS. 2021. Ethnobotanical Study of Edible Plant Communities on the Slopes of Mount Merapi and Merbabu, Indonesia. Biol Med Nat Prod Chem 10: 33-39. DOI: 10.14421/biomedich.2021.101.33-39.
Uprety Y, Poudel RC, Shrestha KK, Rajbhandary S, Tiwari NN, Shrestha UB, Asselin H. 2012. Diversity of use and local knowledge of wild edible plant resources in Nepal. J Ethnobiol Ethnomed 8: 16. DOI: 10.1186/1746-4269-8-16.
Viet TQ, Kien DD. 2001. Dried rice straw-chicken litter and urea-treated rice straw as main fodder resources for local cattle in the dry season. Livest Res Rural Dev 13: 2.
Wijekoon JO, Karim AA, Bhat R. 2011. Evaluation of nutritional quality of torch ginger (*Etlingera elatior* Jack.) inflorescence. Intl Food Res J 18: 1415-1420.
Xu Y, Liang D, Wang G-T, Jun Wen J, Wang R-J. 2020. Nutritional and functional properties of wild food-medicine plants from the coastal region of South China. J Evid Based Integr Med 25: 2515690X20913267. DOI: 10.1177/2515690X20913267.
Yulianti D, Purnama AA, Brahmana EM. 2018. Keanekaragaman tanaman pekarangan di desa Tambusai TImur Kecamatan Tambusai Kabupaten Rokan Hulu Provinsi Riau. J Sains dan Teknologi 10 (1) : 13-19. DOI: 10.31958/js.v10i1.1213. [Indonesian]

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Ecology and microhabitat model of long-tongued fruit bat *Macroglossus minimus* (Chiroptera: Pteropididae) in karst ecosystem of Klapanunggal, Bogor, West Java, Indonesia

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Abstract. *Wibowo AA, Basukriadi A, Nurdin E, Benhard G. 2022. Ecology and microhabitat model of long-tongued fruit bat* Macroglossus minimus *(Chiroptera: Pteropididae) in karst ecosystem of Klapanunggal, Bogor, West Java, Indonesia. Intl J Trop Drylands 6: 11-15.* Karst ecosystem is an important habitat for Chiroptera, including the long-tongued fruit bat *Macroglossus minimus* (E.Geoffroy, 1810) that feeds on nectar. While Klapanunggal is a karst ecosystem located in Bogor, West Java, Indonesia, Klapanunggal has potential Chiroptera habitat. Here, this study aims to assess and model microhabitat covariates that contribute to the density of *M. minimus* in Klapanunggal. The sampling sites in Klapanunggal karst covered forest, plantation, and settlement sites. Measured microhabitat covariates, including tree covariates (canopy covers, Normalized Difference Vegetation Index/NDVI, diversity, height), air humidity, distance to a river, and distance to a cave. The microhabitat model was developed and measured using Akaike Information Criterion (AIC). The result shows a high density of *M. minimus* was observed in the plantation site (13.96 inds./100 m^2, 95%CI: 4-23 inds./100 m^2), followed by the forest (7.13 inds./100 m^2, 95%CI: 1-14 inds./100 m^2), and settlement sites (4.7 inds./100 m^2, 95%CI: 1-10 inds./100 m^2). Based on AIC values, the best model explaining the microhabitat covariates that have positive effects on the density of *M. minimus* were tree diversity and NDVI. While humidity and distance to river covariates have negative effects. Density of *M. minimus* was positively correlated with increase in tree diversity (AIC= 14.73, r= 0.93) and NDVI (AIC= 22.09, r= 0.18) values. The limiting factors of *M. minimus* populations were high air humidity (AIC= 2.85, r= 0.99) and increase in distance to river (AIC= 20.85, r= 0.46). To conclude, the conservation of *M. minimus,* particularly the karst ecosystem, should emphasize increasing tree diversity.

Keywords: AIC, covariate, density, NDVI, tree

Abbreviations: AIC: Akaike Information Criterion, NDVI: Normalized Difference Vegetation Index

INTRODUCTION

Chiroptera is a mammalian group commonly known as bats. The Chiroptera group comprises more than 1300 species, which covers almost 25% of the Mammalia class. While in Indonesia, there are approximately 215 bat species (Nurfitrianto et al. 2013). Chiroptera has a wide variety of feeding guilds, including frugivores, pollinivores/ nectarivores, carnivores, omnivores, insectivores, piscivores, and hematophagous. This great foraging diversity enables Chiroptera to have many ecological roles, including seed dispersal and natural insect control. Hence, the Chiroptera population is very important for ecosystems. Bat diversity and endemism in Indonesia are high, with 6 islands for fruit bats, and the percentage number of endemism accounts for 0-22.7% (Maryanto and Higashi 2011).

Macroglossus is nocturnal nectarivores and feeds on nectar. It has a wide geographical range since it is found in several countries in South and Southeast Asia (Nangoy et al. 2021). The main characteristic of this species is the longer snout. The microhabitat of *Macroglossus* ranges from wooded or disturbed to rural habitats. In other forest habitats, *Macroglossus* favors the flowers of wild banana trees, and in rural areas, they favor cultivated banana trees (*Musa paradisiaca* L.). *Macroglossus* are also known to visit the flowers of durian (*Durio zibethinus* Murray), coconut (*Cocos nucifera* L.), and guava (*Syzygium samarangense* (Blume) Merr. & L.M.Perry) (Phillipps and Phillipps 2018). By day, *Macroglossus* roost alone or in small groups, typically beneath large palm leaves (Nangoy et al. 2021).

One important habitat for bats is the karst ecosystem. In Southeast Asian regions, including Indonesia, karst possesses high species diversity and levels of endemism (Clements et al. 2006). Karst formations provide roosting sites for large aggregations and substantial numbers of bat species (Vermeulen and Whitten 1999; Mickeburgh et al. 2002). Asian karst ecosystem (Furey et al. 2010) with its caves has been identified as one of four regional priorities for bat conservation research (Kingston 2008). Indonesia has a vast karst area, indicating a great potential for karst biodiversity (Sulistiyowati et al. 2021). In contrast, West Java is a region that has a vast karst ecosystem with biodiversity potential (Putri et al. 2017).

Klapanunggal in Bogor, West Java, Indonesia, is a region that still has a karst ecosystem (Pambudi et al. 2020). The information and data of Chiroptera, particularly *Macroglossus* in this karst, is still limited. So then, this study aims to assess and model the ecology and microhabitat of *Macroglossus* in this karst ecosystem. The findings from this study can be used to support the conservation of Klapanunggal karst and Chiroptera species.

MATERIALS AND METHODS

Study area

The study area was the karst ecosystem in Klapanunggal, Bogor, West Java, Indonesia (Figure 1). This ecosystem is a combination of forests, plantations, and settlements. Klapanunggal is within Bogor District, with high rainfall of 2500-5000 mm/year. The temperature range is 21-26ºC, and the average humidity is 70%.

Procedures

Survey and density of Macroglossus minimus

The study and bat observation was conducted in June 2021 in several sampling sites covering forest, plantation, and settlement. The observation followed previous methods (Bansa et al. 2020; Senawi et al. 2020) and was conducted at noon from 17.00 to 19.00 following bat activity times within a 10 m x 10 m grid (100 m^2) in each sampling site. There were 3 replicated observations in each sampling site. First, Chiroptera abundances were recorded and denoted as individuals/100 m^2. The observed Chiroptera was then identified using a field guidebook by Suyanto (2001) and Prasetyo et al. (2011). For identification purposes, bats were captured following methods by Kunz et al. (2009). For capturing the bats, a mist net sizing 6 m wide x 2.5 m high at 2-3 m above the ground near potential fruit trees (Mubarok et al. 2021a,b) was set up in several sampling sites covering forest, plantation, and settlement. Bats were released after identifications.

Microhabitat covariates

The microhabitat was assessed based on in situ measurement of several environmental covariates, including trees, climate, and physics. The tree covariates were tree diversity (Susilowati et al. 2020), height, cover, and Normalized Difference Vegetation Index/NDVI. The tree diversity was based on the measurement of the number of tree species within a 100 m^2 grid that was used to observe the bats. The recorded tree species was then measured for its length, denoted in m. The tree covers were measured based on the areas of the tree canopy divided by 100 m^2 using the following equation:

$$\text{Tree cover } (\%) = \frac{\text{canopy area}}{100 \text{ m}} \text{ x } 100\%$$

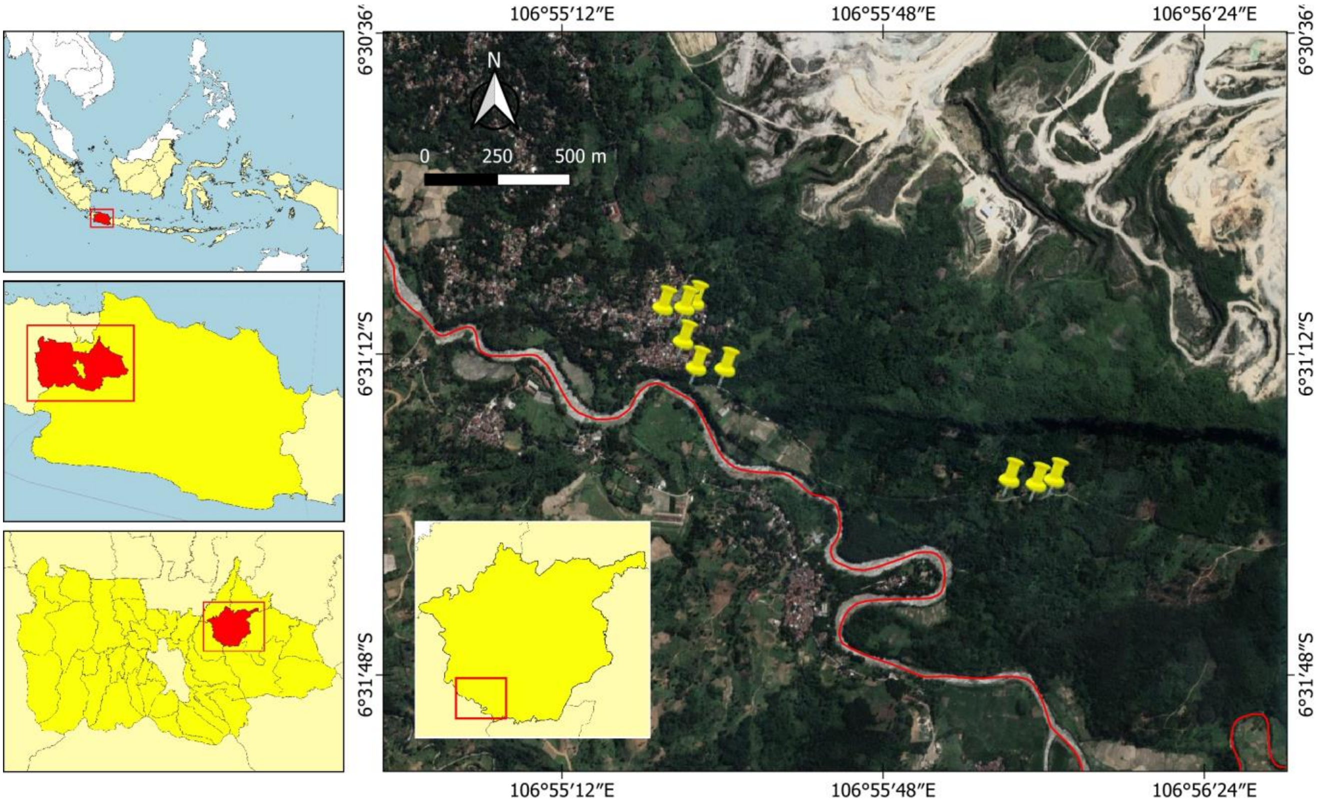

Figure 1. A map of the study area shows nine sampling sites covering forest, plantation, and settlements in the Klapanunggal karst ecosystem, West Java, Indonesia, selected based on the bat preferences and microhabitat variations

The method to measure NDVI of Klapanunggal karst was following Philiani et al. (2016), Kawamuna et al. (2017), and Sukojo and Arindi (2019). The NDVI is described as a simple graphical indicator that can be used to analyze remote sensing measurements, often from a space satellite platform, assessing whether or not the target being observed contains live green vegetation. The NDVI was measured by analyzing the wavelength of satellite image retrieved from Landsat 8 Operational Land Imager (OLI) containing vegetation image, and in this study was forest covers. This measurement is possible since the cell structure of the vegetation leaves strongly reflects near-infrared light wavelengths ranging from 0.7 to 1.1 µm. The calculation of NDVI for each pixel of vegetation pixel was as follows:

NDVI= near-invisible red wavelength – red wavelength / near-invisible red wavelength + red wavelength

The NDVI was denoted as a range from 0 (no vegetation) to 1(high vegetation density). GIS overlaps and maps the NDVI values into Klapanunggal karst land cover layers. The forest covers are then categorized and classified by using NDVI as follows:

- if 0 < NDVI < 0.3 then forest covers < 50%
- if 0.31 < NDVI < 0.4 then forest covers are 50-69%
- if 0.41 < NDVI < 1.0 then forest covers are 70-100%

Climate covariate was measured based on humidity (%). The humidity was recorded using a hygrometer and denoted as %. The physical covariates included distance from sampling sites to nearby rivers and caves and were denoted as a meter (m). The karst ecosystem was characterized by the presence of a cave due to the geological process. Besides that, in the karst ecosystem, bat populations frequently roost caves (Furey et al. 2010).

Data analysis

Principal component analysis and ecology model

The *Macroglossus minimus* (E.Geoffroy, 1810) density correlations with microhabitat covariates (tree canopy covers, NDVI, diversity, height, air humidity, distance to river, and distance to cave) were modeled using Principal Component Analysis (PCA) and validated using Akaike Information Criterion (AIC). The AIC was developed using linear regression with straight-line fit equations of $y_i = b_0 + b_1x_i + \varepsilon_i$. The ε_i represents the residuals from the straight-line fit. If the ε_i is considered to be i.i.d. (independent and identically distributed) Gaussian with zero means, the model contains three parameters: b_0, b_1, and the Gaussian distributions' variance. As a result, we should use k= 3 when calculating the AIC value of this model. In general, the variance of the residuals' distributions should be counted as one of the parameters in any least-squares model using i.i.d. Gaussian residuals. The measured parameters included in AIC, residual standard error, R-squared, F, and P values. Microhabitat covariates correlating with *M. minimus* density were included in the analysis to build and develop the model. The best model was selected based on the model that has the lowest AIC values.

RESULTS AND DISCUSSION

The density of *Macroglossus minimus*

The result (Figure 2) shows that the average density of *M. minimus* in plantation site (13.96 inds./100 m^2, 95%CI: 4-23 inds./100 m^2) was the highest, followed by forest (7.13 inds./100 m^2, 95%CI: 1-14 inds./100 m^2) and settlement sites (4.7 inds./100 m^2, 95%CI: 1-10 inds./100 m^2). The tree diversity and status varied among sites (Table 1). Settlement and plantation sites have more fruiting tree species than forest sites. Fruiting trees were absent in forest sites. In contrast, trees in forest sites were taller than in other sites.

Principal component analysis and model of *Macroglossus minimus*

PCA (Figure 3) shows several microhabitat covariates with positive, negative, and neutral effects on *M. minimus* density. Covariates that have positive effects, including tree diversity and NDVI. That indicates increasing numbers of trees and NDVI values are causing an increase in *M. minimus* density. In contrast, increasing air humidity and distance to the river will reduce the *M. minimus* density. Tree cover, tree height, and distance to the cave have insignificant effects on density. Significant effects of tree diversity, NDVI, air humidity, and distance to river covariates were validated by AIC values (Table 2). Those covariates have lower AIC values than other covariates, indicating the best covariates to describe the microhabitat model of *M. minimus* density in the Klapanunggal karst ecosystem.

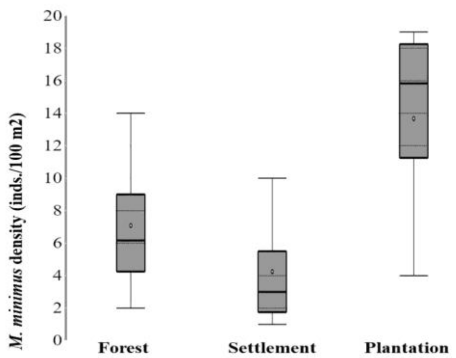

Figure 2. Boxplots of *M. minimus* density (inds./100 m^2) in forest, plantation, and settlement sites in Klapanunggal karst ecosystem, Bogor, West Java, Indonesia

Table 1. Tree diversity in several sites in Klapanunggal karst ecosystem, Bogor, West Java, Indonesia

Sites	Tree species	Status	Height (m)
Forest	*Neolamarckia cadamba*	No fruit	7
	Leucaena leucocephala	No fruit	15.2
Settlement	*Musa paradisiaca*	Fruiting	3.8
	Mangifera indica	Fruiting	5.4
	Cocos nucifera	Fruiting	10.2
Plantation	*Musa paradisiaca*	Fruiting	3.5
	Tectona grandis	No fruit	12.4
	Cocos nucifera	Fruiting	3.3

Table 2. The AIC model of *M. minimus* density with microhabitat covariates (tree canopy covers, NDVI, diversity, height), air humidity, distance to the river, and distance to cave

Microhabitat covariates	AIC	Residual standard error	R-squared	F	P
Tree cover	22.547	6.608	0.054	0.057	0.89
Tree NDVI	22.096*[a]	6.129	0.186**	0.228	0.631
Tree diversity	14.732*[a]	1.796	0.93**	13.31	0.000
Tree height	22.496	6.553	0.069	0.075	0.859
Humidity	2.857*[b]	0.248	0.998**	748	0.000
River distance	20.856*[b]	4.985	0.461**	0.857	0.211
Cave distance	22.0916	6.129	0.182	0.228	0.639

Note: *Best model, **significant correlation, [a]positive correlation, [b]negative correlation

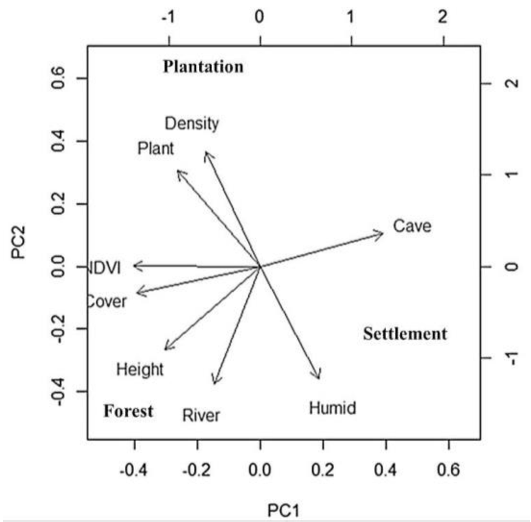

Figure 3. PCA of *M. minimus* (Density) with tree cover, tree NDVI, tree diversity (Plant), tree height, air humidity (Humid), distance to the river (River), and distance to the cave (Cave) in the forest, plantation, and settlement sites in Klapanunggal karst ecosystem, Bogor, West Java, Indonesia

Discussion

The presence of *M. minimus* in Klapanunggal karst is associated with the presence of trees. Karst ecosystem has high tree diversity that can support the bat populations. Karst in Bogor areas was known to have 80 species from 41 families, with the domination of Melastomataceae and Urticaceae (Putri et al. 2017). In Klapanunggal, tree diversity in settlement and plantation sites was dominated by tree species that have commercial values, including *M. paradisiaca* (banana tree), *Mangifera indica* (mango tree), and *C. nucifera* (coconut tree).

Based on the result and model, *M. minimus* was significantly correlated with the tree diversity covariates. This species prefers a habitat with high tree diversity. The *M. minimus* roosts in rolled leaves, large palm leaves, in-ground plants, or under tree branches. *M. minimus* roosts alone or in small groups. These roost sites are sometimes in the trees used for foraging. The *M. minimus* feeds primarily on nectar and pollen and drinks soft fruit juices (Nowak 1991). The flowers *M. minimus* mainly feeds on are from plants of the banana tree (Musaceae), the coconut tree (*C. nucifera*), and even mangroves (Sonneratiaceae) (Gunnell et al. 1996). The high density of *M. minimus* in the plantation of Klapanunggal was associated with the presence of banana trees. That is considering that banana trees dominated plantations in rural West Java. During the survey, the trees were at the fruiting stages. Lower density in forest sites compared to plantation sites despite the preference for tall trees, high tree covers, and NDVI was related to the limited numbers of fruiting trees. In the forest sites, the tree species were *Neolamarckia cadamba* (Roxb.) Bosser and *Leucaena leucocephala* (Lam.) de Wit were not producing fruit.

The density of *M. minimus* in the forest was close to the density in settlements rather than a plantation. The forest site was close to the settlement site, creating a mixed habitat. Borneo's combination of pristine forest habitat with the heavily disturbed forest has provided diverse microhabitat assemblage structures and forest tree species exploration for bats (Bansa et al. 2020). In this study, the disturbed habitat in the form of settlement had the lowest density. This condition is comparable to the previous findings. Settlement sites were characterized by low tree covers and indicating an open habitat. These low abundances may reflect that many bats combine wing morphologies and echolocation call designs, ill-suited for prey detection and capture in the more open habitats typical of degraded landscapes comparable to settlement sites.

In the Klapanunggal karst, the limiting covariates of *M. minimus* were humidity and distance to the river. The *M. minimus* density was lower when the distance to the river was high. In Klapanunggal, water resources were available in the form of river streams in the south of sampling sites, whether in forest, settlement, or plantation sites. This finding agrees with the findings from other studies (Downs and Racey 2006; Kelm et al. 2014). Bat is also a mammal that experiences dehydration; drinking water and proximity to water resources are fundamental covariates for all terrestrial mammals. Furthermore, considering the bat's peculiar morphology and physiology, much water is lost through the bat's body surface, especially via the respiratory system and the extensive surfaces of wing membranes. Then, for this reason, bats prefer to forage in sites close to water resources (Russo et al. 2012), which explains negative correlations between distance to the river and *M. minimus* density.

Besides distance to the river, another covariate affecting the density of *M. minimus* was the humidity. In Klapanunggal karst, an increase in humidity will reduce *M. minimus* density. The presence of bats decreased with an increase in humidity, consistent with previous studies since humidity influenced total bat activity levels and foraging activity. General bat presence and activity and foraging activity decreased with humidity covariates. Humidity affects thermoregulation processes involved in bat flight (Katunzi et al. 2020).

To conclude, the presence and distributions of *M. minimus* across karst ecosystems were varied. Those variations were influenced by numerous environmental covariates, including canopy cover, NDVI, diversity, height, air humidity, distance to a river, and distance to a cave. Among those covariates, river distance and humidity were the limiting covariates for bats. In contrast, tree NDVI and density were covariates supporting the *M. minimus* population.

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REFERENCES

Bansa L, Qhairil R, Ummu D, Amirrah A. 2020. Survey on the small mammals in Kangkawat Research Station Imbak Canyon Conservation Areas. J Trop Biol Conserv 17: 149-163.

Clements R, Sodhi NS, Schilthuizen M. 2006. Limestone karsts of Southeast Asia: Imperiled arks of biodiversity. Bioscience 56: 733-742. DOI: 10.1641/0006-3568(2006)56[733:LKOSAI]2.0.CO;2.

Downs N, Racey P. 2006. The use by bats of habitat features in mixed farmland in Scotland. Acta Chiropterologica 8: 169-185. DOI: 10.3161/1733-5329(2006)8[169:TUBBOH]2.0.CO;2.

Furey N, MackieI, Racey P. 2010. Bat diversity in Vietnamese limestone karst areas and the implications of forest degradation. Biodivers Conserv 19: 1821-1838. DOI: 10.1007/s10531-010-9806-0.

Gunnell A, Yani M, Kitchener D. 1996. Proceedings of the First International Conference on Eastern Indonesian-Australian Vertebrate Fauna. Western Australian Museum, Perth, Australia.

Katunzi T, Soisook P, Webala P, Armstrong K. 2020. Bat activity and species richness in different land-use types in and around Chome Nature Forest Reserve, Tanzania. Afr J Ecol 59: 1-15. DOI: 10.1111/aje.12783.

Kawamuna Al, Suprayogi A, Wijaya AP. 2017. Analisis kesehatan hutan mangrove berdasarkan metode klasifikasi NDVI pada citra Sentinel-2 (Studi Kasus: Teluk Pangpang Kabupaten Banyuwangi. J Geodesi Universitas Diponegoro 6 (1): 277-284. [Indonesian]

Kelm D, Lenski J, Kelm V. 2014. Seasonal bat activity in relation to distance to hedgerows in an agricultural landscape in Central Europe and implications for wind energy development. Acta Chiropterologica 16 (1): 65-73. DOI: 10.3161/150811014X683273.

Kingston T. 2008. Research priorities for bat conservation in Southeast Asia: A consensus approach. Biodivers Conserv 19 (2): 471-484. DOI: 10.1007/s10531-008-9458-5.

Kunz TH, Hodgkison R, Weise CD. 2009. Methods of capturing and handling bats. In: Kunz TH, Parsons S (eds). Ecological and Behavioural Methods for the Study of Bats. Johns Hopkins University Press, Baltimore.

Maryanto I, Higashi.S. 2011. Comparison of zoogeography among rats, fruit bats and insectivorous bats on Indonesian Islands. Treubia 38: 33-52.

Mickeburgh SP, Hutson AM, Racey PA. 2002. A review of the global conservation status of bats. Oryx 36: 18-34. DOI: 10.1017/S0030605302000054.

Mubarok H, Satuti N, Arisuryanti T, Maryanto I. 2021b. Haematology profile of fruit bats *Cynopterus* spp. from Special Region Yogyakarta, Indonesia. Malay Appl Biol 50: 1-9. DOI: 10.55230/mabjournal.v50i1.17.

Mubarok H, Satuti N, Maryanto I, Arisuryanti T. 2021a. Karyotype variation in lesser short-nosed fruit bat *Cynopterus brachyotis* (Müller 1838) from Special Region Yogyakarta, Indonesia. Biodiversitas 22: 2560-2568. DOI: 10.13057/biodiv/d220514.

Nangoy M, Ransaleleh T, Lengkong H, Koneri R, Latinne A, Kyes RC. 2021. Diversity of fruit bats (Pteropodidae) and their ectoparasites in Batuputih Nature Tourism Park, Sulawesi, Indonesia. Biodiversitas 22: 3075-3082. DOI: 10.13057/biodiv/d220609.

Nowak R. 1991. Walker's Bats of the World. The Johns Hopkins University Press, Baltimore, Maryland.

Nurfitrianto H, Budijastuti W, Faizah U. 2013. Kekayaan jenis kelelawar (Chiroptera) di kawasan Gua Lawa Karst Dander Kabupaten Bojonegoro. LenteraBio: Berkala Ilmiah Biologi 2 (2): 143-148. [Indonesian]

Pambudi R, Falah A, Naldi A, Bahri NF. 2020. Satellite imagery detection of land destruction in Klapanunggal Karst landscape induced by limestone surface mining. E3S Web Conf 211: 1-10. DOI: 10.1051/e3sconf/202021104002.

Philiani I, Saputra L, Harvianto L, Muzaki AA. 2016. Pemetaan vegetasi hutan mangrove menggunakan metode Normalized Difference Vegetation Index (NDVI) Di Desa Arakan, Minahasa Selatan, Sulawesi Utara. Surya Octagon Interdisciplinary J Soc Technol 1 (2): 211-222.

Phillipps Q, Phillipps K. 2018. Phillipps' Field Guide to the Mammals of Borneo and Their Ecology. (2nd ed.). John Beaufoy Publishing Ltd., Oxford.

Prasetyo PN, Noerfahmy S, Tata HL. 2010. Jenis-Jenis Kelelawar Khas Agroforest Sumatera: Teknik Survei & Identifikasi. World Agroforestry Centre. [Indonesian]

Putri W, Qayim I, Qadir A. 2017. Soil seed bank of two karst ecosystems in Bogor, Indonesia: Similarity with the aboveground vegetation and its restoration potential. J Trop Life Sci 7 (3): 224-236. DOI: 10.11594/jtls.07.03.07.

Russo D, Cistrone L, Jones G. 2012. Sensory ecology of water detection by bats: A field experiment. PLoS ONE 7 (10): e48144. DOI: 10.1371/journal.pone.0048144.

Senawi J, Mahyudin A, Daud US, Amat A. 2020. Bat diversity in Imbak Canyon Conservation Area: Note on their echolocation calls and ectoparasites. J Trop Biol Conserv 17: 217-232.

Sukojo BM, Arindi YN. 2019. Analisa perubahan kerapatan mangrove berdasarkan nilai Normalized Difference Vegetation Index menggunakan Citra Landsat 8 (Studi Kasus: Pesisir Utara Surabaya). Geoid J Geod Geom 14 (2): 1-5. DOI: 10.12962/j24423998.v14i2.3874. [Indonesian]

Sulistiyowati E, Setiadi, Haryono E. 2021. Karst and conservation research in Indonesia and its implication to education. J Phys: Conf Ser 1796: 012071. DOI: 10.1088/1742-6596/1796/1/012071.

Susilowati A, Elfiati D, Rachmat HH, Yulita KS, Hadi AN, Kusuma YS, Batu SAL. 2020. Vegetation structure and floristic composition of tree species in the habitat of *Scaphium macropodum* in Gunung Leuser National Park, Sumatra, Indonesia. Biodiversitas 21: 3025-3033. DOI: 10.13057/biodiv/d210720.

Suyanto A. 2001. Kelelawar di Indonesia. (Bats of Indonesia). Puslitbang Biologi-LIPI, Cibinong. [Indonesian]

Vermeulen JJ, Whitten AJ. 1999. Biodiversity and Cultural Property in the Management of Limestone Resources. The World Bank, Washington, DC. DOI: 10.1596/0-8213-4508-7.

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Ethnobotany of semi-arid medicinal plants used by Bunaq Tribe in Lamaknen, Belu District, East Nusa Tenggara, Indonesia

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Abstract. *Mela YJA, Bria EJ, Tnunay IMY. 2022. Ethnobotany of semi-arid medicinal plants used by Bunaq Tribe in Lamaknen, Belu District, East Nusa Tenggara, Indonesia. Intl J Trop Drylands 6: 16-25.* The diversity of traditional medicinal plants of the Bunaq Tribe in Lamaknen, Belu District, East Nusa Tenggara, Indonesia, is a basic study of the development of local potential in supporting plant conservation in the border areas of Indonesia. This study aimed to determine the types of medicinal plants, the organs used, processing methods and ways of using plants as traditional medicines, and species use-values (SUV) by the Bunaq Tribe in Belu District, a semi-arid climatic area in Timor Island, Indonesia. This study uses a descriptive qualitative and quantitative approach. The research method used was semi-structured interviews with village shamans. The results showed that there were 26 families consisting of 63 species of plants used as medicine. Fabaceae had the highest number of species used in medicine. The most widely used growth form was a tree and the most frequently used plant part was the leaf (30%). The most widely applied processing method was boiling. Turmeric (*Curcuma longa* L.) showed the highest use-value, 0.57, compared to other species. In conclusion, the Bunaq Tribe still preserves traditional knowledge of medicinal plants through village shamans. This information can be used as the basis for developing the social and cultural values of the Bunaq Tribe in the border areas of Indonesia.

Keywords: Bunaq Tribe, Lamaknen, medicinal plants

INTRODUCTION

Lamaknen is a Sub-district in Belu District, East Nusa Tenggara, located at the border between Indonesia and East Timor. This sub-district consists of nine villages: Dirun, Duarato, Fullur, Kewar, Lamaksenulu, Leowalu, Makir, Mauhitas, and Maudemu (Belu District Profile 2020). The community is dominated by the Bunaq Tribe, who still use natural resources to meet their daily needs. They also use plants for hereditary spiritual interests (Atok et al. 2010). Traditional medicinal practices have developed from generation to generation based on natural medicines, spiritual therapies, manual techniques, and exercises to diagnose, treat, and prevent disease (Bussmann et al. 2010). Traditional medicine is quite popular in this area and is accepted by the wider community even though there are modern health facilities (Yuliani et al. 2019). Besides being used as a first-aid system in the family, traditional medicine is considered cheaper and safer than modern drugs because of the low risk (Rahayu and Andini 2019; Nugroho et al. 2022).

Belu District has an average temperature of 27.6°C with a temperature interval of 21.5-33.7°C; the lowest temperature (21.5°C) in August and the highest temperature (33.7°C) in November. According to the climate classification by Schmidt and Ferguson, the climate type in this district is D (semi-arid climate), with two seasons, namely dry and rainy seasons. The average rainfall for 5 years (2011-2015) is 209 mm/month, with the number of rainy days being 8 days/month. The wind currents in June- September come from Australia with little water vapor, while the winds in December-March contain a lot of water vapor from Asia and the Pacific Ocean. The district has four wet months (December-March) and eight dry months. Community life, including agricultural activities, adapts to this semi-arid climate condition (Belu District 2021)

One practice of traditional medicine is to use medicinal plants. The interaction between humans and plants is getting more intense with the times, resulting in the accumulation of human knowledge and expertise in herbal medicines (Yeung et al. 2020). However, knowledge about traditional medicine and medicinal plants is known only by certain people, and oral delivery has become a tradition in a community groups (Elfahmi et al. 2014; Silalahi and Nisyawati 2018). The ethnobotanical study can inventory, identify and evaluate the most important plant species for a given culture (Zenderland et al. 2019). In addition, this study is useful for uncovering community knowledge systems about biodiversity, conservation, and cultural resources (Albuquerque et al. 2006; Ledo and Seran 2019).

Several previous studies have revealed the distribution of medicinal plants in this area. For example, Atok et al. (2010) found that the Bunaq Tribe in Dirun Village, Belu District used sixty-nine species of medicinal plants. Furthermore, Yuliani et al. (2019) also revealed that the Bunaq Tribe in Kewar Village used twenty-nine traditional medicinal plants. However, these studies are very limited in area and scope even though this information is needed to conserve biodiversity in this region.

This study aimed to analyze the potential of naturally distributed medicinal plants and their use by the Bunaq Tribal community, especially by village shamans in Lamaknen Sub-district, Belu District, East Nusa Tenggara, Indonesia. This information can enrich the database of medicinal plants and their processing by the Bunaq Tribe and be the basis for the sustainable management of biological resources in border areas.

MATERIALS AND METHODS

Study area

This research was conducted in the Lamaknen Sub-district of Belu District, East Nusa Tenggara Province, Indonesia, a tropical semi-arid area. The focus area was the villages of Furur, Makir, and Duarato (Figure 1). Lamaknen has an area of 105.90 km^2. This hilly through to mountainous area has a semi-arid climate with two seasons: the rainy season, from November to May, and the dry season, from June to October. Lamaknen has 9 villages with a population of 13,195 in 2020 (Belu District Profile 2020). Most people are of the Bunaq Tribe and speak the local Marae language.

Selection of participants

Key participants were selected purposively and systematically based on the recommendations of knowledgeable elders and development agents (Jima and Megersa, 2018). The selection of key participants was also based on the cured diseases, personal experience in self-medication, and quality of explanations that particular participants gave during an interview. As a result, seven key informants were village shamans in the three research villages. They consisted of 3 men and 4 women with traditional expertise in medicinal plants known and commonly used by the Bunaq Tribe and others.

Techniques employed for data collection were semi-structured interviews, guided field walks, and observations with participants. Interviews were undertaken using questionnaires on botanical names and local names, parts used, and preparation mode. The use reports, relative importance, and voucher numbers were tabulated for all reported plant species (Hussain et al. 2018).

Specimen collection and identification

Field observations were performed with the help of local guides to describe the morphological features and habitats of each medicinal plant species in the field. Identification was done with the results of field descriptions and cross-checks using Flora of Java (Backer and Bakhuizen 1968) and integrated taxonomic information system report (itis.gov) and the plantlist.org to confirm the correct nomenclature of plant species.

Data analysis

Descriptive analysis was applied by tabulating the information into a specific table. That consisted of a family name, scientific name, and local name of the plant, plant habitus, plant part used as medicine, the name of the disease or disorder that is cured, and the method of processing that part of the plant. Then, the species use-value (SUV) was calculated to see the important plant species for the treatment of certain types of diseases in the study area using the following equation:

$$SUV = \frac{\sum UVis}{ni}$$

Where: *UVi* is the use-value of particular species, and *ni* is the total number of participants (Fathir et al. 2021).

RESULTS AND DISCUSSION

Medicinal plants used by the Bunaq Tribe

The Bunaq Tribal community in Lamaknen Sub-district used 26 families of plants consisting of 63 species (Table 1). Medicinal plants used by the Bunaq people vary greatly regarding species, locations, and organs used. The most widely used plant family was Fabaceae, consisting of 8 species, followed by Euphorbiaceae with 6 species, and Poaceae with 5 species, while others ranged from 1-4 species. Most Fabaceae in Lamaknen Sub-district is closely related to the location and environmental conditions. Atok et al. (2010) stated that Fabaceae is a family most widely used by the community in Dirun Village, Lamaknen Sub-district. Molares and Ladio (2012) also revealed that Fabaceae has an important role both as food and medicinal ingredients in Argentine-Chilean Patagonia. Napagoda et al. (2018) also found that Fabaceae is the community's most widely cited medicinal plant in Gampaha District, Western Province, Sri Lanka.

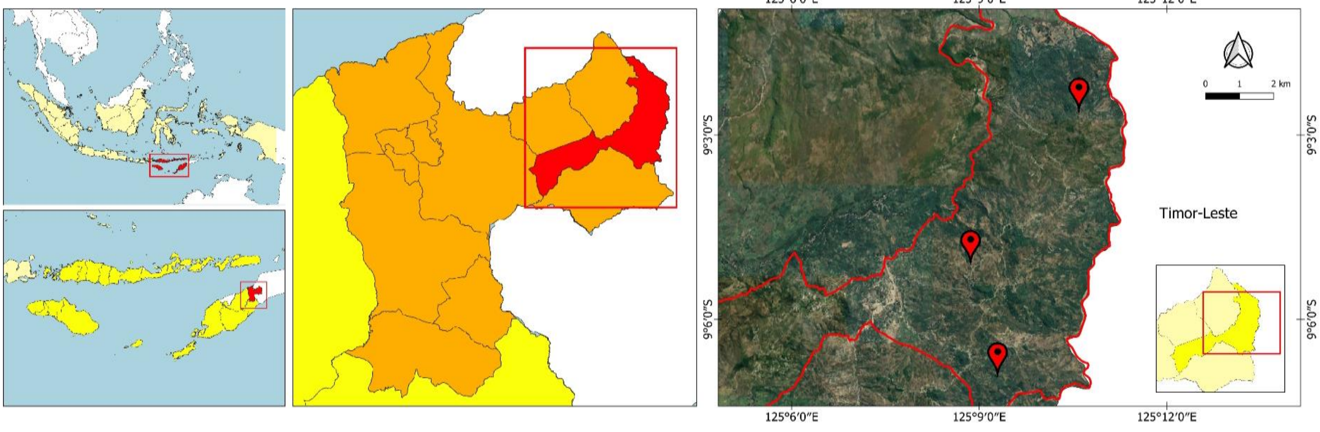

Figure 1. Map showing the study area in Lamaken Sub-district, Belu District, East Nusa Tenggara, Indonesia

The presence of plants in each village also varies greatly among villages in Lamaknen Sub-district. For example, Fulur, which has the most medicinal plants, is strongly influenced by environmental conditions where this village has a mountainous topography and a large forest area. The informants said that most plants used as medicine are wild plants taken from forests. That is because the condition of the forest around the Lamaknen Sub-district is still relatively good, and the community only uses it for traditional gardening and farming. That is also supported by Nagaike (2012), which states that if the condition of the forest is still good, the species found are also very diverse.

The most widely used medicinal plant habitus was a tree (41%) (Figure 2), which was followed by herb (36%), shrub (13%), liana (5%), grass (3%), and fern (2%). The tree was also the most widely used as a source of medicine by the Manobo tribe in the Philippines (Dapar et al. 2020) and by local communities around Lambung Mangkurat Education Forests, South Kalimantan, Indonesia (Nugroho et al. 2022).

The Bunaq Tribe uses plants' vegetative and generative organs as ingredients for traditional medicine. Roots, bark, stem, leaf, fruit, and tuber are used as medicine. The percentage of plant organs (Figure 3) shows that the most widely used plant organ in medicinal plants was the leaf (30%), followed by bark, root, rhizome, seed, fruit, and tuber. All vegetative organs of several plants, such as *Euphorbia heterophylla* L., *Euphorbia thymifolia* L., *Eleusine indica* (L.) Gaertn and *Equisetum debile* Roxb. ex-Vaucher were used as medicines.

Leaf was also the most widely used plant part of medicine by the people of Buwun Sejati Village, West Lombok District, Indonesia (Rahayu and Andini 2019), Batak Toba Tribe in Peadundung Village, North Sumatra, Indonesia (Silalahi et al. 2019), Tengger Tribe in Ngadisari Village, Indonesia (Jadid et al. 2020), Tengger Tribe in Ranu Pani Village, Indonesia (Bhagawan and Kusumawati 2021), local communities around Lambung Mangkurat Education Forests, South Kalimantan, Indonesia (Nugroho et al. 2022), Dayak Tribes, Borneo (Az-Zahra et al. 2021) Ayta community, Philippines (Tantengco et al. 2018), indigenous communities in the Bandarban District of Bangladesh (Faruque et al. 2018) and rural communities of arid regions of Northern Punjab, Pakistan (Ashfaq et al. 2019).

Leaves are widely used because they are easy to obtain and mix due to their high-water content. In addition, as a place for photosynthetic accumulation, leaves contain essential oils, phenols, potassium compounds, and chlorophyll, which can cure diseases (Nahdi and Kurniawan 2019). Alvionita et al. (2020) also revealed that using leaves does not damage other plant parts because the leaves are easy to grow back and are almost always plentiful in wet tropical climates.

Preparation and use of traditional medicinal plants by the Bunaq Tribe

The preparation and consumption of plants as ingredients for traditional medicine by the Bunaq Tribal community in Lamaknen Sub-district, Belu District, is very simple and varies based on the disease suffered by the patient. In this study, there were 34 prescription drugs, mostly a mixture of several plants (Table 2). The traditional treatment of the Bunaq Tribe consists of several methods: the material was boiled and then drunk (BO-DR), boiled and then washed (BO-WA), chewed and then lubricated (CH-LU), chewed and pasted (CH-PA), squeezed and drunk (SQ-DR), soaked with hot water and then drunk (SO-DR), and boiled and then eaten (BO-DA). Of the several methods, the most widely used is boiled and drunk (59%), and the lowest is squeezed and then drunk (3%) (Figure 4).

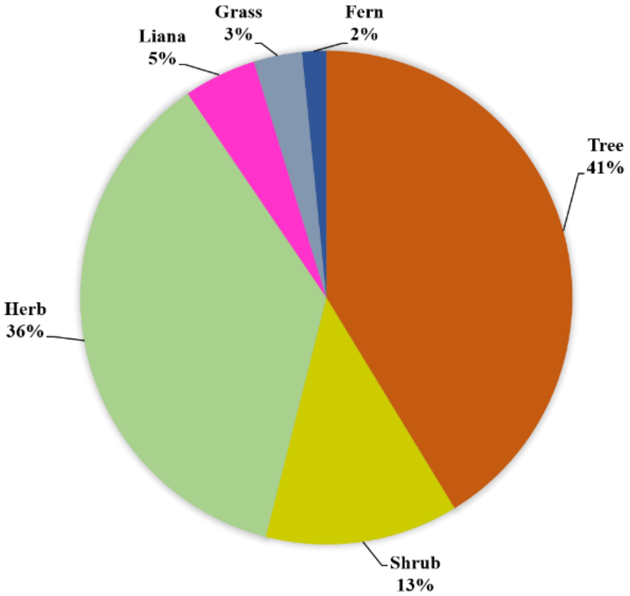

Figure 2. Percentage of medicinal plant habitus used by the Bunaq Tribe, Lamaknen Sub-district, Belu District, East Nusa Tenggara, Indonesia

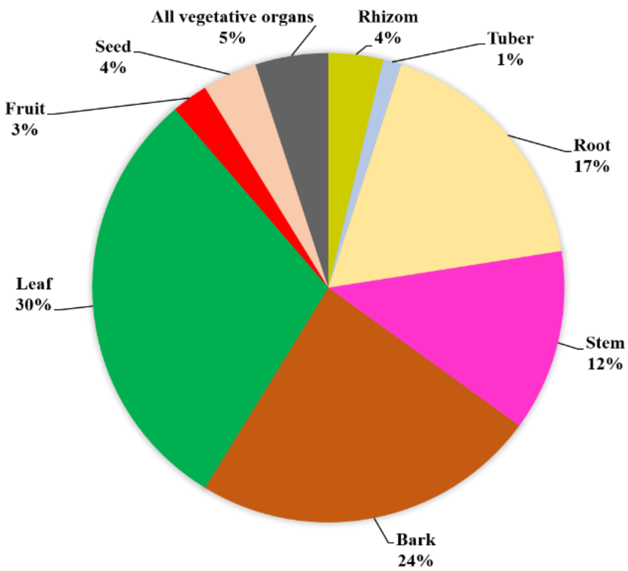

Figure 3. Percentage of plant parts/organs used as medicine by the Bunaq Tribe, Lamaknen Sub-district, Belu District, East Nusa Tenggara, Indonesia

Table 1. Medicinal plants record used by the Bunaq Tribe, Lamaknen Sub-district, Belu District, East Nusa Tenggara, Indonesia

Family	Botanical name	Common name	Local name	Use	Part of plant	Habitus	SUV
Fabaceae	*Cassia fistula* L.	golden shower	Arus norbeka	Bone fracture	Bark	Tree	0,14
	Vachellia farnesiana (L.) Wight & Arn	sweet acacia	Ailo'ok	HIV/AIDS	Root	Shrub	0,14
	Flemingia strobilifera (L.) W.T. Aiton	Wildhops	Ii	Indigestion /stomach ache, fever, snake peck	Root, bark	Shrub	0,29
	Senna siamea (Lam.) H.S. Irwin & Barneby	Siamese cassia	Tomol netel	HIV/AIDS	Root	Tree	0,14
	Albizia procera (Roxb) Benth	tall albizia	Jul geti	HIV/AIDS, fever, snake bite	Bark	Tree	0,29
	Pterocarpus indicus Willd.	Red sandalwood	Majo	Fluor albus/vaginal discharge	Bark	Tree	0,14
	Vigna radiata (L.) R.Wilczek	mung bean	Ho gapa	Appendix	Seed	Herb	0,14
	Arachis hypogaea L.	peanut	Ho'í	Breast cancer	Seed	Herb	0,14
Euphorbiaceae	*Euphorbia heterophylla* L.	Mexican fireplant	Uh suil	Appendix	Root, stem, leaf	Herb	0,14
	Euphorbia tirucalli L.	Indiantree spurge	Lawar geruk	Stroke, headache, fever, food poisoning, spiritual magic	Stem	Tree	0,14
	Sauropus androgynus (L.) Merr	chekurmanis, sweet leaf, star-gooseberry, katuk	Katuk	Breastfeeding production	Leaf	Shrub	0,14
	Jatropha gossypiifolia L.	bellyache bush	Alul geti	Fracture, swollen body	Bark	Shrub	0,14
	Euphorbia hirta L.	pillpod sandmat	Mau meak	Indigestion, fracture, swollen body	Stem, root	Herb	0,29
	Euphorbia thymifolia L.	gulf sandmat	Upe gol	Appendix	Root, stem, leaf	Herb	0,14
Poaceae	Imperata cylindrica (L.) Rausch.	satintail	Hut	Indigestion /stomach ache, stroke, headache, fever, food poisoning	Root, leaf	Grass	0,29
	Bambusa sp.	Bamboo	Mah olas	HIV/AIDS, stroke, headache, fever, food poisoning	Leaf	Tree	0,29
	Cymbopogon citratus (DC.) Stapf	lemongrass	Anmami	Indigestion	Stem	Herb	0,14
	Cymbopogon nardus (L.) Rendle	citronella grass	Anmami bule'en	Hepatitis	Stem	Herb	0,14
	Eleusine indica (L.) Gaertn	crowsfoot grass/Indian goose grass	Uh rikit	Kidney disease	Root, stem, leaf	Herb	0,14
Myrtaceae	*Psidium guajava* L.	Guava	Goiga riki	Diarrhea and vomiting	Leaf	Tree	0,14
	Syzygium aqueum (Burm.f.) Alston	watery rose apple	Pilip pokoi	Stroke, headache, fever, food poisoning, spiritual magic	Bark	Tree	0,14
	Eucalyptus urophylla S.T. Blake	Ampupu/Timor white gum	Tal geti	Stroke, headache, fever, food poisoning, spiritual magic	Bark	Tree	0,14
	Syzygium cumini (L.) Skeels	Java plum	Sibal lebo	Stroke, headache, fever, food poisoning, spiritual magic	Bark	Tree	0,14

Malvaceae	*Sida rhombifolia* L.	Arrow leaf sida	Kibu	Inpartu, HIV/AIDS, stroke, headache, fever, food poisoning, fracture, swollen body, kidney disease	Leaf	Herb	0,43
	Sterculia foetida L.	hazel sterculia	Bane	Orchitis/swollen testicles	Bark	Tree	0,14
	Ceiba pentandra (L.) Gaertn.	white silk-cotton tree/ kapok tree	Gela jhon	Malnutrition	Bark	Tree	0,14
Asteraceae	*Elephantopus scaber* L.	Elephant foot	Apa sakan	Waist pain	Root	Herb	0,14
	Pluchea indica (L.) Less.	Indian camphorweed/ Indian pluchea	Beluntas	Kidney disease	Leaf	Herb	0,14
	Ageratum conyzoides L.	tropical whiteweed	Uh sino	Wound	Leaf	Herb	0,14
	Chromolaena odorata (L.) R.M. King & H. Rob.	Jack in the bush/ Siamweed/ Kirinyuh	Siekelen	Gout	Leaf	Shrub	0,14
Zingiberaceae	*Curcuma longa* L.	Turmeric	Kirun	Indigestion, kidney disease, hypertension, hepatitis	Rhizome	Herb	0,57
	Zingiber officinale Linn. Var Rubrum	Red Ginger	Inma bule'en	Stroke, headache, fever, food poisoning, spiritual magic	Rhizome	Herb	0,29
	Curcuma xanthorrhiza Roxb.	Javanese turmeric/ temulawak	Kirun belis	Indigestion, hypertension	Rhizome	Herb	0,29
Apocynaceae	*Calotropis gigantea* (L.) Dryand.	giant milkweed	Hot gie oe	Stroke, headache, fever, food poisoning, spiritual magic, gout	Stem, leaf	Tree	0,29
	Plumeria rubra L.	frangipani, temple tree	Antoni	Appendix, indigestion	Bark	Tree	0,14
	Alstonia scholaris (L.) R. Br.	blackboard tree/ devil's tree	Joil	Appendix, indigestion	Bark	Tree	0,14
Lamiaceae	*Orthosiphon aristatus* (Blume) Miq	Cats' Whiskers, Java Tea	Kumis kucing	Hypertension	Leaf	Herb	0,14
	Scutellaria galericulata L.	hooded skullcap, marsh skullcap	Bulis gigo	Diarrhea and vomiting	Root	Herb	0,14
	*Plectranthus amboinicu*s (Lour.) Spreng.	Mexican mint	Hol si	Asthma	Leaf	Herb	0,14
Rubiaceae	*Coffea* sp	Coffee	Kopi jhon	Stroke, headache, fever, food poisoning, spiritual magic	Stem	Tree	0,14
	Timonius sericeus (Desf.) K.Schum.	Timo	Miel riki	Breast cancer, HIV/AIDS, Stroke, headache, fever, food poisoning, spiritual magic	Leaf	Tree	0,29
	Morinda citrifolia L.	Indian mulberry	Mengkudu	Kidney disease	Bark	Tree	0,14
Annonaceae	*Annona muricata* L.	Soursop	Kulo	Diarrhea and vomiting, cholesterol, diabetes	Bark	Tree	0,29
	Annona squamosa L.	sweet sop/ sugar apple	Anonak	Stomach ache	Bark	Tree	0,14

Apiaceae	*Apium graveolens* L.	wild celery	Sub	Hypertension	Leaf	Herb	0,14
	Centella asiatica (L.) Urb.	Spadeleaf	Pegagan	Hypertension	Leaf	Herb	0,14
Piperaceae	*Piper retrofractum* Vahl	Java chili	Patal muk	Hepatitis	Leaf	Liana	0,14
	Piper betle L.	betel pepper	Molo	Kidney disease	Leaf	Liana	0,43
Moraceae	*Ficus septica* Burm. F.	Awar-awar	Kaboke	Inpartu, HIV/AIDS, stroke, headache, fever, food poisoning	Leaf	Tree	0,43
	Ficus benjamina L.	weeping fig	Pur geti	Fracture, swollen body	Bark	Tree	0,14
Acanthaceae	*Justicia gendarussa* Burm.f.	Gandarusa	Moruk belis	HIV/AIDS	Root	Shrub	0,14
	Thunbergia grandiflora (Rox b. ex Rottl.) Roxb.	Bengal trumpet	Bubuk belis	Fracture	Root	Liana	0,14
Simaroubaceae	*Brucea javanica* (L.) Merr.	Makasar fruit	Hotel mal	Malaria	Fruit	Shrub	0,14
Urticaceae	*Girardinia palmata* (Forssk.) Gaudich.	girardinia/ bedor	Mebu bule'en	Stroke, headache, fever, food poisoning, spiritual magic	Bark	Herb	0,14
Equisetaceae	*Equisetum debile* Roxb. ex Vaucher	Horsetail	Hura	Gout	Root, stem, leaf	Fern	0,14
Phyllanthaceae	*Phyllanthus niruri* L.	gale of the wind	Gololok	Hypertension	Leaf	Herb	0,14
Meliaceae	*Melia azedarach* L.	Chinaberry tree, chinaberry,	Kelu	HIV/AIDS	Bark	Tree	0,14
Cyperaceae	*Cyperus rotundus* L.	Nutgrass	Kebot apa	Waist pain	Root	Grass	0,14
Moringaceae	*Moringa oleifera* Lam.	Horseradish tree	Marungga	Gout	Leaf	Tree	0,14
Lythraceae	*Punica granatum* L.	Pomegranate	Rumau	Diarrhea and vomiting, breast cancer	Bark, young fruit	Shrub	0,29
Caricaceae	*Carica papaya* L.	Papaya	Dila	Postpartum	Leaf	Tree	0,14
Arecaceae	*Areca catechu* L.	betel palm	Pu	Stomach ache	Seed	Tree	0,43
Amaryllidaceae	*Allium sativum* L.	Garlic	In nuek	Appendix	Tuber	Herb	0,29

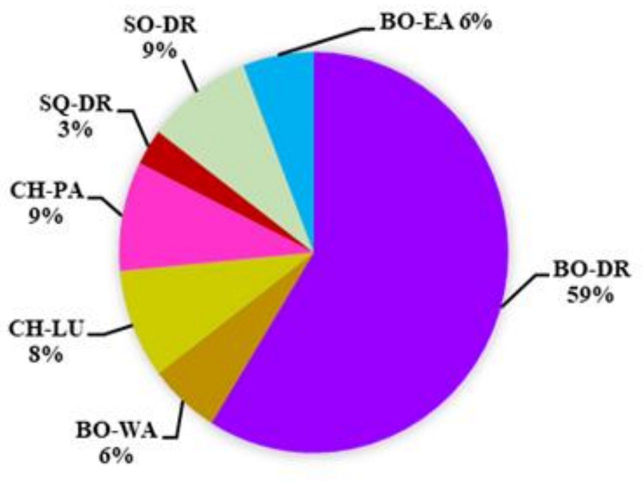

Figure 4. Percentage of processing and use of medicinal plants by the Bunaq Tribe, Lamaknen Sub-district, Belu District, East Nusa Tenggara, Indonesia

The way of processing and using traditional medicine by the Bunaq Tribe is based on diseases. Boiling is the most used method by the Bunaq people because most of the diseases in the community to be cured are internal diseases. According to key informants, consuming boiled water will speed up healing. That is also expressed by Efremila et al. (2015) that people use drugs more by drinking because most species of plants are found and used to treat internal diseases. The process of concocting drugs is closely related to the disease the patient suffered because it also has different effects. People use medicinal plants very diverse, including rubbing, eating, drinking, smearing, sprinkling, pasting, and dripping for external diseases, while the general treatment method for internal diseases is boiling and brewing. During the boiling process, plant substances will come out and dissolve into the water. The community considers this very easy and effective because it is directly processed in the body's metabolism after drinking boiled water (Husain 2015). If the processing of plants is carried out through the boiling process, the compounds in the plant organs will come out and be mixed with water or dissolved in water. The longer the boiling process is carried out, the more compounds present in the plant organs will experience evaporation so that the quality of the ingredients from the plant organs will be more efficacious (Nomleni et al. 2021).

Table 2. The recipes and how to use traditional medicinal plants

Diseases	Species	Organ	Preparation
Vomiting	*Psidium guajava* L.	Leaf (bud)	All ingredients are boiled and drunk 3 times a day
	Punica granatum L.	Bark	
	Annona muricata L.	Bark	
	Scutellaria galericulata L.	Root	
Inpartu	*Ficus septica* Burm. F.	Leaf (bud)	All ingredients are chewed and affixed to the stomach of pregnant women.
	Sida rhombifolia L.	Leaf (bud)	
Breast cancer	*Timonius sericeus* (Desf.) K.Schum.	Leaf (bud)	The leaves were chewed and pasted to the breast affected by cancer.
Vomiting	*Flemingia strobilifera* (L.) W.T. Aiton	Root	Wild hops and satintail roots are boiled with 7 areca nuts, and the water is drunk 3 times a day.
	Areca catechu L.	Seed	
	Imperata cylindrica (L.) Rausch.	Root	
HIV/AIDS	*Vachellia farnesiana* (L.) Wight & Arn	Root	All ingredients are boiled and drunk.
	Justicia gendarussa Burm.f.	Root	
	Senna siamea (Lam.) H.S. Irwin & Barneby	Root	
	Albizia procera (Roxb) Benth	Bark	
	Melia azedarach L.	Bark	
	Ficus septica Burm. F.	Leaf (bud)	
	Bambusa sp.	Leaf (bud)	
	Timonius sericeus (Desf.) K.Schum.	Leaf (bud)	
Orchitis/swollen testicles	*Sterculia foetida* L.	Bark	Bark of sterculia is chewed and pasted to the swollen part of the body.
Stroke, headache, fever, poisoning, and exorcised by evil spirits	*Zingiber oficinale* Linn.Var Rubrum	Rhizome	All ingredients are cut into small pieces and soaked in hot water. The soaking water is drunk twice a day.
	Timonius sericeus (Desf.) K.Schum.	Leaf (bud)	
	Girardinia palmata (Forssk.) Gaudich.	Bark	
	Calotropis gigantea (L.) Dryand.	Stem	
	Syzygium cumini (L.) Skeels	Bark	
	Coffea sp.	Stem	
	Eucalyptus urophylla S.T. Blake	Bark	
	Syzygium aqueum (Burm.f.) Alston	Bark	
	Euphorbia tirucalli L.	Stem	
Malnutrition	*Ceiba pentandra* (L.) Gaertn.	Bark	Bark of the kapok tree was boiled and then used for washing/bathing.
Appendix, indigestion	*Plumeria rubra* L.	Bark	Both ingredients are boiled and drunk.
	Alstonia scholaris (L.) R. Br.	Bark	
Appendix	*Euphorbia heterophylla* L.	Root, stem and leaf	Root, stem, and leaves of Mexican fireplant are boiled with mung beans and 7 cloves garlic, and boiled water is drunk.
	Allium sativum L.	Rhizome	
	Vigna radiata (L.) R.Wilczek	Seeds	
Bone fracture	*Cassia fistula* L.	Bark	Golden shower bark and Bengal trumpet root are sliced, chewed with betel, and areca nut, then lubricated on broken bones.
	Thunbergia grandiflora (Roxb. ex Rottl.) Roxb.	Root	
	Piper betle L.	Fruit	
	Areca catechu L.	Seed	
Vaginal discharge	*Pterocarpus indicus* Willd.	Bark	Bark of red sandalwood was boiled, and boiled water is drunk.
Gout	*Equisetum debile* Roxb. ex Vaucher	Root, stem and leaf	All ingredients were boiled, and then boiled water was used for washing/bathing.
	Calotropis gigantea (L.) Dryand.	Leaf	
Waist pain	*Cyperus rotundus* L.	Root	Both ingredients are cut into small pieces and chewed, then lubricated on the sore waist.
	Elephantopus scaber L.	Root	
Stroke, fever, foot poison, and headache	*Imperata cylindrica* (L.) Rausch.	Leaf (bud)	All ingredients are boiled and eaten.
	Ficus septica Burm. F.	Leaf (bud)	
	Bambusa sp.	Leaf (bud)	
Vomiting	*Euphorbia hirta* L.	Stem	Rhizome of turmeric and temulawak and lemongrass stem are sliced and boiled. After boiling, the pillpod sandmat stem is inserted. Boiled water is drunk 3 times a day.
	Curcuma longa L.	Rhizome	
	Curcuma zanthorrhiza Roxb	Rhizome	
	Cymbopogon citratus (DC.) Stapf	Stem	
Kidney disease	*Pluchea indica* (L.) Less.	Leaf	Rhizomes of turmeric are sliced and boiled, and leaves of betel and pluchea are added. Boiled water is drunk twice a day
	Piper betle L.	Leaf	
	Curcuma longa L.	Rhizome	
Puerperium / post-partum recovery	*Carica papaya* L.	Leaf	Papaya leaves are cut and boiled with palm sugar and salt. Boiled water is drunk for two days after giving birth.

Breast milk production	*Sauropus androgynus* (L.) Merr	Leaf	Katuk leaves are boiled and then eaten
Headache	*Zingiber officinale* Linn. Var Rubrum	Rhizome	Rhizomes of red ginger are burned and pounded, then soaked in hot water. Soaked water is drunk
Hypertension	*Apium graveolens* L.	Leaf	After boiling the sliced ginger and turmeric, add the leaves of celery, spade leaf, cat's whiskers, and a gale of wind. Boiled water is drunk 2 two times a day.
	Centella asiatica (L.) Urb.	Leaf	
	Orthosiphon aristatus (Blume) Miq	Leaf	
	Phyllanthus niruri L.	Leaf	
	Curcuma xanthorrhiza Roxb.	Rhizome	
	Curcuma longa L.	Rhizome	
Cholesterol and diabetes	*Annona muricata* L.	Leaf	Soursop leaves are boiled then the boiled water is drunk.
Hepatitis	*Piper retrofractum* Vahl	Leaf	All ingredients are boiled, and the boiled water is drunk.
	Cymbopogon nardus (L.) Rendle	Stem	
	Curcuma longa L	Rhizome	
Stomach ache	*Annona squamosa* L.	Bark	A bark of sugar apple is boiled, and the boiled water is drunk.
Malaria	*Brucea javanica* (L.) Merr.	Fruit	Makasar fruit is soaked in hot water, and the hot water is drunk
Appendix	*Euphorbia thymifolia* L.	Root, stem and leaf	All ingredients are boiled with 7 cloves of garlic until the water remains 1 cup, then the water is drunk
Wound	*Ageratum conyzoides* L.	Leaf	Whiteweed leaves are chewed and pasted to the wound of the body
Asthma	*Plectranthus amboinicus* (Lour.) Spreng.	Leaf	The Mexican mint leaves are squeezed and drunk
Bone fracture and swelling body	*Ficus benjamina* L.	Bark	All ingredients are chewed and lubricated on broken bones or swollen body
	Euphorbia hirta L.	Root	
	Sida rhombifolia L.	Root	
	Jatropha gossypiifolia L.	Bark	
	Piper betle L.	Leaf	
	Areca catechu L.	Fruit	
Fever and green snake bite	*Albizia procera* (Roxb) Benth	Bark	All ingredients are boiled, and drink the boiled water
	Flemingia strobilifera (L.) W.T. Aiton	Bark	
Urolithiasis	*Sida rhombifolia* L.	Root, stem and leaf	All ingredients are boiled, and drink the boiled water
	Morinda citrifolia L.	Bark	
Gout	*Chromolaena odorata* (L.) R.M. King & H. Rob.	Leaf	All ingredients are boiled, and drink the boiled water
	Moringa oleifera Lam.	Leaf	
Breast cancer	*Punica granatum* L	Fruit	Seven pieces of pomegranate fruit (juvenile) are boiled with red peanuts (single), then the water is drunk.
	Arachis hypogaea L.	Seed	
Kidney disease	*Eleusine indica* (L.) Gaertn	Root, stem and leaf	All vegetative organs of the crowsfoot grass are boiled, and then the boiled water is drunk

Species use-value (SUV)

The SUV ranged between 0.14 and 0.57, with an average of 0.20 (Table 1). *Curcuma longa* L. has the highest score (0.57), having 4 use reports, followed by *Sida rhombifolia* L., *Piper betle* L., *Ficus septica* Burm. F. and *Areca catechu* L., having a value of 0.43 and 3 use reports, while other plants are below it. High or low SUV may be due to extensive or minimum ethnobotanical uses of the reported species. The highest SUV represents the most exploited medicinal plants used to treat a specific ailment (Jadid et al. 2020). Previous research also revealed that turmeric has a fairly high UV value as a medicinal plant (Silalahi et al. 2019; Fathir et al. 2021). This study revealed that turmeric is a prescription ingredient in treating vomiting, kidney disease, hypertension, and hepatitis. Khotimah et al. (2018) revealed that turmeric is the most widely used plant species in traditional medicine by the Banyuwangi tribe. Another study also revealed that turmeric could treat diarrhea, abdominal pain, cough, itching, and injury (Silalahi et al. 2019).

Ani et al. (2021) stated that turmeric has a pharmacological effect and can strengthen its efficacy of mixed with other drugs. In addition, this plant contains medicinal compounds called curcuminoids. Nasri et al. (2014) revealed that this plant has useful properties with antioxidant activities and is useful to treat inflammation, ulcer, and cancer. It also has antifungal, antimicrobial renal, and hepatoprotective activities. Its anti-inflammatory, anti-cancer, and antioxidant roles may be clinically exploited to control rheumatism, carcinogenesis, and oxidative stress-related pathogenesis. Therapeutic uses include AIDS/HIV, anemia, cancer, diabetes, digestion, food poisoning, gallstones, etc. (Rathaur et al. 2012).

In this study, *S. rhombifolia* was used as a prescription drug for childbirth, bone fracture and swelling of the body, and urolithiasis. Singh et al. (2018) revealed that this plant is also used to help childbirths in Assam, India. However, the hot aqueous extract of the entire plant of *S. rhombifolia* is used as an abortifacient when it is taken orally by pregnant women. In addition, this plant has bioactivity as an anti-inflammatory, kidney disorder, hepatoprotective, anti-diabetic mellitus, and analgesic (Silalahi 2020). Furthermore, this plant treats fractures, wounds, fever (Silalahi et al. 2015), and kidney dysfunction (Thounaojam et al. 2010). In addition, in India, this plant, as one of the ayurvedic medicines, is used to cure pain and swelling caused by rheumatism, muscular weakness, and urinary tract wounds and treat tuberculosis, heart diseases, and neurological disorders (Abat et al. 2017).

This study, *F. septica* was used as a mixture of prescription drugs for childbirth, stroke, fever, food poisoning, headache, and HIV-AIDS. In the interview, the village healer who gave this prescription for HIV-AIDS said that this is his personal experience of being diagnosed with HIV-AIDS and declared cured. Furthermore, this plant is known to have the potential of folk medicine to treat colds, fever, and fungal and bacterial diseases (Damu et al. 2005) and as an anti-cancer, especially breast cancer (Nugroho et al. 2015). In addition, the Mamanwa tribe of Surigao del Norte and Agusan del Norte, Mindanao, Philippines, uses this plant as a remedy for headaches and stomach aches and cures skin diseases such as warts (Nuneza et al. 2021) and can treat scabies (Susilo et al. 2017) and burns (Rahman et al. 2013).

Betel (*P. betle*) and areca nut (*A. catechu*) are iconic plants of the tradition/culture of the people of Timor Island in their daily life. In this study, betel nut was used as a prescription mixture for bone fracture, kidney disease, and swollen body, while betel nut was used for vomiting, bone fracture, and swelling. Betel is known to have several pharmacologic effects such as antibacterial, antimicrobial, analgesic, anti-inflammatory, antioxidant, antiproliferative, anti-diabetic, and antiangiogenetic (Sakinah et al. 2020; Nayaka et al. 2021; Nurhidayati et al. 2021). Areca nut is also known to have the potential to treat various diseases/disorders such as diabetes, gastrointestinal disorders, ulcer prevention, Heart diseases, and CNS disorder (depression, seizures), and also exhibits various pharmacological activities including anti-inflammatory, anti-protozoal, antioxidant, anti-allergic, wound healing activity, etc. and the extract of areca palm and its nuts are also useful for the preparation of many natural medicinal and cosmetic products (Tiwari and Talreja 2020; Ansari et al. 2021).

This study concluded that Bunaq Tribe used 63 medicinal plant species to treat many diseases using several preparation methods. The results of this study can be used as the basis for the conservation and sustainable use of medicinal plants in the Bunaq community.

REFERENCES

Abat JK, Kumar S, Mohanty A. 2017. Ethnomedicinal, phytochemical and ethnopharmacological aspects of four medicinal plants of Malvaceae used in Indian traditional medicines: A review. Medicines 4 (4): 75. DOI: 10.3390/medicines4040075.

Albuquerque UP, Lucena RFP, Monteiro JM, Florentino ATN, Almeida CDFCBR. 2006. Evaluating two quantitative ethnobotanical techniques. Ethnobot Res Appl 4 (1): 51-60. DOI: 10.17348/era.4.0.51-60.

Alvionita A, Lambui O, Pitopang R. 2020. Studi etnobotani tumbuhan obat masyarakat Suku Topo Uma di Desa Berdikari Kabupaten Sigi Sulawesi Tengah. Biocelebes 14 (2): 105-118. DOI: 10.22487/bioceb.v14i2.15261. [Indonesian]

Ani N, Sukenti K, Aryanti E, Rohyani IS. 2021. Ethnobotany study of medicinal plants by the Mbojo Tribe community in Ndano Village at the Madapangga Nature Park, Bima, West Nusa Tenggara. J Biologi Tropis 21 (2): 456-469. DOI: 10.29303/jbt.v21i2.2666.

Ansari A, Mahmood T, Bagga P, Ahsan F, Shamim A, Ahmad S, Shariq M, Parveen S. 2021. *Areca catechu*: A phytopharmacological legwork. Food Front 2 (2): 163-183. DOI: 10.1002/fft2.70.

Ashfaq S, Ahmad M, Zafar M, Sultana S, Bahadur S, Abbas N. 2019. Medicinal plant biodiversity used among the rural communities of arid regions of Northern Punjab, Pakistan. Indian J Tradit Knowl 18 (2): 226-241.

Atok AR, Hikmat A, Zuhud EAM. 2010. Etnobotani Masyarakat Suku Bunaq (Studi kasus di Desa Dirun, Kecamatan Lamaknen Kabupaten Belu, Provinsi Nusa Tenggara Timur). Media Konservasi 15 (1): 36-42. [Indonesian]

Az-Zahra FR, Sari NLW, Saputry R, Nugroho GD, Sunarto, Pribadi T, Setyawan AD. 2021. Review: Traditional knowledge of the Dayak Tribe (Borneo) in the use of medicinal plants. Biodiversitas 22: 4633-4647. DOI: 10.13057/biodiv/d221057.

Backer CA, Bakhuisen van den Brink RC. 1968. Flora of Java (Spermatophytes. Only). Vol. III Wolters-Noordhoff, N.V. Groningen, The Netherlands.

Belu District Profile. 2020. Profil Daerah Kabupaten Belu Tahun 2020. In Badan Perencanaan Pembangunan, Penelitian dan Pengembangan Daerah Kab. Belu. http://bp4d.belukab.go.id/wp-content/uploads/2021/11/PROFIL-DAERAH-KABUPATEN-BELU-TAHUN-2020_compressed.pdf. [Indonesian]

Belu District. 2021. Rencana Pembangunan Jangka Menengah Daerah (RPJMD) Kabupaten Belu Tahun 2021-2026. Pemerintah Kabupaten Belu, Belu. [Indonesian]

Bhagawan WS, Kusumawati D. 2021. Ethnobotanical medicinal plant study of Tengger Tribe in Ranu Pani Village, Indonesia. Proceedings of the the 3rd International Conference on Education & Social Science Research (ICESRE). DOI: 10.2139/ssrn.3865725.

Bussmann RW, Glenn A, Meyer K, Kuhlman A, Townesmith A. 2010. Herbal mixtures in traditional medicine in Northern Peru. J Ethnobiol Ethnomed 6 (10): 1-11. DOI: 10.1186/1746-4269-6-10.

Damu AG, Kuo PC, Shi LS, Li CY, Kuoh CS, Wu PL, Wu TS. 2005. Phenanthroindolizidine alkaloids from the stems of *Ficus septica*. J Nat Prod 68 (7): 1071-1075. DOI: 10.1021/np050095o.

Dapar MLG, Meve U, Liede-Schumann S, Alejandro GJD. 2020. Ethnomedicinal appraisal and conservation status of medicinal plants among the Manobo Tribe of Bayugan City, Philippines. Biodiversitas 21 (8): 3843-3855. DOI: 10.13057/biodiv/d210854.

Efremila, Wardenaae E, Lolyta S. 2015. Studi etnobotani tumbuhan obat oleh Etnis Suku Dayak di Desa Kayu Tanam Kecamatan Mandor Kabupaten Landak. J Hutan Lestari 3 (2): 234-246. DOI: 10.26418/jhl.v3i2.10310.

Elfahmi, Woerdenbag HJ, Kayser O. 2014. Jamu: Indonesian traditional herbal medicine towards rational phytopharmacological use. J Herbal Med 4 (2): 51-73. DOI: 10.1016/j.hermed.2014.01.002.

Faruque MO, Uddin SB, Barlow JW, Hu S, Dong S, Cai Q, Li X, Hu X. 2018. Quantitative ethnobotany of medicinal plants used by indigenous communities in the Bandarban District of Bangladesh. Front Pharmacol 9: 40. DOI: 10.3389/fphar.2018.00040.

Fathir A, Haikal M, Wahyudi D. 2021. Ethnobotanical study of medicinal plants used for maintaining stamina in Madura Ethnic, East Java, Indonesia. Biodiversitas 22 (1): 386-392. DOI: 10.13057/biodiv/d220147.

Husain NA. 2015. Studi Etnobotani dan Identifikasi Tumbuhan Berkhasiat Obat Berbasis Pengetahuan Lokal di Kabupaten Enrekang. [Skripsi]. Univertasitas Muhammadiyah Makassar, Makassar. [Indonesian]

Hussain W, Badshah L, Ullah M, Ali M, Ali A, Hussain F. 2018. Quantitative study of medicinal plants used by the communities residing in Koh-e-Safaid Range, northern Pakistani-Afghan borders. J Ethnobiol Ethnomed 14 (1): 30. DOI: 10.1186/s13002-018-0229-4.

Jadid N, Kurniawan E, Himayani CES, Andriyani, Prasetyowati I, Purwani KI, Muslihatin W, Hidayati D, Tjahjaningrum ITD. 2020. An ethnobotanical study of medicinal plants used by the Tengger Tribe in Ngadisari Village, Indonesia. PLoS ONE 15 (7): 1-16. DOI: 10.1371/journal.pone.0235886.

Jima TT, Megersa M. 2018. Ethnobotanical study of medicinal plants used to treat human diseases in Berbere District, Bale Zone of Oromia Regional State, South East Ethiopia. Evid Based Complement Altern Med 2018 (2): 16. DOI: 10.1155/2018/8602945.

Khotimah K, Nurcahayati N, Ridho R. 2018. Studi etnobotani tanaman berkhasiat obat berbasis pengetahuan lokal Masyarakat Suku Osing di Kecamatan Licin Banyuwangi. Biosense 1 (1): 36-50. [Indonesian]

Ledo S, Seran W. 2019. Keanekaragaman tumbuhan obat Taman Wisata Alam Baumata Kabupaten Kupang serta pemanfaatannya oleh masyarakat lokal. Agrikan: J Agribisnis Perikanan 12 (2): 299-310. DOI: 10.29239/j.agrikan.12.2.299-310. [Indonesian]

Molares S, Ladio A. 2012. The usefulness of edible and medicinal Fabaceae in Argentine and Chilean Patagonia: Environmental availability and other sources of supply. Evid Based Complement Altern Med 2012 (5): 901918. DOI: 10.1155/2012/901918.

Nagaike T. 2012. Review of plant species diversity in managed forests in Japan. ISRN For 2012: 1-7. DOI: 10.5402/2012/629523.

Nahdi MS, Kurniawan AP. 2019. Study on the ethnobotany of medicinal plants by people in Gunung Kidul, Yogyakarta, Indonesia. Nusantara Biosci 11 (2): 133-141. DOI: 10.13057/nusbiosci/n110204.

Napagoda MT, Sundarapperuma T, Fonseka D, Amarasiri S, Gunaratna P. 2018. An ethnobotanical study of the medicinal plants used as anti-inflammatory remedies in Gampaha District, Western Province, Sri Lanka. Scientifica 2018: 9395052. DOI: 10.1155/2018/9395052.

Nasri H, Sahinfard N, Rafieian M, Rafieian S, Shirzad M, Rafieian-kopaei M. 2014. Turmeric: A spice with multifunctional medicinal properties. J Herb Med Pharmacol 3 (1): 5-8.

Nayaka NMDMW, Sasadara MMV, Sanjaya DA, Yuda PESK, Dewi NLKAA, Cahyaningsih E, Hartati R. 2021. *Piper betle* (L): Recent review of antibacterial and antifungal properties, safety profiles, and commercial applications. Molecules 26 (2321): 1-21. DOI: 10.3390/molecules26082321.

Nomleni FT, Daud Y, Tae F. 2021. Etnobotani tumbuhan obat tradisional di Desa Huilelot dan Desa Uiasa Kecamatan Semau Kabupaten Kupang. BIO-EDU: J Pendidikan Biologi 6 (1): 60-73. DOI: 10.32938/jbe.v6i1.993. [Indonesian]

Nugroho AE, Akbar FF, Wiyani A, Sudarsono. 2015. Cytotoxic effect and constituent Profile of alkaloid fractions from ethanolic extract of *Ficus septica* Burm. f. leaves on T47D breast cancer cells. Asian Pac J Cancer Prev 16 (16): 7337-7342. DOI: 10.7314/APJCP.2015.16.16.7337.

Nugroho Y, Soendjoto MA, Suyanto, Matatula J, Alam S, Wirabuana PYAP. 2022. Traditional medicinal plants and their utilization by local communities around Lambung Mangkurat Education Forests, South Kalimantan, Indonesia. Biodiversitas 23 (1): 306-314. DOI: 10.13057/biodiv/d230137.

Nuneza O, Rodriguez B, Nasiad JG. 2021. Ethnobotanical survey of medicinal plants used by the Mamanwa tribe of Surigao del Norte and Agusan del Norte, Mindanao, Philippines. Biodiversitas 22 (6): 3284-3296. DOI: 10.13057/biodiv/d220634.

Nurhidayati LG, Nugroho AE, Retnoaji B, Sudarsono, Fakhrudin N. 2021. Antiangiogenesis activity of awar-awar leaf extract (*Ficus septica* Burm. F.) in chorioallantoic membrane assay. Indones J Pharm 32 (1): 1-9. DOI: 10.22146/ijp.607.

Rahayu SM, Andini AS. 2019. Ethnobotanical study on medicinal plants in Sesaot Forest, Narmada,West Lombok, Indonesia. Biosaintifika: J Biol Biol Educ 11 (2): 234-242. DOI: 10.15294/biosaintifika.v11i2.19314.

Rahman S, Kosman R, Mukrima I. 2013. Efek ekstrak etanol daun awar-awar (*Ficus septica* Burm . F) terhadap kemampuan epitelisasi pada tikus (*Rattus norvegicusu*). Bionature 14 (2): 112-116. [Indonesian]

Rathaur P, Raja W, Ramteke PW, John SA. 2012. Turmeric — The golden spice of life. Intl J Pharm Sci Res 3 (7): 1987-1994. DOI: 10.1201/9781420006322-7.

Sakinah D, Rusdi, Misfadhila S. 2020. Review of traditional use, phytochemical and pharmacological activity of *Piper betle* L. Galore Intl J Health Sci Res 5 (3): 59-66.

Silalahi M, Nisyawati, Pandiangan D. 2019. Medicinal plants used by the Batak Toba Tribe in Peadundung Village, North Sumatra, Indonesia. Biodiversitas 20: 510-525. DOI: 10.13057/biodiv/d200230.

Silalahi M, Nisyawati. 2018. The ethnobotanical study of edible and medicinal plants in the home garden of Batak Karo Sub-ethnic in North Sumatra, Indonesia. Biodiversitas 19 (1): 229-238. DOI: 10.13057/biodiv/d190131.

Silalahi M, Supriatna J, Walujo EB, Nisyawati. 2015. Local knowledge of medicinal plants in Sub-ethnic Batak Simalungun of North Sumatra, Indonesia. Biodiversitas 16 (1): 44-54. DOI: 10.13057/biodiv/d160106.

Silalahi M. 2020. Pemanfaatan dan bioaktivitas sidaguri *(Sida Rhombifolia)*. Florea: J Biologi dan Pembelajarannya 7 (1): 22-30. DOI: 10.25273/florea.v7i1.5780. [Indonesian]

Singh A, Dhariwal S, Navneet. 2018. Traditional uses, antimicrobial potential, pharmacological properties and phytochemistry of *Sida rhombifolia* Linn.: A review. Intl J Innov Pharm Sci Res 6 (2): 54-68. DOI: 10.21276/IJIPSR.2018.06.02.263.

Susilo T, Kusuma YR, Pramu. 2017. Efek pemberian ekstrak awar awar (*Ficus Septica*) terhadap gejala klinis scabies pada kelinci. J Pengembangan Penyuluhan Pertanian 14 (25): 125-129. DOI: 10.36626/jppp.v14i25.57. [Indonesian]

Thounaojam MC, Jadeja RN, Devkar RV, Ramachandran AV. 2010. *Sida rhomboidea* Roxb leaf extract ameliorates gentamicin induced nephrotoxicity and renal dysfunction in rats. J Ethnopharmacol 132 (1): 365-367. DOI: 10.1016/j.jep.2010.08.037.

Tiwari S, Talreja S. 2020. A pharmacological and medicinal study of Areca palm and nuts : An overview. Res J Pharm Biol Chem Sci 11 (5): 100-108.

Yeung AWK, Heinrich M, Kijjoa A, Tzvetkov NT, Atanasov AG. 2020. The ethnopharmacological literature: An analysis of the scientific landscape. J Ethnopharmacol 250: 112414. DOI: 10.1016/j.jep.2019.112414.

Yuliani NN, Hilaria M, Elisma E, Sambara J. 2019. Kajian etnofarmakologi Suku Marae terhadap pengobatan tradisional di Desa Kewar Kecamatan Lamaknen Kabupaten Belu. J Kesehatan, The 1st Alauddin Pharmaceutical Conference and Expo (ALPHA-C) 2019: 1-8. DOI: 10.24252/kesehatan.v0i0.11457. [Indonesian]

Zenderland J, Hart R, Bussmann RW, Zambrana NYP, Sikharulidze S, Kikvidze Z, Kikodze D, Tchelidze D, Khutsishvili M, Batsatsashvili K. 2019. The use of "Use Value": Quantifying importance in ethnobotany. Econ Bot 73 (3): 293-303. DOI: 10.1007/s12231-019-09480-1.

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The influence of human activities on wildlife in Kwakuchinja migratory corridor, Tarangire/Manyara Ecosystem, Northern Tanzania

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Abstract. *Njamasi YR, Ndibalema VG, Kioko J. 2022. The influence of human activities on wildlife in Kwakuchinja migratory corridor, Tarangire/Manyara Ecosystem, Northern Tanzania. Intl J Trop Drylands 6: 26-38.* Human population growth in areas adjacent to protected areas is high and has seriously threatened African wildlife management. Local communities around protected areas engage in illegal activities that destroy habitats and threaten wildlife migration routes. Additionally, there is a local extinction of five species of large mammals in Kwakuchinja, Tanzania. Therefore, this study focused on assessing the impact of human activities on wildlife in the Kwakuchinja flyway in the Tarangire-Manyara Ecosystem (TME), Northern Tanzania. The data were collected using Tresect Walk, domestic questionnaires, important informants, and secondary materials. The comparison data of the groups for natural groups were analyzed with the help of Mann Whitney's U-Test man. At the same time, the Pearson test was used to compare relationships between animals in nature, cattle, and human settlements. Additionally, the chi-square test was used to compare the relationship between wildlife status and time spent by the respondent in the study area. The study found that migratory corridors for wildlife had shrunk from five to three. Common wildebeest had the highest density (area of 450 km^2), while Thompon's gazelle had the lowest. Recent trends from aerial survey data show a 50% decrease in the number of large mammals in the ecosystem in the 2000s compared to the 1990s, and land use has changed to cultivation with a 4.2% increase in 'the study area. An insignificant relationship was observed between the number of wild animals and human settlements (r= 0.714). Therefore, these results suggest that human settlements harm the number and distribution of fauna. Since wildlife and livestock share grazing and watering areas, the study recommends using an integrated land use plan, law enforcement, and sustainable use of natural resources to protect the Kwakuchinja Wildlife Corridor.

Keywords: Corridor, human activities, Tarangire/Manyara, wildlife

INTRODUCTION

A wildlife corridor is an area of land used by wildlife in their seasonal migrations from one part of an ecosystem to another in search of basic needs such as water, food, space, and habitat (URT 2009). In addition, wildlife corridors allow the free movement of animals to other geographic locations where access to resources essential for survival and the exchange of genetic material occurs (Hassan 2007). Wildlife corridors are, therefore, essential components of the continuity of the species' population, ecological integrity, and the long-term survival of ecosystems (Noe 2003; Pla-Ard et al. 2021).

Globally, wildlife corridors have been considered important for connectivity, for example, in the case of Kenha and Pench National Parks in Madhya Pradesh, India, where habitat connectivity was important for tigers (*Panthera tigris* Linnaeus, 1758). The main problem in the Kenha-Pench landscape was habitat fragmentation caused by dense human settlements, railways, roads, and agricultural land expansion (Rathore et al. 2012). Those issues were mitigated by emphasizing appropriate wildlife corridors to reduce genetic isolation, offset habitat fragmentation issues, and increase animal dispersal while allowing for ecological processes (Rathore et al. 2012). Wildlife corridors before project development and implementation, such as roads. For example, a study to identify mammalian path-crossing patterns in northern New Hampshire avoided unnecessary habitat fragmentation and successfully modeled and identified wildlife corridors (Leoniak et al. 2012).

In Africa, a study of the seasonal home ranges of elephants (*Loxodonta africana* Blumenbach, 1797) between the Sabi Sand Reserve (SSR) and Kruger National Park (KNP) revealed that the protection of wildlife corridors is important because elephants depend on the resources of both parks (Thomas et al. 2012). In Nairobi National Park in Kenya, wildlife migrates into the Kitengela range. Still, the challenge has been population growth, agricultural expansion, and deforestation, all of which have threatened wildlife survival; in preventing wildlife migration from Nairobi National Park to Kitengela during the rainy season, it was decided to compensate private landowners (Rodriguez et al. 2012). The Tarangire-Manyara Ecosystem (TME) in Tanzania covers a large area of approximately 35,000 km^2. The area extends along the eastern edge of the Great Rift Valley and includes Lake Natron and the game-controlled area of Mto-wa-mbu; Lake Burunge and the Burunge Game Controlled Area; Kwakuchinja Open Area and LMNP; Game controlled area of Mkungunero and Kimotorok; Loikisare and Simanjiro Game Controlled Area and the plains of Simanjiro (Maasai Steppe). Many animal species are found in this area. Many of these animal species, especially elephants, zebras, and wildebeest, depend on the high nutritional value of Maasai grasslands.

The Kwakuchinja Wildlife Corridor is located in TME, the northern part of Tanzania, connecting Tarangire National Park (TNP) and Lake Manyara National Park (LMNP) (Marttila 2011). Biodiversity is threatened by the growth of human settlements and agricultural development (Msoffe et al. 2011). The Kwakuchinja Wildlife Corridor, a subset of an area designated as an Open Game Area, a conservation category that does not restrict habitation or cultivation (Gamassa 1989), faces a serious threat from human activities. As a result, many protected areas in Tanzania are becoming isolated. Reasons for isolation include the increase in human population in areas adjacent to protected areas and the change in land use towards agriculture, infrastructure, and settlements in previously uninhabited areas (Newmark 2008). Human-related impacts also occur in and around protected areas, such as habitat loss of wildlife, physical development, overexploitation of natural resources, wildlife competing with other types, use of soil, and pollution that seriously impacts wildlife.

The increased pressure exerted by the human population and its negative impact on habitat loss for wildlife in African countries, including Tanzania, is a common phenomenon (Kideghesho et al. 2006). This situation applies to TME, where some of the species in the wild have become locally extinct due to habitat destruction and overfishing, indicating a high pressure of human influence on populations in the wild (Shemweta and Kideghesho 2000). So far in the TME, five major mammal species: oryx (*Oryx gazelle* Linnaeus, 1758), hartebeest (*Alcelaphus buselaphus* Pallas, 1766), cheetah (*Acinonyx jubatus* Schreber, 1775), leopard (*Panthera pardus* Linnaeus, 1758), and black rhino (*Diceros bicornis* Linnaeus, 1758) are locally extinct (Hassan 2007). Extinction is largely attributed to settlement growth and agriculture blocking animal movements, increased poaching, and human disturbance.

However, wildlife corridors are seriously threatened by population pressures resulting from a range of population pull factors in the grazing areas and push factors in the areas of high agricultural potential. Secondly, there is a lack of legislation to protect corridors from unsustainable uses and activities incompatible with biodiversity conservation. TME is one of the areas where population pressure is increasing. The main pull factors of the population in this area include the demand for agricultural land, the construction of the Minjingu phosphate factory, the establishment of fishing camps, small-scale mining activities (Marang forest), tourism growth, and other economic opportunities. In addition, push factors related to the population of areas of acute land scarcity, such as the Kilimanjaro region, have also impacted the Lake Manyara basin. The major outcome of all the identified factors is an increased threat to the existing wildlife corridors, which provide ecological links between LMNP and TNP (Jones et al. 2009). Since the identified factors are not well known, there is a need to document the extent of the impacts caused by these identified factors above on wildlife and the Kwakuchinja wildlife migratory corridor.

The specific objectives were: (i) to map the distribution of wildlife, livestock, and human settlements in the Kwakuchinja wildlife migration corridor concerning their habitat, (ii) assessment of population trends and the current status of flyways in terms of wildlife use over the past 16 years (1998-2014), (iii) assess the impact of land use/land cover change on wildlife in the Kwakuchinja Wildlife Corridor.

MATERIALS AND METHODS

Description of the study area

Location

The study was conducted in the three villages of Mswakini, Olasiti, and Kakoi in the Kwakuchinja open area, Tanzania. The Kwakuchinja Wildlife Corridor is part of the Kwakuchinja Open Area (450 km^2) between the LMNP and the TNP. It is located between latitudes 03º35'38" and 03º48'02"S and longitudes 35º48'21" and 35º59'25"E. (Figure 1).

Soil and vegetation

The vegetation is mainly savannah with wooded areas along the waterways. In the natural corridor of Kwakuchinja, there are two types of savannah. These include microphyllous savannahs in river basins dominated by *Acacia tortilis* (Forssk.) Hayne and deciduous broadleaf savannahs on ridges and upper slopes dominated by *Combretum* and *Commiphora* species (Marttila 2011; Pittiglio et al. 2012). Black cotton soil predominates on the floodplains (foot slopes), and dark red sandy clay loam on the upper slopes.

Rainfall

The rainfall pattern is bimodal, with short rains from November to December and long rains from February to May (Marttila 2011). March and April are the wettest months, while July and August are the driest. Estimated rainfall is between 450-650 mm (Caro et al. 2009).

Wildlife

The Kwakuchinja Wildlife Corridor was once vital for 25 large mammal species, some of which (including elephants) moved between the two parks (Msoffe et al. 2011). For example, field observations from two decades ago suggested that elephants (*L. africana*) moved from the LMNP to the corridor through the Marang Forest (adjacent to the LMNP) and then preceded the NPT through the Lake Burunge area. Currently, some populations of bushbuck (*Tragelaphus scriptus* Pallas, 1766), impala, and vervet monkey (*Cercopithecus aethiops* (Linnaeus, 1758) use the corridor all year round, together with cattle (Hassan 2007).

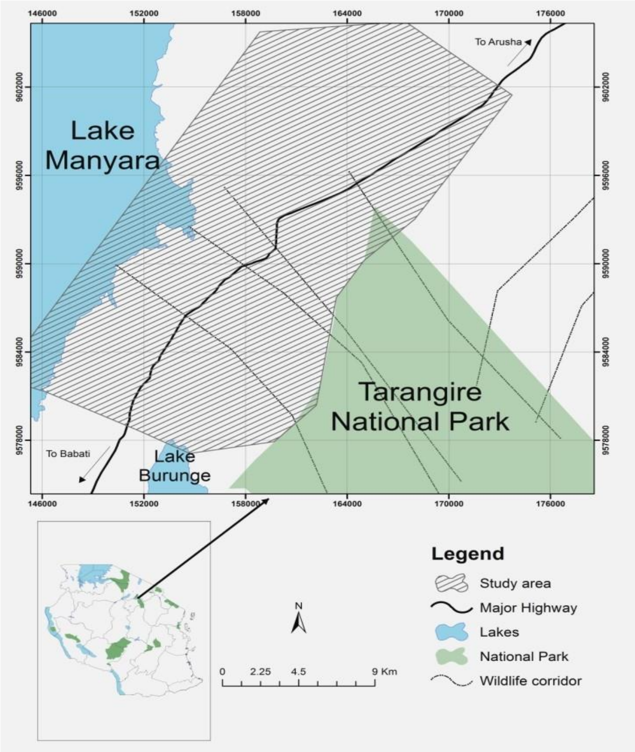


Figure 1. Map of Tanzania showing Kwakuchinja wildlife corridor (Source: GIS Center Tarangire National Park 2013)

Ethnicity and socio-economic activities

The Kwakuchinja wildlife corridor is home to several ethnic groups in five villages (Hassan 2007). In this study, a group of huts under a family or families under the same roof as an elder was considered a settlement. That was necessitated by the social (polygamous) way of life of many ethnic groups in the region, especially pastoralists and agro-pastoralists. Their occupations include cattle herding, subsistence and/or commercial farming, and trades. In addition, fishermen from surrounding areas and up to the town of Babati migrated to the area and established temporary fishing villages (Goldman 2003).

Research design

The study used a cross-sectional research design for data collection. The design allowed for data collection at a given time from a sample chosen to represent the entire population. The design is quick and lends itself to the description and interpretation recommended by Babbie (1990).

Sampling procedure

Through purposeful sampling (Babbie 2007), three villages were selected from six available villages. The villages chosen were Olasiti, Kakoi, and Mswakini. These villages were chosen because they are within the Kwakuchinja Wildlife Corridor. Households were randomly selected from lists provided by respective village administration officials for each village. The communities in the Kwakuchinja Wildlife Corridor made up the study population, using families as the base sampling unit in each village. The sampling framework used was the list of the population available in each village; to have accurate data, the sampling intensity involved 45 families in each village, and a total of 135 families was sufficient for the study. Bailey (1994) reported that studies requiring statistical analysis require a sample size of $\geq$30 regardless of population size. Therefore, the criteria for selecting 45 families meet Bailey's recommendation, above the minimum required.

Reconnaissance surveys

A preliminary survey of the study area was conducted to familiarize themselves with the study area and gather general information on the migration route of the wildlife, the identification of pedestrian transit areas, the terrain, and the accessibility of the study area. The study also included the selection of three study villages. As part of the exploratory survey, questionnaires were pre-tested in one of the villages, and necessary adjustments to existing local conditions were made.

Data collection

Data collection included primary and secondary data collection methods in the study area. Primary data were collected in the field through direct observation, a household questionnaire, a cross-sectional walk, and interviews with key informants. In addition, quantitative and qualitative data were collected.

Direct observation

Direct observation has been used to gather information about human activities. It included observational activities such as farming, collecting firewood, felling trees, and grazing animals. Indeed, the direct observation method was used to tie together the more discrete elements of the data collected by other methods.

Household questionnaire

Householders used a semi-structured questionnaire. The questionnaire was administered, and the researcher asked questions from the questionnaire and noted the respondents' answers. Questionnaires collected demographics, wildlife information, human migration patterns, habitat protection, and land use. A total of 135 households participated in the questionnaire survey.

Transect walk

Data collection on the distribution of wild animals, farm animals, and settlements was carried out by foot sampling. Foot sampling included eight (8) transects of varying lengths and spacing (Western and Grimsdell 1979) within the study area. After transepts, these transepts were made in Manyara Ranch, Mswakini Juu, Oltukai, Open Area Community, Burunge WMA, Vilima Vitatu, and Malamboi, established by Hassan (1998), the corridor of the wildlife of Kwakuchinja. The recording of animals in nature, the cattle, the settlement, and the respective perpendicular distance were carried out inside a 400 m fixed transept width on each side of a line transept (Norton-Griffiths 1978; Hassan 2007). Due to the type of habitat and visibility. The transepts were arranged in two sets that ran east to west with a compass reading of 2790. One set ran from the TNP border to the Arusha-Babati paved road, and the other set ran from the paved road to the lakeshore Manyara. GPS coordinates were used to establish the locations of wildlife, settlements, and livestock and their perpendicular distances. A digital camera was used to photograph wildlife, livestock, and settlements. Accessibility, type of land use, and vegetation cover determined the distribution of transects.

Key informants interview

Key informant interviews were used to collect data on various issues related to wildlife, human settlement by livestock, historical uses of the corridor, and poaching. Key informants for this study included village chiefs, town councilors, community leaders, and staff from TNP, Manyara Ranch, and Burunge WMA present in the study area. A checklist of questions was used to obtain information from key informants. A total of five (5) interviews with key informants were conducted in the study area.

Secondary data on wild population trends, habitat types and migratory routes used by the animals were obtained from published and unpublished reports in Tanzania National Parks (TANAPA), Tanzania Wildlife Research Institute (TAWIRI), and NGO's research conducted in the study area. In addition, land use/cover data was obtained from the TNP GIS Center. The data assessed land use/cover changes and their impact on wildlife based on habitat loss and local extinction. Satellite imagery for 2000 and 2013 generated land use/cover changes from 2000 to 2013.

Data analysis

Both qualitative and quantitative data were analyzed. Quantitative data were analyzed using Statistical Package for Social Sciences (SPSS) version 16.1, whereby descriptive analysis involving measures of central tendencies, frequencies, and standard deviations were computed.

Mapping distribution of wildlife, livestock, and human settlement in the Kwakuchinja wildlife migratory corridor

During the transect walk, wildlife sighting coordinates were identified using GPS, and then Arc GIS was used for mapping. Following Sutherland (2001), calculations on population density and size were calculated as follows:

Density:

$D = n/2WL$ .... [1]

Population size:

$N = DA = An/2WL$ ……………….......................... [2]

Where:

N : population size estimate;
D : density estimate of the population;
A : total area of the census zone;
n : total number of animals or objects counted;
L : total length of the transect lines; and
W : mean perpendicular distance.

Mann Whitney - U -test was used to test the differences in the size of the natural group between the numerous Ranch and Burunge WMA. Pearson's correlation was used to analyze the relationship between wild animals and cattle and the numbers of natural and human settlements. One rationale for using Pearson's correlation analysis was that wildlife, settlements, and livestock are numerical values.

Assessment of the population trend and present status of migratory corridors concerning wildlife use for the past sixteen years (1998-2014)

Data based on a questionnaire survey were analyzed using SPSS, and the Chi-square test was used to test the decrease or increase of wildlife based on respondents' perceptions. Also was used to test the relationship between wildlife increase and respondents' time spent in the study area.

Assessing the impact of land use/cover changes on wildlife in the Kwakuchinja wildlife corridor

Landsat TM (UTM / WGS84) images from Tarangire GIS Center were interpreted using patch analysis from the Arc GIS (Projection 1960) program to generate land use/cover maps for 2000 and 2013. They were also used to compare changes in land use. In addition, the interpretation of aerial photographs and land-use maps was used to gather information and create land-use change charts. Finally, content analysis was used to analyze respondents' views on land-use change and wildlife status in the study area.

RESULTS AND DISCUSSIONS

Demographic and socio-economic characteristics of the respondents

The demographic and socio-economic characteristics of the respondents comprised gender, age, educational level, occupation, residence status, human population, and tribe. More men than women were interviewed. That is due to the nature of the male dominance of the Maasai. The traditional Maasai ethic is male dominance; in most cases, men respond to visitors in the house, leaving women shy or sometimes fearful of going out and talking to the counters. This argument is supported by Noe (2003), who also reported on male dominance in Masai traditions. That is the case in the Kwakuchinja study area, as many respondents were men. Most of the respondents were over 47 years old. The involvement of different age groups in the study was very important because different age groups had different experiences with the past situation of the Kwakuchinja natural corridor, particularly with the movement pattern and the wildlife status. The survey also found that most respondents had completed primary education, and only a few had secondary education (Table 1). The low level of formal education was due to the traditions of pastoral communities such as Maasai, which do not encourage their children to go to school; instead, many stay home to look after livestock. Only those considered troublemakers and didn't care for livestock were allowed to attend school. They then spent most of their lives looking after livestock for those who were not considered troublemakers, who were the community's illiterates.

In Tanzania, the Maasai are traditionally herders (Rodriguez et al. 2012). However, this is not the case in Kwakuchinja, as they are also involved in growing food crops. Thus, this study revealed that the main socio-economic activities of the respondents were polyculture-livestock, and very few were only farmers (Table 1). Most of the respondents mainly depend on intercropping and livestock as their main source of income. That is, in part, a strategy to meet the demand for food and other expenses after realizing the costs associated with raising large herds of cattle and a lack of pasture. Furthermore, during the 2007 drought, many cattle died from a lack of grazing (Muyungi 2007). Therefore, the situation may have forced many farmers to switch from their normal traditional farming lifestyle to a mixed farming system.

The survey found that most respondents were from the Maasai tribe and very few from other tribes (Table 1). It was also found that most of them had immigrated to the study area from Arusha, Arumeru, and Monduli, mainly for cattle breeding and grazing. Furthermore, all respondents said that the number of people in the study area is increasing.

Wildlife distribution, livestock, and human settlements in the Kwakuchinja wildlife corridor

Wildlife sightings, abundance, and distribution

Five large herbivore species have been recorded at twenty-seven observation points in the Manyara Ranch and Burunge WMA. These include Burchell's zebra (*Equus burchelli* Gray, 1824), wildebeest (*Connochaetes taurinus* Burchell, 1823), Masai giraffe (*Giraffa camelopardalis* Linnaeus, 1758), impala (*Aepyceros melampus* Lichtenstein, 1812), and Thomson's gazelle (*Gazella thomsonii* Günther, 1884) (Figure 2). The results show that Burchell's zebra was more conspicuous than other wild species, while Thomson's gazelle was the least conspicuous. Elephant droppings (*L. africana*) were also observed but excluded from population estimates because it was impossible to estimate their numbers. Two cheetahs (*A. jubatus*) were found dead on 12 December 2013 after being killed by Olasiti villagers for being associated with killing livestock (according to key informants interviewed).

The results from the transect survey showing the abundance of species are presented in Table 2. A comparison of densities among large mammal species in the study area shows that wildebeest rank high with an average number of 221 ± 102 SE, followed by Burchell's zebra with 28 ± 20 SE, impala with 7 ± 5 SE, Giraffe with 3 ± 2 SE and Thomson gazelle with 4 ± 0SE (Figure 3). The variation is so high because little data is collected due to time and resources. The wildebeest group sizes between Manyara Ranch and Burunge WMA were compared. Mean wildebeest group size was 221 ± 102 SE. At Manyara Ranch, a single group of Common Wildebeest was found about 2 km from the paved road leading to the Manyara Ranch Dam. At Burunge WMA, five groups were found beside Lake Manyara in Malamboi.

Zebra group sizes did not differ between Manyara Ranch and Burunge WMA in the study area. Total group size for zebra was 30 ± 7 SE (n1= 48, n2= 23, U= 8.5, p= 0.712). The size of giraffe groups did not differ between Manyara Ranch and Burunge WMA. The total group size of giraffes in the study area was 3±1 SE (n1= 1, n2= 5, U= 0.5, p= 0.264). Area. The total group size for the impala was 8 ± 3SE, (n1= 3, n2= 33, U= 0.5, p= 0.1). Only one group of Thomson's gazelle has been found at Burunge WMA adjacent to the Lake Manyara-Malamboi.

Table 1. General demographic and socio-economic characteristics of the respondents

Attribute		Percentage %
Sex	Male	60.7
	Female	39.3
		98.5
Tribe	Maasai	
	Others	1.5
		43.7
Residency	Indigenous	
	Immigrants	56.3
		1.5
Occupation	Farmer	
	Livestock keeper	0.0
	Farmer and livestock	98.5
		36.4
Education	Illiterates	
	Primary	60.7
	Secondary	2.9
		22.9
Age (Years)	18-27	
	28-37	31.2
	38-47	13.3
	>47	32.6
		100.0
Human population	Increasing	
	Decreasing	0.0

Table 2. Wildlife abundance

Species	Counts (number)	Density (number/area)	Mean group size (counts/sightings)	Population	Percentage %
Common wildebeest	1324	177.2	221	4646	75.4
Burchell's zebra	283	37.9	28	993	16.2
Impala	125	16.7	7	1096	7
Maasai giraffe	15	2	3	53	0.9
Thomson's gazelle	4	0.2	4	8	0.5

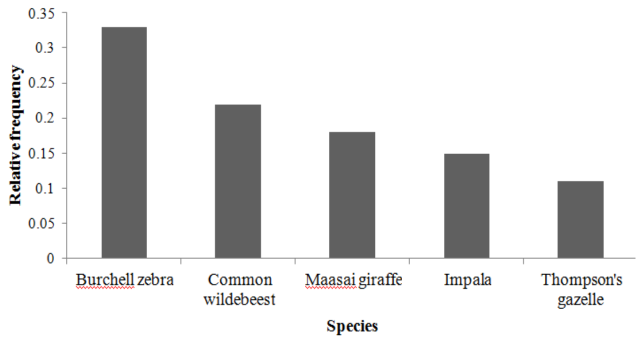


Figure 2. Wildlife species sighting relative frequencies in Kwakuchinja wildlife corridor, Tanzania (n= 27)

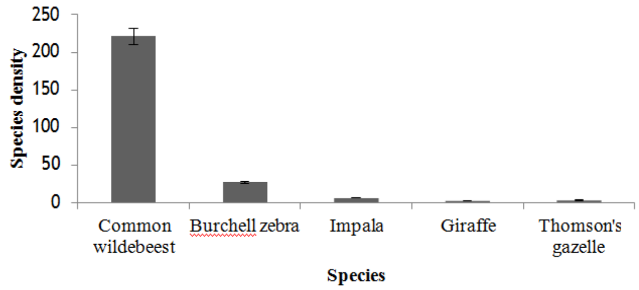


Figure 3. Wildlife species group size comparison (N=1751)

Wildlife distribution

Animal species were recorded in the Manyara Ranch and Burunge WMA during the transect studies and not in the open area (Table 3). In Manyara, wildlife has been found in grassland habitats. Manyara Ranch has a protected land-use status; rangers patrol the ranch, monitor wildlife, and fend off poachers. The Burunge WMA (Municipality Protected) fauna was found in areas of forest and bush, which are ecologically important for the fauna (Figure 4). Burunge WMA occupies the terrestrial and migratory corridors between Tarangire, Lake Manyara, and the adjacent Manyara Ranch, making it an area of high conservation importance. The municipal outdoor area has no wildlife protection status. Surveys revealed that wildlife was not present in the open areas of the community due to displacement and loss of habitat. The increased physical development in the corridor leads to the displacement of wildlife and, hence, the decline of the Kwakuchinja Wildlife Corridor. Examples of physical development range from institutions such as schools and pharmacies to the Minjingu Phosphate Mining Factory in Minjingu Village in the corridor. Others contain tourist campsites. Some of these are directly on migratory routes within the corridor, resulting in movements of endangered wildlife that may have led to diversions of wildlife routes. Others have addressed the diversion of effects due to the placement of physical structures in wildlife migration routes (Soini 2006; Ogutu et al. 2012). In addition to those institutions and the factory, it has also been established that the human settlements in the village are expanding Minjingu and becoming a small town, as indicated by Hassan (2003).

The results showed that although the correlation coefficient between settlement and livestock and wildlife is not statistically significant at the 5% significance level, there is a greater correlation between wildlife population and wildlife establishment (r= 0.714) than between wildlife and livestock (r= 0.263). That reasonably implies that colonization has more impact on wildlife than on livestock. The results that colonization is more strongly correlated with wildlife population are consistent with comments by Kideghesho et al. (2006) found that human activities such as colonization, deforestation, bushfires, mining, cultivation, and overgrazing are the main causes of habitat destruction and hence population reduction of wild animals.

Land use practices

Regarding land use, all respondents (100%, N= 135) surveyed in the study area indicated that animal and wildlife species readily share the same pasture and drinking water at different times of the day. They also said that cattle and wild animals have co-existed for a long time without any problems, which was observed during the study period in transept walks where wildlife and livestock shared the same habitat. The results suggest that the coexistence of wildlife and livestock is possible, provided that changes in land-use patterns are regulated in a way that does not compromise the habitat requirements necessary for wildlife conservation. Cultivation has also been reported to be bad land use for wildlife. Preserve wildlife habitats; most respondents said this could be achieved through law enforcement. Also, preventing animals from leaving protected areas and preventing trees (Table 5). Bhola et al. (2012) suggest that livestock facilitate feeding small and medium-sized herbivores in the rainy season and help create and maintain conditions that allow movement.

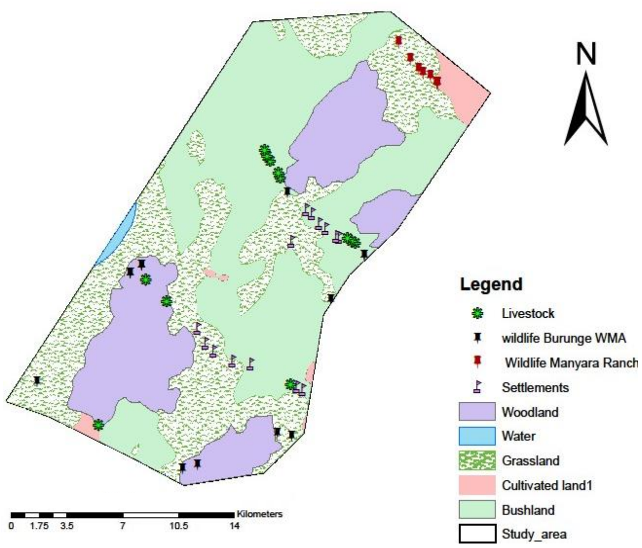


Figure 4. Map of Kwakuchinja, Tanzania, showing wildlife, livestock, and human settlement distribution concerning habitat

Table 3. Wildlife numbers counted in respective areas

Species	Manyara ranch	Burunge WMA	Community open area
Zebra	145	138	0
Wildebeest	18	1306	0
Impala	25	100	0
Giraffe	3	10	0
Thomson gazelle	0	6	0
Total	191	1560	0

Table 4. Livestock population in Kwakuchinja study zone, Tanzania

Area	Counted number (n)	Density (n/A)	Population	Percent (%)
Manyara ranch	130	18.1	475	8.1
Burunge WMA	525	73.2	1919	32.8
Community open area	945	131.8	3455	59.1
Total	1600		5849	100

Table 5. Respondents' views on land use practice

Parameter	Response	N=135	Percent (%)
Land use	Livestock keeping	1	0.7
	Cultivation	4	3.0
	Livestock keeping & cultivation	130	96.3
Bad land use	Cultivation	115	85.2
	Hunting	9	6.7
	Cultivation and hunting	11	8.1
Habitat conservation	Tree cutting	25	18.5
	Law enforcement	64	47.4
	Prevent animals	46	34.1

Table 6. Human settlement in Kwakuchinja study zone, Tanzania

Year	Settlement	Increase	% increase	% annual increase
1988	1281	0	0	0
1998	1582	301	23.5	2.4
2013	2378	795	33.5	3.3

Livestock distribution

During the transect survey, livestock was sighted in all three areas in the study zone. Livestock sightings in open community areas were high, followed by Burunge WMA and Manyara ranch (Table 4).

Settlement distribution

Settlements were found in the open community area, not Manyara ranch or Burunge WMA. Results also show that wildlife and livestock were found in woodlands and bushland habitats (Figure 4). These habitats are ecologically favorable to both wildlife and livestock.

Human population estimates in areas around TME are constantly changing, but nearly one million people are believed to live in areas covered by wildlife migration and grazing patterns (Marttila 2011). That study shows that from 1998 to 2013, there was an increase in human settlements of 33.5%, representing an annual increase in settlements of 3.3% (Table 6). That is consistent with the study by Gamassa (1989) and Hassan (1998) in the study area, which indicated a 23.5% increase in human settlement, corresponding to an annual increase of 2.4% in the establishment. Also, all kinds of human activities such as settlement, agriculture, animal husbandry, ranching, charcoal burning, and commercial farming are accelerating around the study area from Kwakuchinja. As a result, annual population growth (3.8%) is higher than the Tanzanian average (2.8%) (URT 2012). Therefore, this trend of increasing population and the current trend of agricultural expansion make no doubt that the existence of the Kwakuchinja flyway will be threatened and endangered shortly.

Assessment of the population trend and present status of migratory corridors concerning wildlife use for the past sixteen years (1998-2014)

Wildlife population trend

During the study, it was observed that wild animals and livestock grazed harmoniously at Manyara Ranch and Burunge WMA, except that in Burunge WMA, where hunting is permitted, the animals were very alert and fearful and kept a long flight distance. Hunting alters the reproductive behavior, population structure, and spatial and temporal distribution pattern of wild animals. The study found that the practice of hunting in the study area can affect wildlife, both legal and illegal (poaching. The study also found that the wildlife protection level is high at the Manyara Ranch, as explorers have patrol equipment to deploy law enforcement. That is not the case in Burunge WMA, where protection is poor as scouts do not have patrol equipment and poaching is unavoidable in Burunge WMA. In addition, during the questionnaire survey, 51.1% of respondents indicated that the number of lions is decreasing. The reason for the reduction is due to trophy hunting and retaliation.

The total number of large mammals was estimated to be more than 120,000 in 1980. Still, in 1999-2000 the number was about 45,000 large mammals, of which 34,000 were seasonal migrants, oryx (*Oryx beisa* Rüppell, 1835), lesser kudu (*Tragelaphus imberbis* Blyth, 1869), gerenuk (*Litocranius walleri* (Brooke, 1879), included (Arron 2001). Two migratory species counted were zebras (15664) and wildebeest (9103). This aerial survey data point shows a more than 50% decrease in the number of large mammals in the ecosystem over the past decade (the 2000s compared to the 1990s) (Arron 2001), and the long change was more dramatic. The 2004 aerial survey counted 23,440 large mammals, including 5249 buffalo (*Syncerus caffer*), 12,000 Thomson's gazelle (*G. thomsonii*), 1151 eland (*Taurotragus oryx* Pallas, 1766), 113 oryx (*O. beisa*), 1426 Maasai giraffe, (*G. camelopardalis*), 338 Common waterbuck (*Kobus elipsiprymnus* Ogilby, 1833), 170 Bushbuck (*Tragelaphus sylvaticus* Pallas, 1766), 72 leopards (*P. pardus*), 140 hyenae (*Crocuta crocuta* Erxleben, 1777), 25 cheetahs (*A. jubatus*), 48 wild dog (Arron 2004) and 200 lions (*Panthera leo* Linnaeus, 1758) (Martilla 2011).

Previous studies have shown that during migration, lions partially expand their territories outside TNP, where conflicts with pastoralists are inevitable. Most lion pride leave TNP and spend 4-5 months outside the park in ranges where lions face retaliatory killings due to predation by herders (Kisui 2011). There are three causes of death for lions in the Maasai Steppe: retaliatory killings, trophy hunting, and natural mortality. Although lion population declines have been attributed to trophy hunting, natural death, and conflict, retaliatory killings may be the leading cause of lion mortality in the Maasai Steppe (Kisui 2011). However, further analysis is needed to disentangle the relative contribution of each source of mortality.

In the Maasai Steppe, retrieving lions from livestock predation remains a major challenge for lion conservation. Due to their seasonal migratory nature, lions are only safe if they are in the park during the dry season (Kisui 2011). However, when most lions follow migrating herbivores to the common land in the rainy season, there is greater interaction between lions and livestock. That is when lions are at a greater risk of being killed due to predation by livestock. Tarangire Lion Project records show that between 2003 and 2011, at least 226 lions were killed concerning livestock predation, with an average of 20-30 lions killed yearly. The prediction is that very few lions will remain in TME by 2020 (Marttila 2011) (Figure 5).

This study observed that when lions expand their territories outside TNP, the Maasai hunt and/or kill them. It was also found that sport hunting is poorly managed; Sport hunters select older, mature males for good trophies, leaving the pride to juvenile males. During the acquisition of female pride, pup mortality is greater as the new males will kill all the pups. The dilemma in TME is the lack of time for males to defend their young from other males, as the hunting season does not allow sufficient time for reproduction and protection of the young until maturity. Consequently, the breeding rate is low, and the number of lions in the area will continue to decline with each hunting season.

Since retaliation is the primary motivation for killing lions (Kisui 2011), improving farming is one strategy to reduce human-lion conflict. For example, improving livestock security from predators at night using low-tech, low-cost techniques such as chain-link fencing to reduce livestock predation in bomas (an artificial structure used to secure livestock) can reduce the impact of conflict and breeders. In addition, more efforts should be made to reduce the impact of reprisal killings through participatory approaches involving pastoral communities in surrounding villages. Improving law enforcement that deals with lion killings can also help reduce the rate of retaliatory lion killings. Data from 2003-2011 show that the lion population in Tarangire was estimated at around 170 individuals (Kisui 2011). That shows a decrease of approximately 15% from the demographic estimates of 2003 when systematic and continuous monitoring began (Figure 6). In 2005, the population recovered briefly from the decline in 2004, but the numbers show a sustained decline since 2005, with the largest decline in 2006. The first half of 2007 and 2008 showed signs of recovery, but in 2009 the population plunged again and reached its lowest point before entering a new recovery phase in 2010/2011. These fluctuations in population size may reflect regular population dynamics, but it remains whether the upward trend observed in 2011 will continue to reach 2003 levels in the coming years (Kisui 2011).

The most numerous ungulates in the NPT are the Impalas (4088), although their numbers have significantly decreased; the current figures are only a tenth of those of 30 years ago (1980 counted 30,750). The decline in numbers is related to a sharp increase in human activities across the TME (Arron 2004). Tarangire and LMNPs are highly protected by Tanzania National Parks, prohibiting cattle grazing and sport hunting. Manyara Ranch is protected by scouts employed by the Manyara Ranch Conservancy. Manyara Ranch Conservancy is a business that operates in partnership with Maasai communities through the Tanzania Land Conservation Trust and the African Wildlife Foundation. The Conservancy exists to protect the migration corridors that connect Lake Natron, Ngorongoro, Manyara, Tarangire, and the Maasai lands to the south. On the other hand, Burunge WMA is an area designated by the municipality to protect wildlife and habitat where cattle grazing and sport hunting are also permitted.

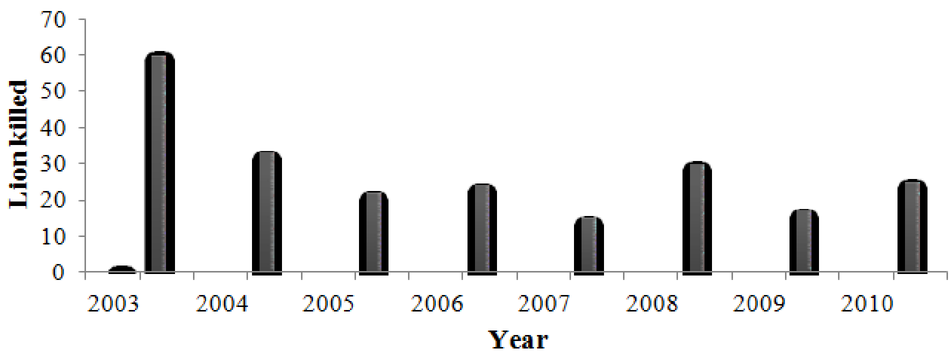


Figure 5. Number of lions killed as a result of livestock predation in Maasai Steppe, Tanzania (Source: Tarangire Lion Project 2011)

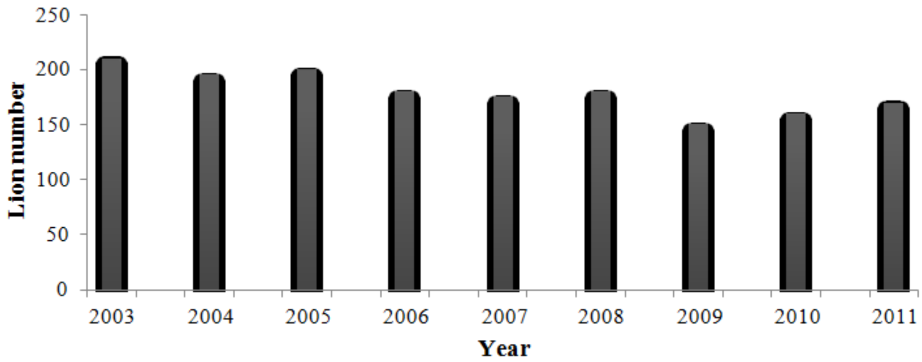


Figure 6. Estimated lion population size in Tarangire National Park, Tanzania, from 2003-2011 (Source: Tarangire Lion Project 2011)

Respondents' perceptions of wildlife status

During the questionnaire survey, all respondents stated that no new animal species were found in the study area that was not present in the past or migrated to the study area. However, respondents said giraffes, buffaloes, African wild dogs, lions, and Maasai moose are declining in the area (Table 7).

On the status of wild animals, most of the residents (80.7%) said that wildlife was increasing with a significantly different relationship ($\chi^2 = 51.03$, $p < 0.0001$). Opinions on the increase or decrease in wildlife depended on the number of variables, such as sex and time spent in the study area. The respondents' perception of the increase in wildlife and sex was insignificant ($\chi^2 = 0.28$, $p = 0.59$). Most of the respondents surveyed believe that the number of wild animals (81.5%) generally increases with their time in the study area (Table 8). There is a positive and significant association between increased wildlife and the time respondents spend in the study area ($\chi^2 = 53.09$, $p=0.05$).

Migratory corridors have been used by wildlife for the past sixteen years (1998-2014)

Most migratory animal species congregate around the Tarangire River during the dry season. Still, once the rainy season begins in November (with an annual variation of up to two months), the animals disperse through TME. The two wild migratory species, the common wildebeest and the Burchell's zebra, completely abandon the NPT. Some common wildebeest and Burchell's zebras migrate both north and south of the NPT, but most migrate east to grazing and calving areas in the Simanjiro Plains, 20 to 60km away. About 16,000 wildebeest and zebras have been estimated together in the lowlands. When the plains dry quickly from June to July, migratory species return to the Tarangire River; by August, all animals become available in the NPT. However, distant migrants such as the beisa oryx can still travel to Lake Natron, or perhaps southern Kenya, and will not be among the first to return (Kahurananga and Silkiluwasha 1997). Elephants to 1890 (2004); 1447 (76%) counted remained within the limits of the TNP (Arron 2004). According to Gamassa (1989), migratory wildlife species, notably zebras and wildebeests, enter the study area on their way to the TNP in mid-June. The peak is in July/August (season dried). The animals use the corridor again on the way back from the TNP at the start of the rains (early November), and the highest density of wild animals is observed at the end of December.

Table 7. Respondent's perception of wildlife status (N=135)

Species	Status	Percent	Reasons
Giraffe	Decreasing	84.4	Human disturbance and loss of habitat
Impala	Increasing	97.8	Conducive habitat
Buffalo	Decreasing	68.9	Hunted for meat and trophy Poached
Elephant	Increasing	99.3	They are not hunted in the area, and they are frequently seen in villages
Wild dog	Decreasing	99.3	Loss of habitat, disease, route /corridor blockade
Zebra	Increasing	100	Conducive habitat
Lion	Decreasing	51.1	Hunted for trophy Migrated with ungulates Killed by Maasai
Hyena	Increasing	100	Availability of food
Eland	Decreasing	88.9	Hunted for trophy Poached Loss of habitat and displaced

Table 8. Responses of the respondents on the wildlife trend

Wildlife status	Frequency	Percent %
Increasing	109	80.7
Decreasing	26	19.3
Total	135	100.0

It has been observed that agricultural activities, settlements, crops, and livestock are carried out in some areas previously used as faunal corridors and dispersal areas. These human activities have impacted wildlife that previously used the areas to drink water or obtain mineral nutrients not found in other areas. The main threats to the long-term sustainability of the Tarangire/Manyara ecosystem are the loss of some migration corridors and areas outside the national parks. Migration corridors and areas have shrunk, and some have been lost due to human activities. The study by Lamprey (1964) identified eight wildlife corridors from TNP, two of which are connected to LMNP. Borner (1985) found that only five remained. In 2000, five wildlife corridors remained in the ecosystem (Msoffe et al. 2011). Only three corridors currently remain, (i) in the northeast, the Kwakuchinja Wildlife Corridor, used primarily by TNP wildebeest and zebra at Manyara Ranch and Lake LMNP; (ii) the TNP corridor through the Loikisare Game Control Area to the Losimingori Mountains, used mainly by elephants, and (iii) the third corridor east of the TNP to the Simanjiro Plains, used mainly by wildebeest and zebras to calving grounds used. All of these are currently under severe threat from extensive agriculture and settlements.

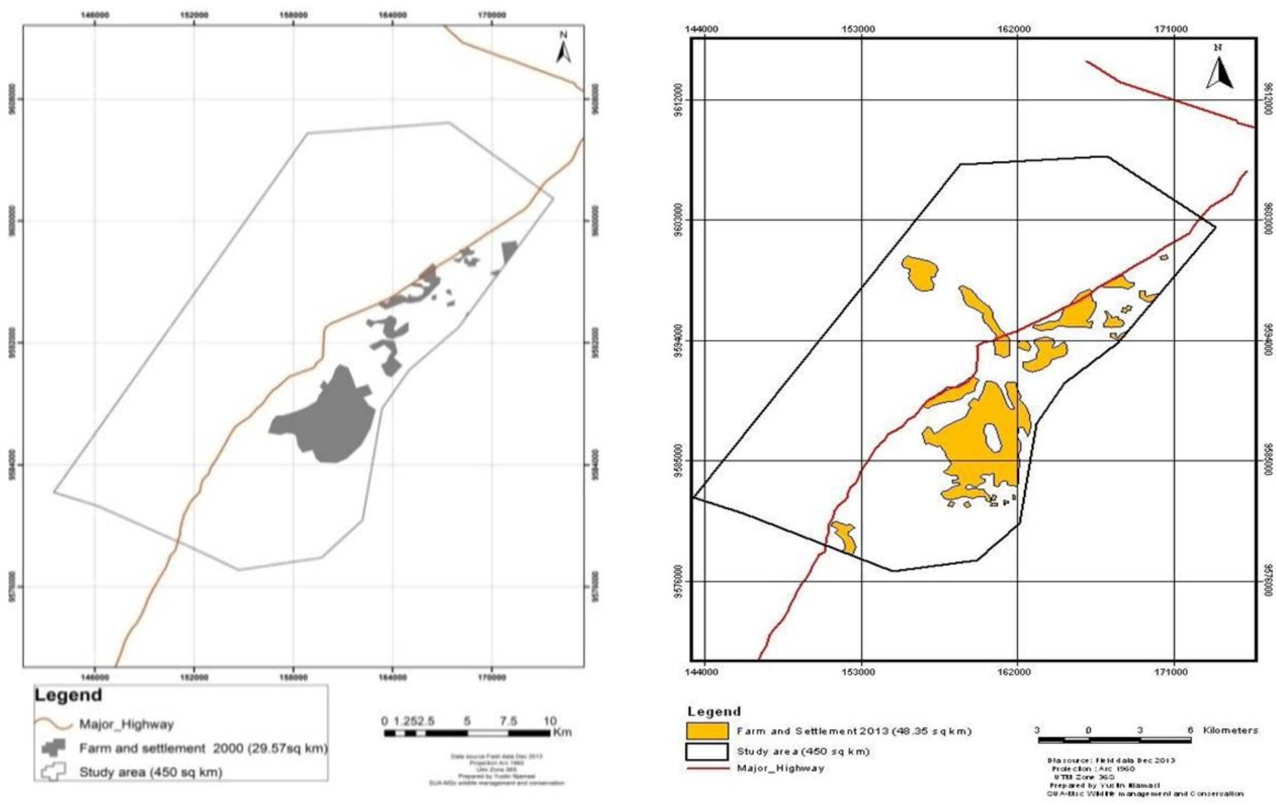
Two corridors that have been blocked are the corridor from the TNP - Vilima vitatu - Mwada - Magara to the LMNP and the one from Tarangire to the Mkungunero range. In addition, there has been an immigration of people from other areas (Babati, Monduli, Simanjiro, and Kiteto) to the study area for cultivation, animal husbandry, work, and fishing. The process of immigration increased the human population and led to the formation and registration of new villages in areas previously used by wildlife. The new villages were founded due to political influences. However, it has been observed that the established villages do not have a land-use plan. That has resulted in communities not having specific areas designated for a particular activity. Hence, habitat was destroyed due to the community's needs acquired from natural habitats (e.g., firewood, infrastructure development, crops, and pastures). The study also found that the increase in human population was related to infrastructure development, most notably the asphalt road from Babati to Arusha, electricity, and the Minjingu Phosphate mining plant.

On the other hand, the extensive agricultural expansion in the Mkungunero area led to the obstruction of the corridor. The ranges have been converted to Mamire agricultural fields. These activities have severely affected the corridors and routes formerly used by wildlife.

Strong overlap between land suitable for agriculture and the main wildlife corridors and wet season distribution areas shows that agricultural development is the main blocking factor for five of the eight wildlife corridors. The blocking of the two former historic routes that connected the TNP and the LMNP denies the animal's right of passage to migrate between the two parks. During the investigation, it was found that agricultural expansion led to the loss of these remaining corridors. In rural areas such as the Kwakuchinja study area, many people depend directly on agriculture, which is still the backbone of the Tanzanian economy, to support their daily needs. Lack of community awareness of the importance of wildlife has led communities to view wildlife as a nuisance because they don't directly encourage it. Therefore, they cannot see the importance of wildlife rather than just as their enemies (Ogutu et al. 2012). As a result, wild animals (especially carnivores) are killed when found on cropland farms and when they attack livestock in their homes, which is also the case in this study, where the lion, leopard, and cheetah have been reduced. Pettorelli et al. 2010) the results reported that agriculture had serious consequences for carnivores, as it was found that they avoided cultivated land.

Assessment of the impacts of land use/cover changes on wildlife in the Kwakuchinja wildlife corridor

Land use/cover change in square kilometers and the percentage was derived from 2000 and 2013 satellite imagery in the study area. In 2000, the cultivated area was 29.6 km^2 (6.6%) (Figure 7A) and 48.4 km^2 (10.8%) in 2013 (Figure 7B). The results show that from 2000 to 2013, the cultivated area in the study area increased by 4.2% in thirteen years. During the study period, it was observed that much of the Kwakuchinja wildlife corridor was under agricultural land. As a result, 4.2% of natural land has been altered for cultivation, reducing the habitat used by wildlife. The current conversion of natural land to cultivation occupying large areas has destroyed natural vegetation and reduced the areas for wildlife to graze and exercise. During the study, it was observed that the current increase in human settlements between the villages of Mswakini, Olasiti, and Kakoi goes hand in hand with increasing arable land to feed the growing human population. The study also revealed that people who migrate to the study area include agriculture, fishing, small business, animal husbandry, employment, and marriage. Most immigrants immigrated during the period 2000-2010. Physical developments that have taken place, such as schools, pharmacies, tourist camps, and Minjingu phosphate mining in Minjingu Village, are within the corridor. These developments threaten wildlife movement, which may have led to diverging wildlife routes, reduced wildlife populations, and food availability, impacting wildlife.



A B

Figure 7. Map of Kwakuchinja study area, Tanzania: A. Showing land use/the cover year 2000, B. Showing land use/cover change for year2000-2013 (Source**,** field data December 2013, Arc GIS projection 1960)

Kideghesho et al. (2006) support this study and reported a loss of wildlife habitat to cultivation in the Western Serengeti Wildlife Corridor. It was also reported by Rodgers et al. 2003) that 16% of Kwakuchinja-Gang was converted into agriculture from 1987 to 2001. Most land-use changes in the Kwakuchinja corridor occurred from 2000 to 2010.

Hassan (2003) reported that the expansion of human settlements in the village of Minjingu transformed the village into a small town. Minjingu village is currently divided into three villages, namely Minjingu, Olasiti, and Kakoi, which was caused by the immigration of people from neighboring districts such as Arusha, Arumeru, and Monduli. The increased human settlement in the area has greatly contributed to the lack of free space for wildlife movements; as found during this survey, this observation is also supported by Ndibalema (2010) in the Serengeti ecosystem and Magige (2010), who also reported the loss of bird habitats due to agricultural expansion. Those have resulted in a narrowing of the corridor area and could block the entire corridor if the current trend of increasing human population continues in the Kwakuchinja Wildlife Corridor. Noe (2003) observed the shrinkage in the size of the Kitendeni Natural Corridor in Kilimanjaro National Park to about 5 km^2 in 2001 from 21 km^2 in 1952. The main reasons were the expansion of cultivated land, human settlements, and changes in the use of the soil. Kwakuchinja characterizes the same threats today as activities such as settlement, agriculture, livestock farming, coal burning, and even commercial farming increase at an accelerating pace.

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In conclusion, the study found that wildlife and livestock were in areas with less human habitat destruction. Wildebeest were also found to have the highest density in the study area. There is also a stronger correlation between wildlife population and colonization than between wildlife and livestock. The study found that traditional migration corridors have shrunk from five to three and found local extinctions of five species of large mammals. The natural trend based on aerial survey data shows a more than 50% decrease in the number of large mammals in the ecosystem in the 2000s compared to the 1990s. These results imply that wildlife and livestock graze and share areas of watering. The increase in the number of animals does not affect the number of wildlife, but an increase in human settlement and cultivation affects wildlife and their habitat.

REFERENCES

Arron H. 2001. Aerial wildlife census: Elephant and buffalo in the Tarangire Ecosystem. Kakakuona 20: 52-55.

Arron H. 2004. Total count of Elephants and Buffalo in the Tarangire Ecosystem. Dry season, 2004 Preliminary Report. Tanzania Wildlife Research Institute, Conservation Information and Monitoring Unit, Arusha. Tanzania.

Babbie E. 1990. Survey Research Method. Wadsworth Publishing Company, Calfornia.

Babbie E. 2007. Survey Research. The Practice of Social Research. Belmont, CA: Thomson Wadsworth.

Bailey DK. 1994. Methods of Social Sciences Research. The Free Press Collier Macmillan Publisher, London.

Bhola N, Ogutu JO, Said MY, Piepho HP, Olff H. 2012. The distribution of large herbivore hotspots in relation to environmental and anthropogenic correlates in the Mara region of Kenya. J Anim Ecol 10: 1365-2656. DOI: 10.1111/j.1365-2656.2012.02000.x.

Borner M. 1985. The increasing isolation of Tarangire National Park. Oryx 19: 91- 96. DOI: 10.1017/S0030605300019797.

Caro T, Jones T, Davenport TRB. 2009. Realities of documenting wildlife corridors in tropical countries. Biol Conserv 142: 2807-2811. DOI: 10.1016/j.biocon.2009.06.011.

Gamassa DM. 1989. Land Use Conflicts in Arid Areas. A Demographical and Ecology Case study. The kwakuchinja Wildlife Corridor in Northern Tanzania. [Dissertation]. Agricultural University of Norway, Norway.

Goldman M. 2003. Partitioned nature, privileged knowledge: Community-based conservation in Tanzania. Dev Chang 34: 833-862. DOI: 10.1111/j.1467-7660.2003.00331.x.

Hassan SH. 2003. Conservation status of the Kwakuchinja wildlife corridor in the last two decades. Kakakuona Wildl Mag 16: 12-15.

Hassan SN. 1998. Assessment of Space Use of the Kwakuchinja Wildlife Corridor in Northern Tanzania, By Both Wildlife and Residents. [Dissertation]. Manchester Metropolitan University, Manchester.

Hassan SN. 2007. Impacts of space use by humans on large mammal species diversity in the Kwakuchinja-Mbugwe wildlife Corridor, Northern, Tanzania. Tanzania J For Nat Conserv 76: 134-143.

Jones T, Caro T, Davenport TRB. 2009. Wildlife Corridors in Tanzania. Tanzania Wildlife Research Institute (TAWIRI), Arusha, Tanzania.

Kahurananga J, Silkiliwasha F. 1997. The migration of Zebra and Wildebeest between Tarangire National Park and Simanjiro plains, Northern Tanzania, in 1972 and recent trends. Afr J Ecol 35: 179-185. DOI: 10.1111/j.1365-2028.1997.071-89071.x.

Kideghesho JR, Nahonyo JW, Hassan SN, Tarimo TC, Mbije NE. 2006. Factors and ecological impacts of wildlife habitat destruction in the Serengeti ecosystem in northern Tanzania. AJEAM-RAGEE 11: 917-932.

Kisui B. 2011. Lion population monitoring: Tarangire Lion Research Report. African Wildlife Foundation, Arusha, Tanzania.

Lamprey HF. 1964. Ecological separation of the large mammal species in the Tarangire Game Reserve, Tanganyika. East Afr Wildl J 1: 63-92. DOI: j.1365-2028.1963.tb00179.x.

Leoniak G, Barnum S, Atwood JL, Rinehart K, Elbroch M. 2012. Testing GIS-generated least-cost path predictions for martes pennant (Fisher) and its application for identifying mammalian road-crossings in northern New Hampshire. Northeast Nat 19: 147-156.

Magige FJ. 2010. Importance of birds in conservation of African National Parks. In: Roskaft E, Gereta EJ (eds). Conservation of Natural Resources, Some African and Asian Examples. Tapir Academic Press. Trondheim.

Marttila O. 2011. The Great Savanna, the National Parks of Tanzania and Other Key Conservation Areas. Auris Publishers, Torkkelintie 12, Fin-15300 Rauha, Finland.

Msoffe F, Kshatriyaj M, Neselee M, Said M. 2011. Novel Forms of Livestock and Wildlife Integration Adjacent Protected Areas in Africa. Arusha, Tanzania.

Muyungi RS. 2007. Managing land use, protecting land and mitigating land degradation: Tanzania case study. In: Sivakumar MVK, Ndiangui N (eds). Climate and Land Degradation. Springer-Verlag Berlin, Berlin.

Ndibalema VG. 2010. Conservation of African national parks, Challenges from migratory mammals. In: Røskarf E, Gereta JE (eds). Conservation of Natural Resources, some African and Asian Examples. Tapir Academic Press, Trondheim.

Newmark WD. 2008. Isolation of African protected areas. Front Ecol Environ 6: 321-328.

Noe C. 2003. Land-use change impacts and dynamics. LUCID Working paper No. 31, International Livestock Research Institute, Nairobi, Kenya.

Norton-Griffiths M. 1978. Counting Animals. African Wildlife Foundation. Second Edition, Handbook Number 1, Nairobi, Kenya.

Ogutu JO, Owen-Smith N, Piepho HP, Kuloba B, Edebe J. 2012. Dynamics of ungulates in relation to climatic and land use changes in an insularized African savanna ecosystem. Biodivers Conserv 21: 1033-1053. DOI: 10.1007/s10531-012-0239-9.

Pettorelli N, Lobora AL, Msuha MJ, Foley C, Durant SM. 2010. Carnivore biodiversity in Tanzania: Revealing the distribution patterns of secretive mammals using camera traps. Anim Conserv 13: 131 -139. DOI: 10.1111/j.1469-1795.2009.00309.x.

Pittiglio C, Skidmore AK, van Gils H, Prins HHT. 2012. Identifying transit corridors for elephant using a long time-series. Intl J Appl Earth Obs Geoinf 14: 61-72.

Pla-Ard M, Khioesree N, Keawdee B, Hungheng W, Chattrakuldee P, Pengthong P, Thongbanthum J, Paansri P, Charaspet K, Panganta T, Chanachai Y, Duengkae P, Marod D, Uthairasmee S, Kaewkrachang T, Bhumpakphan N, TrisuratY, Suksavate W, Sungkaew S, Pongpattananurak N, Racharak P, Wiwatwittaya D, Tasen W, Sukmasuang R. 2021. Monitoring the diversity, abundance, activity period and habitat use of wildlife species around the wildlife corridor that connects the natural world heritage site in Thailand. Biodiversitas 22: 4983-4996. DOI: 10.13057/biodiv/d221134.

Rathore CS, Dubey Y, Shrivastava A, Pathak P, Patil V. 2012. Opportunities of habitat connectivity for Tiger (*Panthera tigris*) between Kanha and Pench National Parks in, India. PLoS One 7 (7): e39996. DOI: 10.1371/journal.pone.0039996.

Rodgers A, Melameri L, Nelson F. 2003. Wildlife Conservation In Northern Tanzanian Rangelands. Conservation in Crisis: Experiences and Prospects for Saving Africa's Natural Resources. Tanzania, Mweka College of African Wildlife Management, Tanzania.

Rodriguez LC, Henson D, Herrero M, Nkedianye D, Reid R. 2012. Private farmers' compensation and viability of protected areas: The case of Nairobi National Park and Kitengela dispersal corridor. Intl J Sustain Dev World Ecol 19: 34-43. DOI: 10.1080/13504509.2011.587549.

Shemweta DTK. and Kideghesho, J.R. 2000. Human-wildlife conflicts in Tanzania. In: Proceedings of the 1st University Wide Conference, 5th-7th April 2000, Morogoro, Tanzania.

Soini E. 2006. Bird diversity and land use on the slopes of Mt Kilimanjaro and the adjacent plains, Tanzania. Afr Zool 41: 193-209. DOI: 10.1080/15627020.2006.11407355

Sutherland WJ. 2001. Sustainable exploitation: A review of principles and methods. Wildl Biol 7: 131-140. DOI: 10.2981/wlb.2001.017

Thomas B, Holland JD, Minot EO. 2012. Seasonal home ranges of elephants (*Loxodonta africana*) and their movements between Sabi Sand Reserve and Kruger National Park. Afr J Ecol 50: 131-139.

URT. 2009. United Republic of Tanzania. The Wildlife Conservation Act No. 5. Ministry of Natural Resources and Tourism, Wildlife Division, Dar es Salaam, Tanzania.

URT. 2012. United Republic of Tanzania.2012 Population and Housing Census. National Bureau of Statistics, Ministry of Finance, Dar es Salaam, Tanzania.

Western D, Grimsdell JJR. 1979. Measuring the Distribution of Animals in Relation to the Environment. African Wildlife Foundation Handbook, Nairobi.

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The toxicity of *Annona squamosa* seeds and *Anacardium occidentale* seed shells from East Nusa Tenggara, Indonesia, against cabbage caterpillar (*Crocidolomia pavonana*)

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Abstract. *Nenotek PS, Londingkene JA, Ludji R, Harini TS, Kapa MJ, Nguru ESO, Roefaida E, Konanin M. 2022. The toxicity of* Annona squamosa *seeds and* Anacardium occidentale *seed shell from East Nusa Tenggara, Indonesia, against cabbage caterpillar (*Crocidolomia pavonana*). Intl J Trop Drylands 6: 39-44.* The study objective was to determine the effect of methanol extracts of *Annona squamosa* L. seeds and seed coat of *Anacardium occidentale* L. from East Nusa Tenggara, Indonesia, on the *Crocidolomia pavonana* (Fabricius, 1794), the cabbage caterpillar. Bioassay was done using with a residue method in feed for one minute at each concentration of *A. squamosa* seed extract (0.01%; 0.03%; 0.06%; 0.125%; 0.25%; and control) and extract *A. occidentale* (0.06%; 0.125%; 0.25%; 0.5%; 1%; and control). The results showed that the methanol extract of *A. squamosa* seeds was more toxic to *C. pavonana* larvae compared to the methanol extract of *A. occidentale*. The LC_{50} and LC_{95} values of *A. squamosa* seed extract against the tested insects were 0.04% and 0.16%.

Keywords: *Anacardium occidentale, Annona squamosa, Croccidolomia pavonana,* lethal concentrate, toxicity

INTRODUCTION

Farmers' overreliance on synthetic pesticides in agriculture caused negative impacts on various non-target organisms and the environment. For example, it posed serious health risks to humans, damaged biodiversity and the environment, increased bioaccumulation of pesticide residues in the food chain, killed pollinators, polluted water and air, influenced changes in the microbiome to reduce mammalian resistance to pathogens, and the emergence of resistant insect (Mahmood et al. 2016; Tarar 2019; Syromyatnikov et al. 2020; Kalyabina et al. 2021; Riyaz et al. 2022). Mesnage et al. (2021) found 186 pesticide residues from the pyrethroid and organophosphate groups in human urine samples. According to World Health Organization (WHO), every year, there are three million cases of poisoning by synthetic pesticides, which cause the death of about 220,000 people (Mughal 2018). To reduce the negative impact of the unwise use of synthetic pesticides, the United States government has issued laws on the protection of food quality and regulations to reduce the circulation of synthetic pesticides in the market (Dayan et al. 2009). In addition, there is an increasing public demand for food safety and quality (Damalas and Koutroubas 2018). Thus, pest control technology must comply with these standards; one of the control technologies is botanical insecticides. Botanical insecticides have advantages compared to synthetic pesticides. The volatile residue is relatively safe for human health and the natural environment and does not cause insect resistance. Botanical pesticide is an alternative pest control technology that is relatively safe in producing quality food (Damalas and Koutroubas 2020) and causes no environmental harm. Sources of botanical pesticides are secondary metabolites produced from various species of plants such as flavonoids, alkaloids, essential oils, glycosides, ethers, and fatty acids that function as antifeedants, repellents, attractants, inhibit growth and kill the pests and diseases of the plant (Hikal et al. 2017). These secondary metabolites are stored in tissues such as stems, seeds, latex, cell wall, trichome, and seed coat. Furthermore, more then hundreds of plants have been demonstrated in the laboratory as insecticides, including *Annona squamosa* L. and *Anacardium occidentale* L. (Murray 2011; Nenotek and Ludji 2020).

Compounds of secondary metabolites of *A. squamosa* and *A. occidentale* have insecticidal properties against pests. For example, hexane seed extract of *A. squamosa* on LD_{50}= 13.98, larvae instar three *Spodoptera litura* (Fabricius, 1775) (Vetal and Pardeshi 2019). Seed methanol extract of *A. squamosa* killed larvae of *Aedes albopictus* (Skuse, 1894) and *Culex quinquefasciatus* (Say, 1823) (Ravaomanarivo et al. 2014). The *A. occidentale* can control the beetle *Callosobruchus maculatus* (Fabricius, 1775) on cowpea (Ileke and Olotuah 2011). Leaves of *A. occidentale* can suppress the development of mosquito larvae (Tripathy et al. 2011). The research by Oparaeke and Bunmi (2006) showed that cashew nut shells killed 100% of *C. subinnotatus* at a concentration of 2.5% and reduced their oviposition.

A. squamosa and *A. occidentale* mostly grow in dryland areas of the East Nusa Tenggara islands. Their waste contains secondary metabolite compounds that can function as botanical insecticides. Their toxicities were tested on the caterpillar *Crocidolomia pavonana* (Fabricius, 1794), one of the important pests of the cabbage. The damage caused by these pests can cause yield losses, so farmers control them with synthetic insecticides such as profenofos. However, profenofos residues attached to cabbage leaves can interfere with human health. Because cabbage leaves are often directly consumed in fresh form and to reduce the negative impact of synthetic insecticides on human health, pest control techniques that are safe for human health and the environment and competitive in the free market are urgently required. Thus, this research was carried out to determine the efficacy of *A. squamosa,* and *A. occidentale* extracts on *C. povonana* larvae.

MATERIALS AND METHODS

Insecticidal plant materials

The experiment was conducted at the Bioscience Laboratory of Universitas Nusa Cendana (for extraction) and Plant Pests, Department of Agrotechnology, Faculty of Agriculture, Universitas Nusa Cendana (for bioassay), East Nusa Tenggara, Indonesia. The materials used as candidate plant insecticides were *A. squamosa* seeds and *A. occidentale* seed coats. Both materials were collected from Salbait Village, West Mollo Sub-district, South Central Timor District, East Nusa Tenggara, Indonesia.

Extraction of plant material

The *A. squamosa* seeds were peeled, and the kernel was collected. Meanwhile, *A. occidentale* was taken from the pseudo-seed coat. Each of these materials was ground using a blender and then sieved through a 0.5 mm mesh. The pulverized *A. squamosa* and *A. occidentale* were macerated separately with methanol for 24 hours at a ratio of 1:5, followed by filtration using a watchman paper No 41. The filtrates were collected in an Erlenmeyer flask. The solvent was evaporated using a rotary evaporator at a temperature of 50°C and a pressure of 240 m bar. The maceration mentioned above was repeated until the extraxt was slightly clear or colorless. The extract was then stored in a refrigerator at a temperature of ± 4°C until it was used for the bioassay.

Preparation of tested insect feed

Pesticide-free cabbage leaves were used for feeding the tested insects and treatment. The cabbage plants were prepared as follows. First, the seeds were sown on the tray. The seedling media consisted of a mixture of soil and compost at 1:1. Two seeds were given to each tray hole at a depth of 1 cm. Second, after the seedlings were 2 weeks old, they were transferred to polybags measuring 20 cm x 20 cm x 20 cm, filled with soil and manure in a ratio of 3:1 (v/v). Each polybag contained one cabbage seed. Cabbage maintenance includes watering, fertilizing, and controlling pests by mechanical means. The cabbage leaves were taken one month after planting and used as feed for the tested insect.

Rearing of tested insects

The tested insect used in this study was the second instar larvae of *C. pavonana*. Rearing of tested insects, following procedures as described by Nenotek (2010) and Prijono and Hassan (1992). Larvae were obtained from cabbage plantations in Tarus Village, East Kupang District, East Nusa Tenggara, Indonesia, then reared in plastic boxes measuring 20 cm x 10 cm x 5 cm by feeding them insecticide-free cabbage leaves. Before pupating, the last instar larvae were transferred to another plastic box which had been given sterile sawdust as a medium for pupating. The pupae were then placed in cages until the emergence of imago. Imago were kept in cages (40 cm x 40 cm x 40 cm). The emerging imago was given a 10% honey solution (absorbed on the cotton) as food. In the cage, pesticide-free cabbage leaves were put in a film bottle filled with water as a place for the imago to lay eggs. The group of eggs contained in the cabbage leaf was removed from the cage and put in another plastic box. Before the eggs hatch, the steamed cabbage leaves are transferred to a plastic box that has been lined with opaque paper and provided with insecticide-free cabbage leaves. Newly hatched second-instar larvae were used for bioassay.

Bioassay

Both extracts of *A. squamosa* and *A. occidentale* were tested at different concentrations. *A. squamosa* extract was tested at a concentration of 0.01%; 0.03%; 0.06%; 0.125%; 0.25%; and control while that of *A. occidentale* extract was 0.06%; 0.125%; 0.25%; 0.5%; 1%; and control. Each treatment was three replicates. Each concentration of each extract was diluted with a mixture of agristic, acetone, and methanol (15:5:4, final concentration 1.2%), then diluted with distilled water to the desired volume. The control solution consisted of aquadest and a mixture of methanol, acetone, and agricultural.

Each treatment was tested on the second instar *C. pavonana* larvae using the residue method on cabbage leaves. Pesticide-free cabbage leaf pieces measuring 4 cm x 4 cm were immersed in the extract for one minute, then dried on opaque paper. The cabbage leaves were placed in a Petridish (9 cm x 9 cm), lined with tissue, then ten instars II larvae of *C. pavonona* (which had just molted) were added to the Petridish. The larvae were given treatment or control feed for 2 days, then replaced with untreated feed for up to 6 days after treatment (DAT). Observations were made 24 hours after treatment by counting the number of dead larvae. Dead larvae were removed from the cup. Mortality monitoring was continued until 6 DAT.

Data analysis

The observed variables were the symptoms of larval mortality and the number of dead larvae in each treatment. Mortality data were analyzed using the POLO PC probit analysis to determine the LC_{50} and LC_{95} toxicity values (LeOra Software 1987).

RESULTS AND DISCUSSION

Toxicity of *A. squamosa* and *A. occidentale* seed extracts against *C. pavonana* larvae

Compared with *A. occidentale* seed extract, *A. squamosa* seed extract is an effective botanical insecticide against *C. pavonana* larvae. The mortality rate of *C. pavonana* larvae was 58% at the concentration of 0.06% *A. squamosa* seed extract, reaching 96%-100% at the concentration of 0.125-0.25%. On the other hand, the mortality of tested insects caused by *A. occidentale* extract did not reach 50%, even at a concentration of 1% (Table 1).

The mortality of *C. pavonana* larvae treated with *A. squamosa* and *A. occidentale* seed extracts started after 24 hours or a day after treatment. On the first day, the mortality of *C. pavonana* larvae reached 100% at a concentration of 0.25%. At a concentration of 0.125%, mortality reached 96% and 100% on the 5th day after treatment (DAT). All 2nd instar larvae died at these two concentrations.

The mortality of 2nd instar larvae of *C. pavonana* reached 34% at a concentration of 0.06%. Larvae mortality increased by 44%, 50%, and 58% on the 2nd, 3rd, and 4th DAT. No larvae died on the 5th and 6th DAT. At the lowest concentration, mortality was 2%, and there was no mortality increase until the observation's end. At this concentration, the live test insects reached instar IV on the 5th and 6th DAT. The same thing was found at a concentration of 0.06%. The mortality development of *C. pavonana* larvae treated with *A. squamosa* seed extract is shown in Figure 1A.

The mortality of *C. pavonana* larvae occurred more at a concentration of 0.5% given *A. occidentale* seed coat extract, which was observed on the first day after treatment. The larvae mortality continued to increase until the 3rd DadAT, after which there was no increase in mortality. At a concentration of 1%, mortality was lower than that of 0.5%. Larvae mortality reached 3%, observed on the first DAT at that concentration. Larvae mortality increased continuously from 2-5 DAT. Larvae mortality reached 18% on the 5th DAT, and there was no increase in mortality on the 6th DAT.

At a concentration of 0.06% larvae mortality reached 1% and 2% at a concentration of 0.125%. Furthermore, no larvae died until the end of the observation. Treatment larvae that did not die successfully developed into IV instars on the 5th and 6th DAT. In control, no larvae died and developed into four instars on the 4th DAT. The mortality development of *C. pavonana* larvae treated with *A. occindentale* seed coat extract is shown in Figure 1B.

The *C. pavonana* larvae decreased growth and development after being treated with *A. squamosa* seed oil and *A. occidentale* seed coat extract. Symptoms of poisoning began to appear 24 HAT, such as decreased feeding activities and moving slower, body size smaller or shrinking compared to the control as a result of not eating, and lack of fluids, the color of the cuticle of the larvae changed from green to cream, the dead larvae were dark in color.

The death of the tested insects was thought to be due to the biological activity of secondary metabolites that can affect behavior and physiology, inhibit and damage body tissues and ultimately result in the death of *C. pavonana* larvae. There is also the possibility that secondary metabolites are antifeedants which causes the larvae not to eat and lack energy which can interfere with the physiological metabolism of the tested insects.

Table 1. Mortality of *C. pavonana* larvae treated with *Annona squamosa* seed extract and *Anacardium occidentale* cashew seed shell

Extract type	Concentration (%)	Mortality (%)*
A. squamosa	Control	0
	0.01	2
	0.03	48
	0.06	58
	0.125	96
	0.25	100
A. occidentale	Control	0
	0.06	2
	0.125	4
	0.25	12
	0.50	18
	1.00	36

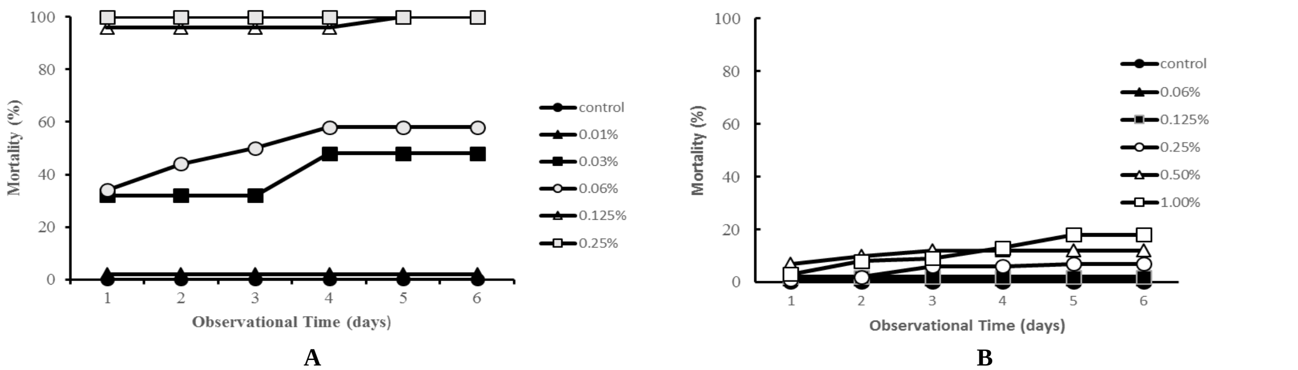

Figure 1. Daily mortality development of *C. pavonana* larvae treated by extracting (A) *A. squamosa* seeds and (B) *A. occidentale* seed coat

Previous studies revealed two main compounds in *A. squamosa* seeds, i.e., polyphenolics and acetogenins, that inhibited growth and development and killed the tested insects (Bhattacharya and Chakraverty 2016). Polyphenolic compounds consist of flavonoids, saponins, tannins, and alkaloids (Al-ghazzawi 2019; Ma et al. 2019). Saponin works as an antifeedant (Sang et al. 2019), flavonoids interfere with the respiratory system of insects (Justino 2017), and tannins are contact poisons that can reduce amylase and protease activity in digestive enzymes so that protein absorption is disrupted. The effect is lethal due to the disruption of nutrient absorption (Mappau et al. 2018). If the tested insects survive, the growth of larvae will be disrupted and inhibited. Flavonoids and alkaloids contained in *A. squamosa* seeds can kill *A. albopictus* and *C. quinquefasciatus* larvae, with LC_{50} values of 0.5% -1% for larvae and 1% -5% for adults (Ravaomanarivo et al. 2014) so that polyphenic compounds are suspected of interfering with and inhibiting the behavior of *C. pavonana* larvae.

The compounds of the acetogenin group are annonain, squamosin, annonacin, asimicin, cohibinsin, squamostatin-A, and bullatacin (Chen et al. 2012). In addition, Acetogenin also contains squamocin I, squamocin II, squamocin III, and squamoxinone-D, which inhibit cancer cells in mammalian groups (Miao et al. 2015). Squamosin concentrations are abundant in *A. squamosa* (Isman 2006)

The death of *C. pavonana* larvae is suspected to be due to the action of compounds from the acetogenin group by blocking the production of ATP energy in the mitochondria so that the energy supply is blocked and cut off, which causes the tested insects to become weak and eventually die. In addition, the acetogenin group inhibits electron transfer in complex I by blocking the bonds between NADH-ubiquinone oxidoreductase in mitochondrial oxidative phosphorylation, causing a reduction in the amount of ATP (adenine triphosphate) (González-Coloma et al. 2002; Yabunaka et al. 2003) so that metabolism is disrupted because it does not get energy, which can cause insects to experience ATP deficiency, poisoning, and death.

The acetogenin group (anonnain and squamosin) works in the body of insects as contact poisons and stomach poisons (Khair and Noraida 2019). As a contact poison, the poison enters the insect's body through cuticles, natural openings, sensory with antenna, and tarsi. Furthermore, the poison spreads throughout the body through the bloodstream, which will, in turn, poison and damage the body. Toxins also enter and disrupt the nervous system through the trachea, thus damaging the body tissue of the test insect because the information obtained is disturbed in the trachea system. Finally, toxins that enter through the hemolymph will interfere with the cholinesterase enzyme so that the nerves do not function due to the accumulation of acetylcholine and receive excessive or continuous signals (Mustika et al. 2016).

Acetogenin works as a stomach poison in the mesenteron that is carried by eating; da Silva Costa et al. (2016) showed that squamosin's effect could change the brush border's position and vacuolize the apical cytoplasm of cells in the digestive system of *Aedes aegypti* (Linnaeus, 1762) larvae so that the possibility of these changes causes the changes in water balance. In addition, squamosin also plays a role in reducing the expression of the V-ATPase gene in the digestion of *A. aegypti* larvae. As a result, it can interfere with nutrient absorption, electrolytic ions, and nutrient transport. Furthermore, Squamosin damages the AQP4 gene so that there is no balance of cell osmosis and damages the cell walls of the middle intestine. This phenomenon may have occurred in the digestive system of *C. pavonana* larvae so that the 2^{nd} and 3^{rd} instar larvae consuming *A. squamosa* seed extract could damage their digestive system. Therefore, it is suspected that one of the squamosin control mechanisms is to damage the digestive cell walls of *C. pavonana* larvae, resulting in the death of more larvae in *A. squmosa* extract as compared to *A. occidentale* seed coat extract.

The seed coat of *A. occidentale* was extracted with methanol as a solvent in the form of oil. The oil contains alkaloids, flavonoids, phenolics, cardonals, and tannins (Paiva et al. 2017; Aga 2018). Other compounds in the seed coat of *A. occidentale* are steroids, triterpenoids, xanthoproteins, volatile oils, and emodins that can inhibit the development of pathogens *Aspergillus flavus*, *Aspergillus niger*, *Fusarium* sp., and *Curvalaria* sp (Kannan et al. 2009). At a 60.36 mg/ml concentration, phenol can kill 50% of *Sitophilus oryzae* (A.Hustache, 1930) imago, while cardanol can kill 50% of *A. aegypti* larvae at a concentration of 0.0023 ppm 72 HAT of exposure (Buxton et al. 2017). Flavonoids and tannins inhibit the proliferation of cancer cells (Tietbohl et al. 2017). In another study, it was explained that the growth of *Trichoderma* sp. and *Gliocladium* sp. was inhibited after being treated with 2.5% CNSL oil (Bande et al. 2018). In this study, CNSL oil applied to *C. pavonana* larvae did not have a significant effect compared to *A. squamosa* oil. Still, the role of several compounds such as alkaloids, flavonoids, phenols, steroids, triterpenoids, xanthoproteins, essential oils, and emodin was able to kill larvae *C. pavonana* by 36% at the concentration of %. It is suspected that each secondary metabolic compound in CNSL acts at their respective target sites but is not synergistic in suppressing the growth of *C. pavonana* larvae.

Table 2. Estimating the toxicity parameters of *Annona squamosa* seed extract and *A. occidentale* cashew seed shell to *Crocidolomia pavonana* larvae

Extract type	**a±SE**	***b* ± SE**	**LC_{50} (CI 95%) (%)**	**LC_{95} (CI 95%) (%)**
A. squamosa	3.84±0.42	2.85 ± 0.31	0.04 (0.03-0.05)	0.16 (0.11-0.31)
A. occidentale	0.40 ± 0.15	1.32 ± 0.27	2.02 (0.99-17.83)	34.99 (6.71-10216.00)

Note: Description: a = probit regression intercep, b = the slope of the probit regression, SE = Standard error, CI = confidence interval

Estimation of toxicity of *A. squamosa* seed extract and *A. occidentale* cashew seed shell to *C. pavonana* larvae

The relationship between the treatment concentration with plant insecticide extracts and mortality of *C. pavonana* larvae was analyzed using probit analysis. The slope value of *A. squamosa* extract was higher than that of *A. occidentale* (Table 2). This result can explain that adding *A. squamosa* seed extract concentration will increase the mortality of *C. pavonana* larvae higher than that of *A. occidentale* extract at the same concentration. Meanwhile, the intercept value and the slope of *A. occidantale* did not show accurate results, presumably because the secondary metabolic compounds contained in the extract were less effective in poisoning *C. Pavonana* larvae.

The probit analysis showed that the seed extract of *A. squamosa* was more toxic to *C. pavonana* larvae than the seed shell of *A. occidentale* (Table 2). At a concentration of 0.04%. *A. squamosa* extract can kill 50% of *C. pavonana* larvae. Meanwhile, a concentration of 2.02% of *A. occidentale* seed coat is required to kill the same number of tested insects. *A. squamosa* seed extract at a lower concentration (0.16%) killed 95% of *C. pavonana* larvae, but *A. occidentale* oil required a high concentration (34.99%). These results explained that the seed extract of *A. squamosa* was more toxic to *C. pavonana* larvae than the seed coat extract of *A. occidentale*. Based on LC_{50}, *A. squamosa* sees extract is more toxic to *C. pavonana* larvae by 50,5 times than the *A. occidentale* seed coat. Based on the value of the probit analysis, it can be concluded that *A. squamosa* extract was effective for controlling *C. pavonana* larvae because only a small amount of test material is required to kill the test insects. Botanic insecticides are said to be effective if extracted with organic solvents. They can kill ≥80 test insects at the highest concentration of 1% while using water as a solvent at 10% (Dadang and Prijono 2008).

Based on the LC_{50}, the seed extract of *A. squamosa* was more toxic to *C. pavonana* larvae by 50.5 times higher than the seed coat of *A. occidentale*. At the LC_{95} level, *A. squamosa* seed extract was 218.68 times more toxic than *A. occidentale*. The results of Taslimah's research (2014) showed that the LC_{50} value of *A. squamosa* seed extract caused the death of *A. aegypti* larvae by 14.71% or 14.71 ml/100 ml. Furthermore, the seed extract of *A. squamosa* inhibited the feeding activity of *Trichoplusia ni* (Hübner, 1803) larvae (Hubner (DC_{50}= 2.3 mg/mL), inhibited growth (EC_{50}= 38.0 ppm) and killed by feeding method (LC_{50}= 167.5 ppm) (de Cássia Seffrin et al. 2010; Vetal and Pardeshi 2019). Methanol and hexane extract of seeds of *A. squmosa* larvae instar III (Maisng LD_{50}= 13.98 mg/mL; LD_{50}= 22.48 mg/mL) (Vetal and Pardeshi 2019). That illustrates that *A. squamosa* extract has strong insecticidal properties in *C. pavonana* larvae compared to *A. aegypti* larvae, *T. ni* larvae, and larvae of *S. litura*.

The leaves and bark of *A. squamosa* also contain secondary metabolites found in the seeds. Some of the compounds found in the leaves are phenols, alkaloids, flavonoids, and isomeric hydroxyl ketones (Bhattacharya and Chakraverty 2016; Kumar et al. 2021). The compounds found in the bark are Acetogenin and squamocin (Bhattacharya and Chakraverty 2016). The results of this study indicate that the extract of *A. squamosa* is more effective than *A. occidentale* because there is a possibility that the acetogenins and or polyphenolics group of compounds work on different targets. Therefore, the compounds contained in A. squamosa work synergistically. Based on the results of this research and a review of the literature, it is shown that *A. squamosa* has the potential to be developed into an environmentally friendly insecticide product.

In conclusion, *A. squamosa* seed extract effectively controlled *C. pavonana* larvae compared to *A. occidentale* seed extract. The results of probit analysis showed that at concentrations of 0.04% and 0.16% of *A. squamosa* seed extract, it could kill 50% and 95% of *C. pavonana* larvae. On the other hand, while seed coat extract of *A. occidentale* was ineffective in killing larvae *C. pavonana* at a concentration of 1%, it only killed 36% of the tested insects. Therefore, this research shows that *A. squamous* seed extract from dryland in East Nusa Tenggara needs to be developed as an environmentally friendly pest control.

REFERENCES

Aga KN. 2018. Uji Kadar Flavonoid Total Ekstrak Etanol Kulit Batang Jambu Mete (*Anacardium Occidentale* Linn) dengan Metode Spektrofotometri UV-VIS. [Diploma]. Poltekkes Kemenkes Kupang, Nusa Tenggara Timur. http://repository.poltekeskupang.ac.id/241/ [Indonesian]

Al-ghazzawi AM. 2019. Anti-cancer activity of new benzylisoquinoline alkaloid from Saudi plant *Annona squamosa*. BMC Chem 13 (1):13-18. DOI: 10.1186/s13065-019-0536-4.

Bande LOS, Mariadi, Gusnawaty H, Nuriadi, Trisulpa L, Rahmania. 2018. Botanical pesticides effect from shells of bean's cashew nut on biological agents of *Trichoderma* sp. and *Gliocladium* sp. IOP Conf Ser: Earth Environ Sci 122: 012047. DOI: 10.1088/1755-1315/122/1/012047.

Bhattacharya A, Chakraverty R. 2016. The pharmacological properties of *Annona squamosa* Linn: A Review. Intl J Pharm Eng 4 (2): 692-699.

Buxton T, Takahashi S, Niwata I, Owusu EO, Kim CS. 2017. Isolation and characterization of the insecticidal compounds in *Anacardium Occidentale* (cashew nut) shell liquid against the rice weevil, *Sitophilus oryzae* L. (Coleoptera: Curculionidae). J Entomol Zool Stud 5 (2): 1241-12466.

Chen Y, Xu S, Chen J, Wang Y, Xu H, Fan N, Li X. 2012. Anti-tumor activity of *Annona squamosa* seeds extract containing annonaceous acetogenin compounds. J Ethnopharmacol 142 (2): 462-466. DOI: 10.1016/j.jep.2012.05.019.

da Silva Costa M, de Paula SO, Martins GF, Zanuncio JC, Santana AEG, Serrão JE. 2016. Multiple modes of action of the squamocin in the midgut cells of *Aedes aegypti* Larvae. PLoS One 11 (8): e0160928. DOI: 10.1371/journal.pone.0160928.

Dadang, Prijono D. 2008. Botanic Insecticides: Principles, Use and Development. Departemen of Plant Protection, Institut Pertanian Bogor, Bogor.

Damalas C, Koutroubas S. 2018. Current status and recent developments in biopesticide use. Agriculture 8 (1): 13-18. DOI: 10.3390/agriculture8010013.

Damalas CA, Koutroubas SD. 2020. Botanical pesticides for eco-friendly pest management. In: Srivastava PK, Singh VP, Singh A, Tripathi DK, Singh S, Prasad SM, Chauhan DK (eds). Pesticides in Crop Production: Physiological and Biochemical Action, John Wiley & Sons Ltd. DOI: 10.1002/9781119432241.ch10.

Dayan FE, Cantrell CL, Duke SO. 2009. Natural products in crop protection. Bioorg Med Chem 17 (12): 4022-4034. DOI: 10.1016/j.bmc.2009.01.046.

de Cássia Seffrin R, Shikano I, Akhtar Y, Isman MB. 2010. Effects of crude seed extracts of *Annona atemoya* and *Annona squamosa* L. against the cabbage looper, *Trichoplusia ni* in the laboratory and greenhouse. Crop Prot 29 (1): 20-24. DOI: 10.1016/j.cropro.2009.09.003.

González-Coloma A, Guadaño A, Inés C, de Martínez-Díaz R, Cortes D. 2002. Selective action of acetogenin mitochondrial complex I inhibitors. Zeitschrift Für Naturforschung C 57 (11-12): 1028-1034. DOI: 10.1515/znc-2002-11-1213.

Hikal WM, Baeshen RS, Said-Al Ahl HAH. 2017. Botanical insecticide as simple extractives for pest control. Cogent Biol 3 (1): 1404274-1404291. DOI: 10.1080/23312025.2017.1404274.

Ilike KD, Olotuah OF. 2011. Bioactivity of *Anacardium occidentale* (L) and *Allium sativum* (L) powders and oils extracts against cowpea bruchid, *Callosobruchus maculatus* (Fab.) [Coleoptera: Chrysomelidae]. Intl J Biol 4 (1): 96-103. DOI: 10.5539/ijb.v4n1p96.

Isman MB. 2006. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Ann Rev Entomol 51 (1): 45-66. DOI: 10.1146/annurev.ento.51.110104.151146.

Justino J. 2017. Flavonoids: From Biosynthesis to Human Health. InTech, Croatia. DOI: 10.5772/65575.

Kalyabina VP, Esimbekova EN, Kopylova KV, Kratasyuk VA. 2021. Pesticides: Formulants, distribution pathways and effects on human health – a review. Toxicol Rep 8: 1179-1192. DOI: 10.1016/j.toxrep.2021.06.004.

Kannan VR, Sumathi CS, Balasubramanian V, Ramesh N. 2009. Elementary chemical profiling and antifungal properties of cashew (*Anacardium occidentale* L.) nuts. Bot Res Intl 2 (4): 253-257.

Khair A, Noraida N. 2019. Young and old sugar apple (*Annona squamosa* Linn) leaf extracts as an *Aedes aegypti* larva insecticide. Med Lab Technol J 5 (2): 81-87. DOI: 10.31964/mltj.v0i0.231.

Kumar M, Changan S, Tomar M, Prajapati U, Saurabh V, Hasan M, Sasi M, Maheshwari C, Singh S, Dhumal S. Radha, Thakur M, Punia S, Satankar V, Amarowicz R, Mekhemar M. 2021. Custard apple (*Annona squamosa* L.) leaves: nutritional composition, phytochemical profile, and health-promoting biological activities. Biomolecules 11 (5): 614-636. DOI: 10.3390/biom11050614.

Ma C, Yan X, Yin G, Wang Y, Hu S, Xia W, Chen Y, Liu X, Chen J, Li X. 2019. Non-targeted metabolomics analysis on multidrug resistance hepatocellular carcinoma cell and reversal effect of annonaceous acetogenins. J Pharm Biomed Anal 164: 489-495. DOI: 10.1016/j.jpba.2018.10.037.

Mahmood I, Imadi SR, Shazadi K, Gul A, Hakeem KR. 2016. Effects of pesticides on environment. Plant Soil Microb 253-269. DOI: 10.1007/978-3-319-27455-3_13.

Mappau Z, Akbar F, Ada A. 2018. Effectiveness of tembelekan plants (*Lantana camara* Linn) to *Aedes Aegypti* larvae mortality. Indian J Public Health Res Dev 9 (1): 379-401. DOI: 10.5958/0976-5506.2018.00070.0.

Mesnage R, Bowyer RCE, Balkhi SE, Saint-Marcoux F, Gardere A, Ducarmon QR, Geelen AR, Zwittink R D, Tsoukalas D, Sarandi E, Paramera EI, Spector T, Steves CJ, Antoniou MN. 2021. Impacts of dietary exposure to pesticides on faecal microbiome metabolism in adult twins. BioRxiv 21: 46. DOI: 10.1101/2021.06.16.448511.

Miao Y, Xu X, Yuan F, Shi Y, Chen Y, Chen J, Li X. 2015. Four cytotoxic annonaceous acetogenins from the seeds of *Annona squamosa*. Nat Prod Res 30 (11): 1273-1279. DOI: 10.1080/14786419.2015.1055490.

Mughal FH. 2018. Environmental impact of pesticide overuse. Dawn.com. https://www.dawn.com/news/1406013

Mustika AA, Hadi UK, Wardhana AH, Wientarsih I. 2016. The efficacy of larvicides of leaves of yam bean (pachyrhizuserosus) as botanical insecticides against fly larvae myiasis *Chrysomya bezziana*. IOSR J Pharm 6 (6): 76-81.

Nenotek PS, Ludji R. 2020. The efficacy of seed extract of *Tephrosia vogelii* and *Annona squmosa* on larvae of *Helicoverpa armigera*. Trop Drylands 4: 5-9. DOI: 10.13057/tropdrylands/t040102.

Nenotek PS. 2010. Bioactivity of stem bark extracts of Simaroubaceae plants and leaf extract *Tephrosia vogelii* on the cabbage head caterpillar, *Crocidolomia pavonana (*F.) (Lepidoptera: Crambidae). http://repository.ipb.ac.id/handle/123456789/57165

Oparaeke AM, Bunmi OJ. 2006. Insecticidal potential of cashew (*Anacardium occidentale* L.) for control of the beetle, *Callosobruchus subinnotatus* (Pic.) (Bruchidae) on bambarra-groundnut (*Voandzeia subterranea* L.) Verde. Arch Phytopathol Pflanzenschutz 39 (4): 247-251. DOI: 10.1080/03235400500094431.

Paiva DR, Lima DPD, Avvari NP, Arruda EJD, Cabrini I, Marques MR, Santos EAD, Biaggio FC, Sangi DP, Beatriz A. 2017. A potent larvicidal agent against *Aedes aegypti* mosquito from cardanol. Anais Da Academia Brasileira de Ciências 89 (1): 373-382. DOI: 10.1590/0001-3765201720160615.

Prijono D, Hassan E. 1992. Life cycle and demography of *Crocidolomia binotalis* Zeller (Lepidoptera: Pyralidae) on broccoli in the laboratory. Indones J Trop Agric 4 (1): 18-24.

Ravaomanarivo LHR, Razafindraleva HA, Raharimalala FN, Rasoahantaveloniaina B, Ravelonandro PH, Mavingui P. 2014. Efficacy of seed extracts of *Annona squamosa* and *Annona muricata* (Annonaceae) for the control of *Aedes albopictus* and *Culex quinquefasciatus* (Culicidae). Asian Pac J Trop Biomed 4 (10): 798-806. DOI: 10.12980/APJTB.4.2014C1264.

Riyaz M, Mathew P, Zuber SM, Rather GA. 2022. Botanical pesticides for an eco-friendly and sustainable agriculture: new challenges and prospects. In: Bandh SA (eds). Sustainable Agriculture. Springer, Cham. DOI: 10.1007/978-3-030-83066-3_5.

Sang J, Rimal S, Lee Y. 2019. Gustatory receptor 28b is necessary for avoiding saponin in *Drosophila melanogaster*. EMBO Rep 20 (2): 1-12. DOI: 10.15252/embr.201847328.

Syromyatnikov MY, Isuwa MM, Savinkova OV, Derevshchikova MI, Popov VN. 2020. The effect of pesticides on the microbiome of animals. Agriculture 10 (3): 79-93. DOI: 10.3390/agriculture10030079.

Tarar MA. 2019. Effects of pesticides on male farmer's health: A study of muzaffar garh. Pak J Agric Sci 56 (04): 1021-1030. DOI: 10.21162/PAKJAS/19.9157.

Taslimah. 2014. Uji Elifikasi Ekstrak Biji Srikaya (*Annona squamosa* L.) sebagai Bioinsektisida dalam Upaya Integrated Vector Management terhadap *Aedes aegypti*. [Skripsi]. Fakultas Kedokteran dan Ilmu Kesehatan UIN Syarif Hidayatulloh, Jakarta. [Indonesian]

Tietbohl LAC, Oliveira AP, Esteves RS, Albuquerque RDDG, Folly D, Machado FP, Corrêa AL, Santos MG, Ruiz ALG, Rocha L 2017. Antiproliferative activity in tumor cell lines, antioxidant capacity and total phenolic, flavonoid and tannin contents of *Myrciaria floribunda*. Anais Da Academia Brasileira de Ciências 89 (2): 1111-1120. DOI: 10.1590/0001-3765201720160461.

Tripathy A, Samanta L, Das S, Parida SK, Marai N, Hazra RK, Mallavdani UV, Kar SK, Mahapatra N. 2011. The mosquitocidal activity of methanolic extracts of *Lantana cramera* root and *Anacardium occidentale* leaf: Role of glutathione s-transferase in insecticide resistance. J Med Entomol 48 (2): 291-295. DOI: 10.1603/ME09122.

Vetal D, Pardeshi A. 2019. Insecticidal potential of ethanol and hexane solvent seed extract of *Annona squamosa* against *Spodoptera litura* Fab. J Pharmacogn Phytochem 8 (3): 842-845.

Yabunaka H, Abe M, Kenmochi A, Hamada T, Nishioka T, Miyoshi H. 2003. Synthesis and inhibitory activity of ubiquinone–acetogenin hybrid inhibitor with bovine mitochondrial complex I. Bioorg Med Chem Lett 13 (14): 2385-2388. DOI: 10.1016/S0960-894X(03)00439-6.