JUSTEK : JURNAL SAINS DAN TEKNOLOGI
http://journal.ummat.ac.id/index.php/justek
ISSN 2620-5475
Vol. 9, No. 3, September 2026, pp. 388-396

Medicinal Plant Diversity and Local Knowledge in Kelimutu, Ende: Development of an E-Atlas for Biodiversity Learning

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ARTICLE INFO

Article History:

Received : 04-08-2026
Revised : 10-09-2026
Accepted : 13-09-2026
Online : 17-09-2026

Keywords:
Medicinal Plants;
Local Knowledge;
E-Atlas;
Biodiversity Learning;
Kelimutu.

ABSTRACT

Medicinal plant knowledge represents both biocultural diversity and a potentially valuable source of contextual biology learning. This study aimed to document medicinal plant diversity and community-reported uses in Wolokelo, Nuamuri, and Nduaria villages of Kelimutu District, Ende Regency, Indonesia, and to develop a Grade X biodiversity E-Atlas based on the findings. A descriptive field study was integrated with a limited research-and-development process using the Analysis, Design, and Development stages of ADDIE. Seventeen residents with knowledge and experience in medicinal plant use were selected purposively. Data were collected through structured interviews, field documentation, observation, and morphology-based identification supported by published botanical references. The E-Atlas underwent a preliminary internal feasibility review using a five-point instrument. The study documented 33 medicinal plant entries representing 20 families. Zingiberaceae and Poaceae were the most represented families with four records each, followed by Asteraceae and Fabaceae with three records each. Leaves were the most frequently reported plant part, while preparation methods included boiling or decoction, pounding, grating, soaking or infusion, squeezing, and direct or topical application. Material and media review scores were 82.35% and 96.25%, respectively, yielding a mean feasibility score of 89.30% and indicating high preliminary feasibility under the study rubric. These findings show that place-based medicinal-plant knowledge can be organized into a context-rich digital resource that potentially supports biodiversity learning by linking familiar local species with classification, plant characteristics, conservation, and human-environment relationships. Because taxonomic identification was field-based and the feasibility review was internal, independent taxonomic verification, external validation, student usability testing, and classroom effectiveness studies remain necessary before wider implementation.

A. INTRODUCTION

Medicinal plant knowledge is an important component of biocultural diversity because it connects plant diversity with community experience, health practices, food systems, and cultural identity. Ethnobotanical studies across different regions consistently show that local communities maintain detailed knowledge of plant species, useful organs, preparation methods, and therapeutic indications, although the composition of the medicinal flora varies according to ecology and cultural history (Pala et al., 2019; Mengistu et al., 2022; Mincheva et al., 2022; Ralte et al., 2024). Documentation is therefore important not only for recording plant diversity but also for preserving knowledge that is often transmitted orally.

In Indonesia, medicinal plant use remains closely connected with local landscapes and community traditions. Studies in Sesaot Forest, West Nusa Tenggara, and among the Lio community around Kelimutu National Park demonstrate that medicinal plant knowledge is embedded in everyday interactions with forests, gardens, and settlement environments (Rahayu & Andini, 2019; Mbia Wae et al., 2022). Kelimutu District in Ende Regency, East Nusa Tenggara, has a particularly relevant biocultural setting because communities live close to a conservation landscape while continuing to use locally available plants for household health practices.

The persistence of this knowledge cannot be assumed. Research from Africa and Asia shows that medicinal plant knowledge can change as a result of modernization, altered land use, changing access to health services, and weakening intergenerational transmission ((Hussain et al., 2018); (Seile et al., 2022); (Agize et al., 2022); (Bekele et al., 2022); (Alemu et al., 2024)). Comparative ethnobotanical evidence also shows that medicinal plants are selected from cultivated, wild, food, spice, and multipurpose species, indicating that local pharmacopoeias are dynamic rather than fixed collections of specialized medicinal plants ((Sõukand et al., 2017a); Sutjaritjai et al., 2022; Islam et al., 2022; Laldingliani et al., 2022; Muhakr et al., 2024; Corroto et al., 2021).

For biology education, locally documented plants offer an opportunity to make biodiversity concepts more concrete. Digital resources can extend this value by combining photographs, names, taxonomic information, local terminology, and contextual descriptions in a format that students can revisit independently. Digital mapping and identification tools have been reported to support engagement with biological objects, field observation, species identification, and outdoor learning when the technology is used to scaffold scientific inquiry rather than replace direct observation (Berendsen et al., 2018; Mäder et al., 2021; Stagg et al., 2022; Finger et al., 2022; Coşkunserçe, 2024). Digital spatial approaches have also been used to organize medicinal-plant information in ecologically meaningful ways.

An electronic atlas (E-Atlas) is particularly appropriate for biodiversity learning because it can organize multiple plant records in a consistent visual structure. However, the educational value of an atlas depends on the accuracy of its biological information, the clarity of its visual design, and the extent to which local examples are connected to learning objectives. At the same time, community-reported medicinal uses must be presented carefully: ethnobotanical documentation records knowledge and practice, but it does not by itself establish pharmacological efficacy or clinical safety. Experimental studies of medicinal plants illustrate the additional evidence required to move from traditional use to pharmacological claims (Bafor et al., 2019; Li et al., 2024).

Previous work around Kelimutu has documented ethnobotanical knowledge, but an educational gap remains at the intersection of ethnobotany and biology education. Existing local studies have primarily contributed to documenting medicinal-plant diversity and traditional uses, whereas comparatively limited attention has been given to transforming these place-based records into structured learning resources for senior high school biology. In particular, Grade X biodiversity learning requires contextual examples that can help students connect species diversity, classification, plant characteristics, conservation, and human-environment relationships with organisms encountered in their own region. This study addresses that gap by transforming medicinal-plant knowledge from three Kelimutu villages into a structured E-Atlas designed as a contextual bridge between local biocultural knowledge and formal biodiversity learning. The novelty therefore lies not merely in digitizing ethnobotanical records, but in their educational transformation while explicitly distinguishing community-reported medicinal uses from pharmacological or clinical evidence.

Accordingly, this study aimed to (1) document medicinal plants and their community-reported uses in Wolokelo, Nuamuri, and Nduaria villages; (2) describe the plant parts and preparation methods reported by community members; and (3) develop and conduct a preliminary feasibility review of an E-Atlas for Grade X biodiversity learning.

B. METHODS

1. Research Design and Setting

This study integrated a descriptive field study with a limited research-and-development process. Fieldwork was conducted in December 2025 in Wolokelo, Nuamuri, and Nduaria villages, Kelimutu District, Ende Regency, East Nusa Tenggara, Indonesia. The development component followed the Analysis, Design, and Development stages of the ADDIE framework; implementation and evaluation in a school classroom were outside the scope of the study.

2. Participants and Data Collection

Seventeen respondents were selected purposively because they had knowledge or direct experience related to medicinal plant use. The respondents comprised nine residents from Wolokelo, two from Nuamuri, and six from Nduaria. Selection emphasized residents who understood local plant use, including community figures, traditional knowledge holders, and other residents with practical experience using medicinal plants. Data were collected through structured interviews, field documentation, and observation of the reported plants.

Table 1. Distribution of respondents by village

Village	Number of respondents	Proportion (%)
Wolokelo	9	52.94
Nuamuri	2	11.76
Nduaria	6	35.29

3. Plant Identification and Data Analysis

Local names obtained from interviews were matched with field photographs and morphological characteristics, then compared with published botanical references. Scientific names were standardized during manuscript preparation where the thesis record contained clear spelling inconsistencies. Because no herbarium voucher verification or specialist taxonomic confirmation was documented, the resulting identifications are treated as field-based identifications and should be verified in future botanical work. Interview data were analyzed descriptively to summarize plant taxa, useful organs, preparation methods, community-reported indications, and sources of the plants.

4. E-Atlas Development and Feasibility Review

During the Analysis stage, field data and the learning needs of biodiversity material were organized into content categories. During Design, the E-Atlas structure was prepared to include a cover, introduction, contents, plant entries, local and scientific names, family, photographs, parts used, reported uses, preparation information, index, and references. During Development, the product was assembled in Canva and converted into a digital flipbook using AnyFlip. The prototype underwent a preliminary internal feasibility review using a five-point instrument covering material and media aspects. The two reviewers were university lecturers involved in academic supervision; therefore, the scores are interpreted as internal preliminary evidence rather than independent external validation. Percentage scores were calculated as obtained score divided by maximum score multiplied by 100. Under the study rubric, 81-100% was categorized as highly feasible/very valid, 61-80% as feasible/valid, 41-60% as moderately feasible, 21-40% as low feasibility, and 0-20% as very low feasibility.

C. RESULT AND DISCUSSION

1. Medicinal Plant Diversity

The field study documented 33 medicinal plant entries representing 20 families. Zingiberaceae and Poaceae were the most represented families with four records each, followed by Asteraceae and Fabaceae with three records each. Amaryllidaceae, Myrtaceae, and Arecaceae each contributed two records, while the remaining families were represented by one record. This pattern indicates that household medicinal knowledge in Kelimutu draws on rhizomatous plants, grasses, herbs, trees, food plants, spices, and other multipurpose species rather than on a single botanical group.

Table 2. Medicinal plants documented in Wolokelo, Nuamuri, and Nduaria villages

No.	Indonesian name	Local name	Scientific name	Family
1	Krinyu	Inga	*Chromolaena odorata*	Asteraceae
2	Jahe	Lea	*Zingiber officinale*	Zingiberaceae
3	Kunyit	Kune	*Curcuma longa*	Zingiberaceae
4	Kencur	Seku	*Kaempferia galanga*	Zingiberaceae
5	Temulawak	Ladja	*Curcuma xanthorrhiza*	Zingiberaceae
6	Cocor bebek	Cocor Bebek	*Kalanchoe pinnata*	Crassulaceae
7	Sereh	Nawe	*Cymbopogon nardus*	Poaceae
8	Binahong	Binahong	*Anredera cordifolia*	Basellaceae
9	Krokot	Bene Leri	*Portulaca oleracea*	Portulacaceae
10	Bawang merah	Somu	*Allium ascalonicum*	Amaryllidaceae
11	Kayu manis	Kaju Mani	*Cinnamomum verum*	Lauraceae
12	Jambu biji	Ngoe Awa	*Psidium guajava*	Myrtaceae
13	Cengkeh	Cengkeh	*Syzygium aromaticum*	Myrtaceae
14	Jeruk nipis	Nilu	*Citrus aurantiifolia*	Rutaceae
15	Bunga telang	Twoang	*Clitoria ternatea*	Fabaceae
16	Daun Afrika	Daun Afrika	*Vernonia amygdalina*	Asteraceae
17	Bunga karet	Bunga Karet	*Ficus elastica*	Moraceae
18	Johar	Jita	*Senna siamea*	Fabaceae
19	Damar merah	Dama Mera	*Agathis dammara*	Araucariaceae
20	Kacang tanah	Bue Tana	*Arachis hypogaea*	Fabaceae
21	Pare	Uta Leba	*Momordica charantia*	Cucurbitaceae
22	Alang-alang	Kii	*Imperata cylindrica*	Poaceae
23	Sirih	Mota	*Piper betle*	Piperaceae
24	Pinang	Keu	*Areca catechu*	Arecaceae
25	Pisang	Muku	*Musa paradisiaca*	Musaceae
26	Pepaya	Uta Ba'i	*Carica papaya*	Caricaceae
27	Elderberry	Bunga Bara	*Sambucus sp.*	Adoxaceae
28	Sereh merah	Nawe Mera	*Cymbopogon nardus*	Poaceae
29	Nanas	Ru'ejawa	*Ananas comosus*	Bromeliaceae
30	Bawang putih	Sunga	*Allium sativum*	Amaryllidaceae
31	Padi/beras	Are	*Oryza sativa*	Poaceae
32	Kelapa	Nyio	*Cocos nucifera*	Arecaceae
33	Sintrong	Uta Mbaka	*Crassocephalum crepidioides*	Asteraceae

The diversity observed in Kelimutu is consistent with ethnobotanical evidence showing that local pharmacopoeias usually comprise plants from many families and life forms, with composition shaped by plant availability, familiarity, and cultural transmission (Pala et al., 2019; Mengistu et al., 2022; Laldingliani et al., 2022; Hussain et al., 2018; Ralte et al., 2024). The findings also extend local evidence from the Lio community around Kelimutu National Park and from other Indonesian settings where medicinal knowledge is closely associated with nearby forests, gardens, and settlement vegetation (Mbia Wae et al., 2022; Rahayu & Andini, 2019).

The presence of both food and medicinal species is not unusual. Cross-cultural studies have documented the multifunctionality of plants used as food, spices, household resources, and remedies, emphasizing that the boundary between food plants and medicinal plants is often culturally fluid (Sõukand et al., 2017; Sutjaritjai et al., 2022; Corroto et al., 2021). Similar diversity in the organization of local medicinal knowledge has been reported among Munda communities in Bangladesh and communities in Ethiopia and Sudan (Islam et al., 2022; Agize et al., 2022; Bekele et al., 2022; Alemu et al., 2024; Muhakr et al., 2024).

2. Plant Parts, Preparation, and Community-Reported Uses

Leaves were the most frequently reported plant part, followed by rhizomes and other organs such as roots, stems, bark, fruits, flowers, and bulbs. Common preparation methods included boiling or decoction, pounding, grating, soaking or infusion, squeezing, and direct or topical application. These patterns resemble findings from other ethnobotanical studies in which leaves are favored because they are accessible, easy to harvest, and comparatively simple to prepare, while rhizomes and underground organs are particularly important in plant groups with strong culinary and medicinal traditions (Pala et al., 2019; Mincheva et al., 2022; Seile et al., 2022; Mengistu et al., 2022). From a conservation perspective, repeated harvesting of leaves may be less destructive than removal of roots or whole plants, although sustainable use still depends on species biology and harvesting intensity (Seile et al., 2022).

Respondents associated the documented plants with a broad range of household health purposes, including minor wounds, fever-related complaints, digestive discomfort, respiratory symptoms, musculoskeletal complaints, and other conditions. These statements are reported here as community knowledge rather than as evidence of efficacy. For example, Chromolaena odorata was locally associated with wound care, and experimental work has reported hemostatic, anti-inflammatory, wound-healing, and antimicrobial properties of active fractions from this species (Li et al., 2024). Nevertheless, such laboratory findings cannot validate every traditional preparation, dose, indication, or route of use recorded in this study. Pharmacological evidence is species-, extract-, dose-, and method-specific, as illustrated by controlled medicinal-plant studies such as Bafor et al. (2019). Accordingly, the E-Atlas presents reported uses as ethnobotanical information and should not be interpreted as clinical guidance.

3. Development, Preliminary Feasibility, and Pedagogical Use of the E-Atlas

The 33 plant records were transformed into an E-Atlas for Grade X biodiversity learning. Each entry links local and scientific names, family-level classification, photographs, useful organs, preparation information, and community-reported uses. This organization was designed to connect observable local plant diversity with formal biodiversity concepts, allowing students to compare species, recognize taxonomic relationships, relate plant characteristics to uses, and discuss connections between biodiversity, community practices, and conservation.

Table 3. Preliminary internal feasibility review of the E-Atlas

Review aspect	Score obtained	Percentage	Interpretation
Material	70	82.35%	Highly feasible
Media	77	96.25%	Highly feasible
Mean	–	89.30%	Highly feasible

The material review yielded 82.35% and the media review yielded 96.25%, resulting in a corrected arithmetic mean of 89.30%. Under the rubric used in the thesis, this value falls in the highest feasibility category. The result suggests that the prototype has acceptable internal content and media characteristics for further development, but it should not be interpreted as evidence that the E-Atlas improves learning outcomes. The reviewers were lecturers involved in the academic supervision of the study, so independent external review remains necessary.

The educational rationale for the E-Atlas is supported by studies showing that digital maps, digital plant-identification tools, and outdoor digital resources can help learners connect visual evidence, species names, location, and biological classification (Berendsen et al., 2018; Mäder et al., 2021; Stagg et al., 2022; Finger et al., 2022; Coşkunserçe, 2024). Digital tools are most useful when they scaffold observation and interpretation rather than replace direct engagement with biological specimens. In the present study, the E-Atlas therefore functions as a structured representation of local biodiversity rather than merely as a repository of photographs. The broader use of digital spatial information for medicinal plants further illustrates how organized digital datasets can support interpretation of plant distributions and ecological context (Wu et al., 2019).

Pedagogically, the potential value of the E-Atlas lies in bridging abstract biodiversity concepts with biological objects that are familiar within students' regional environment. By presenting the same plant through local terminology, scientific nomenclature, family-level classification, observable characteristics, and documented community uses, the resource can support comparison, classification, evidence-based discussion, and interpretation of human-environment relationships. Its educational contribution therefore lies not in digitization alone, but in organizing place-based evidence so that local biodiversity can function as a meaningful entry point to formal biology concepts. Because classroom effectiveness was not tested in this study, these statements describe the intended pedagogical mechanism rather than demonstrated learning gains.

In classroom practice, the E-Atlas can be used as a scaffold before, during, and after biodiversity instruction. Before learning, students may explore selected entries to activate prior knowledge and identify familiar plants. During instruction, teachers can guide students to compare morphological features, group species by family or useful organ, relate local uses to biodiversity and conservation concepts, and discuss why ethnobotanical claims must be distinguished from clinical evidence. After instruction, the E-Atlas can support independent observation or simple field-based assignments in which students compare plants found around their homes or schools with the documented entries. In this way, the E-Atlas is positioned as a support for observation and biological reasoning rather than as a substitute for direct engagement with living specimens.

4. Limitations and Research Implications

Several limitations should be considered. First, the sample comprised 17 knowledgeable residents from three villages and was selected purposively; the findings therefore document the knowledge represented in this sample and should not be generalized to all residents of Kelimutu District. Second, plant identification was based on morphology, photographs, local names, and published references, without documented herbarium vouchers or independent taxonomic verification. Third, the development process stopped at the Development stage of ADDIE. The E-Atlas was not tested for student readability, usability, learning effectiveness, scientific literacy, or conservation attitudes. Fourth, feasibility assessment was internal rather than independent. Future studies should verify specimens using voucher collections and botanical expertise, involve independent content and media validators, conduct student usability testing, and evaluate the E-Atlas in controlled or quasi-experimental classroom studies.

D. CONCLUSION AND SUGGESTIONS

This study documented 33 medicinal plant entries representing 20 families in Wolokelo, Nuamuri, and Nduaria villages of Kelimutu District, Ende Regency. The records show that community medicinal-plant knowledge draws on a diverse set of cultivated, wild, food, spice, and multipurpose plants. Leaves were the most frequently reported plant part, and preparation commonly involved boiling, pounding, grating, soaking, squeezing, or direct topical use. The field data were transformed into an E-Atlas for Grade X biodiversity learning. Preliminary internal review produced scores of 82.35% for material and 96.25% for media, with a corrected mean of 89.30%, indicating high preliminary feasibility under the study rubric. The E-Atlas provides a contextual bridge between local biocultural knowledge and formal biology concepts and can potentially support species comparison, classification, discussion of plant characteristics, conservation reasoning, and guided observation. However, because classroom implementation was not part of this study, these pedagogical functions remain design-based propositions rather than demonstrated learning effects. Independent external validation, voucher-based taxonomic confirmation, student usability testing, and classroom effectiveness research are recommended before wider educational implementation.

ACKNOWLEDGEMENT

The authors express their appreciation to the residents of Wolokelo, Nuamuri, and Nduaria villages who shared their knowledge and experience during field data collection, and to the Biology Education Study Program, Universitas Katolik Widya Mandira, for academic support during the study.

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