Journal of Tropical Biology and Conservation 23: 248–265, 2026 *ISSN 1823-3902*
E-ISSN 2550-1909

Research Article

Species Composition, Assessment, and Ecological Threats of Understory Seed Plants in the Upstream Sawaga River, Malaybalay City, Bukidnon, Philippines

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Received 8 January 2026| Accepted 12 August 2026| Published 26 November 2026
Associate Editor: Marcela Pimid
DOI: https://doi.org/10.51200/jtbc.v23i.7184

ABSTRACT

This study presents an inventory of understory seed plants along the riparian forest of upstream Sawaga River in Malaybalay City, Bukidnon, Philippines, assessing their conservation status, endemism, and ecological threats. Repeated transect walks along the two-kilometre established trail and opportunistic sampling documented a total of 75 species belonging to 61 genera and 27 families, with Araceae as the most species-rich family with 13 species. *Crepidium purpureum* (Lindl.) Szlach. represents a new distribution record for Mindanao, while *Aeschynanthus asclepioides* (Elmer) B.L.Burtt & P.Woods*, Cyrtandra pallidiifolia* Kraenzl.*,* and *Rhynchoglossum obliquum* Blume are new records for Bukidnon province. Three threatened species were identified, with two species classified as Endangered (*Medinilla banahaensis* Elmer and *Dendrobium bullenianum* Rchb.f.) and one as Vulnerable (*Hedychium philippinense* K.Schum.). Twenty-three species were Philippine endemics, with three restricted to Mindanao. Triangulation of land-use/land-cover analysis, key informant interviews, and field observations identified land use change, deforestation, pollution, biodiversity decline, soil and geomorphological instability, climate-related stress, and invasive species as ecological threats to understory seed plants. These findings underscore both the high conservation value of the upstream Sawaga River and the vulnerability of the area to species loss. These further highlight the need for the reinforcement of the 40-m riparian buffer, habitat restoration, and sustained awareness campaigns and long-term biodiversity monitoring programmes.

Keywords: angiosperms; anthropogenic; environmental threats; flora, herbs; riparian.

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INTRODUCTION

Understory seed plants are herbs, shrubs, vines, lianas, and other plant species that grow beneath the canopy layer (Acma et al., 2021). These are important components of forest structure and complexity, providing habitat and food for fauna, thus increasing species richness and ecosystem integrity and stability (Dauber et al., 2003; Duguid et al., 2013). Understory seed plants have been used as indicators of forest health and environmental quality. This is primarily due to their sensitivity to even the slightest changes in the canopy and forest structure, availability of light, soil nutrients and pH, and anthropogenic disturbances (Ellsworth et al., 2004; Yu & Sun, 2013; Luo et al., 2024). Due to this, they have been increasingly integrated in the assessment of riparian forest quality (Dieterich et al., 2006; Jayasuriya et al., 2021).

The Philippines is a biodiversity-rich country with high levels of species endemism (Mittermeier et al., 1997; Myers et al., 2000). However, Philippine forests, particularly in Mindanao, have been subject to threats. In a study by Agduma et al. (2023), they identified deforestation, mining, illegal logging, land-use conversion, and climate change as critical threats and challenges to biodiversity. As sensitive and indicator species, understory seed plants are susceptible to these disturbances, decreasing plant growth, and altering phenology and diversity (Kutnar et al., 2019; Brown et al., 2022; Rosas et al., 2024; Wei et al., 2024).

The province of Bukidnon in Central Mindanao has numerous freshwater bodies considered important natural resources (Galan et al., 2015). One of these is the Sawaga River that drains into the Mindanao River Basin. Sawaga River, flowing through the capital city of the province, Malaybalay City, is one of the main sources of water for nearby communities for household, agricultural, and industrial uses (Opiso & Alburo, 2014; Bertomen et al., 2017). Despite this, the river and its adjacent riparian forests have been subject to anthropogenic disturbances, noted with unsafe levels of coliforms (Bertomen et al., 2017; Lubos et al., 2020; Violon et al., 2024). To provide baseline information for its subsequent conservation, the river has been surveyed for its macrophyte and ichthyofaunal composition (Lubos et al., 2022; Robosa et al., 2025). However, its surrounding flora, particularly understory seed plants, have yet to be documented. To fill these gaps, this study presents a checklist of understory seed plants along the upstream Sawaga River, along with an assessment of their conservation status, endemicity, and associated environmental threats. By establishing an inventory of riparian understory flora in the study area, this study provides a reference for biodiversity monitoring, conservation prioritization of threatened and endemic species, and the development and integration of sustainable management strategies in the riparian buffer in the face of increasing anthropogenic pressures.

METHODOLOGY

Entry protocol

The study was conducted in the upstream Sawaga River on September 27–28 and October 25–27, 2025 following the acquisition of the Wildlife Gratuitous Permit from the Department of Environment and Natural Resources (DENR) (R10-2025-09-522). An institutional ethics permit (0965 s. 2025) was also obtained for the conduct of the Key Informant Interview.

Site description

The upstream Sawaga River (8°09'23.364" N, 124°58'26.652" E) is located in Sitio Inhandig, Barangay Dalwangan, Malaybalay City, Bukidnon (Fig. 1).

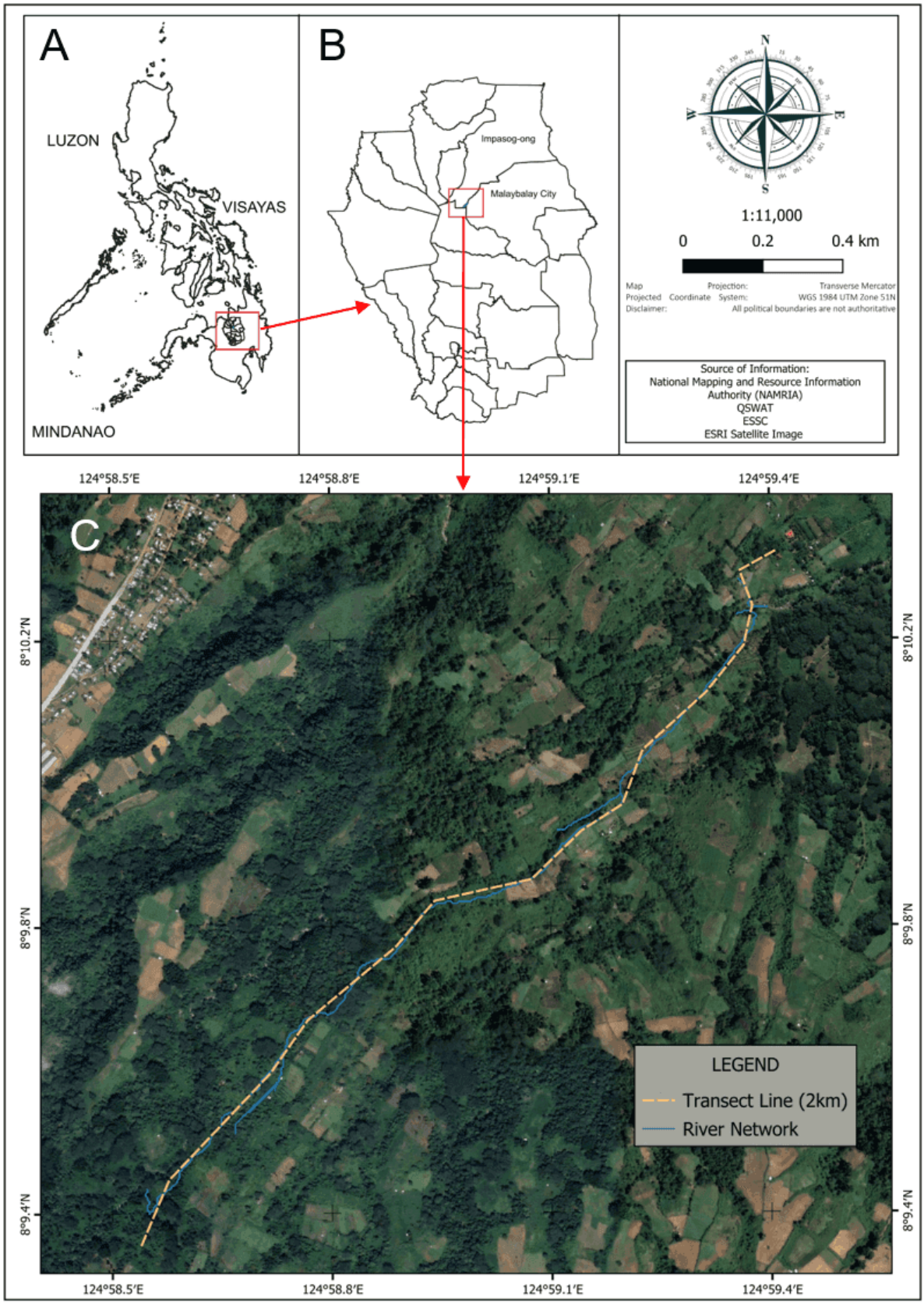


Figure 1: Map of the study site: **A.** Map of the Philippines showing the study site in Mindanao; **B.** Bukidnon province; **C.** the study area showing the 2-km transect line (yellow broken line) and the stream channel (blue).

According to Oscar M. Lopez Center and PAGASA (2024), the climate in the area is classified as Type IV with no pronounced dry season. The average temperature ranges between 19º C–30º C, with an annual rainfall of 2,800 mm. The study area lies at an elevation of about 1,200–1,400 metres above sea level and is characterized by diverse riparian ecosystems. The general study area is characterized by tree species such as *Lithocarpus* spp. (Fagaceae), *Saurauia* spp. (Actinidiacaeae), and *Ficus* spp. (Moraceae), along with ferns and lycophytes including *Asplenium thunbergii* Kunze (Aspleniaceae), *Diplazium esculentum* (Retz.) Sw. (Athyriaceae), *Antrophyum pseudolatifolium* C.W. Chen (Pteridaceae), *Drynaria heraclea* (Kunze) T. Moore (Polypodiaceae), and *Selaginella* spp. (Selaginellaceae).

Inventory, collection, and processing of the specimens

Repeated transect walks were carried out to collect specimens of understory seed plants along the established two-kilometre transect with a width of 10 m in the upstream Sawaga River. Understory seed plants outside the established transect were also sampled to ensure comprehensive documentation of the taxa. Herbaceous species were collected by uprooting them from the soil. Epiphytes, vines, lianas, and small shrubs with flowers and/or fruits were collected using pruning shears. All collections were pressed in a newspaper bearing necessary field information such as collection number, collectors' names, preliminary identification, coordinates, elevation, and field notes. The specimens were then placed in a large polyethylene bag and soaked in denatured alcohol for preservation (Hodge, 1947), and subsequently dried in a mechanical air drier for two weeks. All collected specimens were stored in a separate cabinet at Central Mindanao University Museum with collection number under the first author, KBMLC (Ken Bien Mar L. Caballes). However, accession numbers are yet to be given due to the large amount of backlogged specimens of the herbarium that are also being accessioned until now. These specimens will then be deposited at the Central Mindanao University Herbarium (CMUH) once accessioning is done.

Identification of the specimens

Species identification was accomplished using field guides and several online databases, including the JSTOR Global Plants, International Plant Names Index, the Global Biodiversity Information Facility (www.gbif.org), and Co's Digital Flora of the Philippines (Pelser et al., 2011 onwards). Identification of plant specimens was made using relevant taxonomic literature (Tandang et al., 2014; Acma et al., 2021; Mendez et al., 2025) and in consultations with experts.

Assessment of conservation status and endemism

The conservation status of each species was evaluated using the national list of threatened Philippine plants (Fernando et al., 2022) and the DENR Administrative Order 2026-20. Species endemicity was determined using the Co's Digital Flora of the Philippines (Pelser et al., 2011 onwards).

Observation of ecological threats

Ecological threats adjacent to the upstream Sawaga River were assessed in conjunction with the floristic survey. A land-use/land-cover (LULC) analysis was generated by delineating the river network along the transect using QSWAT 3.16 within the QGIS environment, after which a 40-m buffer was created in a GIS platform. The 40-m buffer was used as per PD 1067 (Water Code of the Philippines) that is considered as easement in riparian forest areas. Land use/land cover (LULC) data was initially obtained from the 2024 ESRI Land Cover (10-m spatial resolution). To evaluate its suitability, the mapped land-cover classes were visually compared with high-resolution 2025 Google Earth imagery.

The comparison indicated inconsistencies in portions of the study area, where the ESRI dataset classified areas as forest while the Google Earth imagery showed a heterogeneous land-cover pattern. Consequently, the 2018 detailed Land Use/Land Cover map (ESSC, 2020), which exhibited better agreement with the observed land-cover pattern, was adopted as the reference dataset. The resulting LULC information was used to characterize the surrounding land-cover types and interpret spatial patterns of disturbance.

Key Informant Interviews (KII) were also conducted using a standardized questionnaire to provide additional qualitative insights into land-use practices and historical disturbances. A total of four (4) key informants, comprising a forest guide, a resident, a City Environment and Natural Resources Office (CENRO) personnel, and the barangay captain, were purposely interviewed. These informants were aged 27 to 42 years (mean = 34.25 years) with residency or engagement in the upstream Sawaga River from 2 to 27 years, representing an active and professionally engaged age group capable of providing informed assessments of ecological changes. To address the small sample size, information obtained from the qualitative interviews was triangulated with direct field observations, photographic documentation, and the LULC analysis to substantiate the identified anthropogenic and environmental pressures affecting the study area.

RESULTS

Species composition

The inventory of understory seed plants recorded 75 species belonging to 27 families and 61 genera along the upstream section of the Sawaga River (Table 1). These species represent 0.80% of all known Philippine angiosperm species, 11.07% of the country's angiosperm families, and 3.41% of its documented genera. At the family level, Araceae emerged as the most species-rich group with 13 species, followed by Orchidaceae and Zingiberaceae with nine species each, and Gesneriaceae and Urticaceae with five species each (Fig. 2).

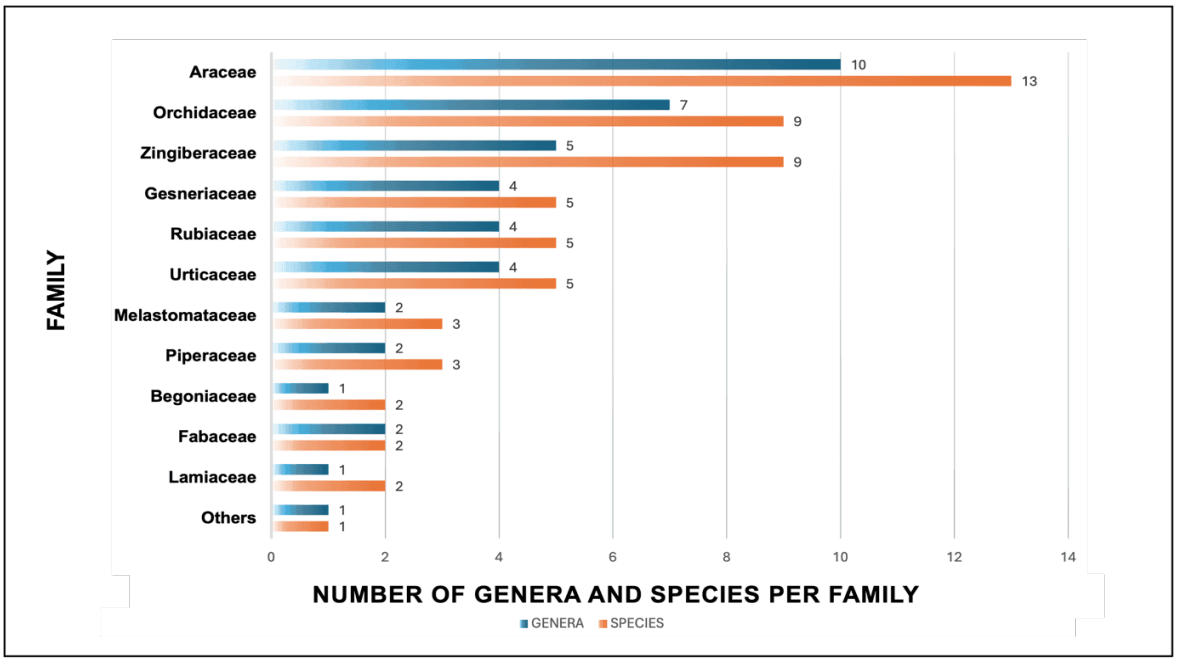


Figure 2: Number of genera and species per family. *Note: "Others" includes families represented by a single genus and species each in the inventory.*

Table 1: Checklist of understory seed plants along the upstream Sawaga River, Malaybalay City, Bukidnon, Philippines.

Family		Species	Collection No.	Conservation Status (DAO 2026-20)	Endemicity
I. Acanthaceae	1.	*Strobilanthes* sp.	KBMLC 247	-	-
II. Araceae	2.	*Alocasia macrorhizos* (L.) G.Don	-	-	-
	3.	*Amydrium zippelianum* (Schott) Nicolson	-	-	-
	4.	*Arisaema polyphyllum* (Blanco) Merr.	-	-	-
	5.	*Colocasia esculenta* (L.) Schott	-	-	-
	6.	*Epipremnum pinnatum* (L.) Engl.	-	-	-
	7.	*Homalomena rubescens* (Roxb.) Kunth	-	-	-
	8.	*Rhaphidophora* cf. *elmeri* Engl. & K.Krause	-	-	-
	9.	*R. korthalsii* Schott	-	-	-
	10.	*R.* cf. *perkinsiae* Engl.	-	-	-
	11.	*R.* cf. *todayensis* K.Krause		-	PE
	12.	*Schismatoglottis calyptrata* (Roxb.) Zoll. & Moritzi	KBMLC 237, 261	-	-
	13.	*Scindapsus pictus* Hassk.	KBMLC 282	-	-
	14.	*Xanthosoma sagittifolium* (L.) Schott		-	-
III. Asteraceae	15.	*Mikania cordata* (Burm.f.) B.L.Robinson	KBMLC 274	-	-
IV. Balanophoraceae	16.	*Balanophora papuana* Schltr.	KBMLC 266	-	-
V. Balsaminaceae	17.	*Impatiens platypetala* Lindl.	KBMLC 226	-	-
VI. Begoniaceae	18.	*Begonia malindangensis* Merr.	KBMLC 268, 284	-	PE
	19.	*B. rieckei* Warb.	KBMLC 241, 273	-	-
VII. Commelinaceae	20.	*Tradescantia zebrina* Bosse	KBMLC 294	-	-
VIII. Fabaceae	21.	*Mucuna reticulata* Burck	KBMLC 272	-	-
	22.	*Strongylodon pulcher* C.B.Rob.	KBMLC 271	-	PE
IX. Gesneriaceae	23.	*Aeschynanthus asclepioides* (Elmer) B.L.Burtt & P.Woods*	KBMLC 260	-	PE
	24.	*A. irigaensis* (Merr.) B.L.Burtt & P.Woods	KBMLC 259	-	PE
	25.	*Cyrtandra pallidifolia* Kraenzl.*	KBMLC 295	-	PE
	26.	*Rhynchoglossum obliquum* Blume*	KBMLC 296	-	-
	27.	*Rhynchotechum discolor* (Maxim.) B.L.Burtt	KBMLC 236	-	-
X. Hypoxidaceae	28.	*Curculigo capitulata* (Lour.) Kuntze	KBMLC 230	-	-
XI. Lamiaceae	29.	*Clerodendrum lanuginosum* Blume	KBMLC 297	-	-
	30.	*Clerodendrum* sp.		-	-
XII. Loranthaceae	31.	*Amyema serriata* (Merr.) Barlow	KBMLC 235	-	PE
XIII. Lythraceae	32.	*Cuphea carthagenensis* (Jacq.) J.F.Machr.	KBMLC 263	-	-
XIV. Malvaceae	33.	*Urena lobata* L.	KBMLC 280	-	-
XV. Melastomataceae	34.	*Medinilla banahaensis* Elmer	KBMLC 229	EN	PE
	35.	*M. teysmannii* Miq.	KBMLC 276	-	-

Table 1: Continued.

Family	Species	Collection No.	Conservation Status (DAO 2017-11)	Endemicity
	36. *Melastoma malabathricum* L.	KBMLC 277	-	-
XVI. Menispermaceae	37. *Tinospora* sp.	KBMLC 258	-	-
XVII. Orchidaceae	38. *Bulbophyllum* sp.	KBMLC 258	-	-
	39. *Crepidium purpureum* (Lindl.) Szlach.**	KBMLC 249	-	-
	40. *Dendrobium bullenianum* Rchb.f.	KBMLC 253	EN	PE
	41. *D. butchcamposii* Cootes, M.Leon & R.Boos	KBMLC 287	-	PE
	42. *D. tiongii* Cootes	KBMLC 248	-	PE
	43. *Gastrodia cajanoae* Barcelona & Pelser	KBMLC 234	-	PE
	44. *Liparis* sp.	KBMLC 269	-	-
	45. *Phreatia sulcata* (Blume) J.J.Sm.	KBMLC 279	-	-
	46. *Pteroceras* sp.	KBMLC 228	-	-
XVIII. Piperaceae	47. *Peperomia tetraphylla* (G.Forst.) Hook. & Arn.	KBMLC 254	-	-
	48. *Piper macropiper* Pennant	KBMLC 290	-	-
	49. *P. umbellatum* L.	KBMLC 281	-	-
XIX. Poaceae	50. *Oplismenus* sp.	KBMLC 288	-	-
XX. Polygalaceae	51. *Polygala paniculata* L.		-	-
XXI. Primulaceae	52. *Ardisia warburgiana* Mez	KBMLC 270	-	PE
XXII. Rosaceae	53. *Rubus rosifolius* Sm.	KBMLC 231	-	-
XXIII. Rubiaceae	54. *Argostemma solaniflorum* Elmer	KBMLC 280, 256	-	-
	55. *Coffea arabica* L.		-	-
	56. *Lasianthus* sp.	KBMLC 293	-	-
	57. *Mycetia cauliflora* Reinw.	KBMLC 252	-	-
	58. *Nertera granadensis* (Mutis ex L.f.) Druce	KBMLC 256	-	-
XXIV. Urticaceae	59. *Elatostema lagunense* C.B.Rob.	KBMLC 245, 285	-	PE
	60. *E.* cf. *obtusiusculum* C.B.Rob	KBMLC 243	-	PE
	61. *Nothocnide repanda* (Blume) Blume	KBMLC 265	-	-
	62. *Pilea* cf. *sylvatica* Elmer	KBMLC 246	-	PE
	63. *Poikilospermum erectum* (Blanco) Merr.	KBMLC 240	-	-
XXV. Verbenaceae	64. *Stachytarpheta jamaicensis* (L.) Vahl	KBMLC 275	-	-
	65. *Lantana camara* L.		-	-
XXVI. Vitaceae	66. *Tetrastigma papillosum* (Blume) Planch.	KBMLC 227	-	-
XXVII. Zingiberaceae	67. *Alpinia haenkei* C.Presl	KBMLC 232	-	PE
	68. *Etlingera dostseiana* Naive, Demayo & Alejandro	KBMLC 298	-	PE
	69. *E. fimbriobracteata* (K.Schum.) R.M.Sm.	KBMLC 299	-	-
	70. *Hedychium flavescens* Carey ex Roscoe	KBMLC 300	-	-

Table 1: Continued.

Family	Species	Collection No.	Conservation Status (DAO 2017-11)	Endemicity
	71. *H. philippinense* K.Schum.	KBMLC 301	VU	PE
	72. *Hornstedtia conoidea* Ridl.	KBMLC 302	-	PE
	73. *H. lophophora* Ridl.	KBMLC 233, 238	-	PE
	74. *Meistera muricarpa* (Elmer) Škorničk. & M.F.Newman	KBMLC 303	-	PE
	75. *Zingiber banahaoense* Mood & Theilade	KBMLC 204	-	PE

Legend: (EN) Endangered; (VU) Vulnerable; (OTS) Other Threatened Species; (PE) Philippine endemic; (*) new provincial record for Bukidnon; (**) new island record for Mindanao.



Figure 3: Some species of understory seed plants in the remaining forest patches of upstream Sawaga River: **A.** *Schismatoglottis calyptrata*; **B.** *Balanophora papuana*; **C.** *Impatiens platypetala*; **D.** *Begonia malindangensis*; **E.** *Strongylodon pulcher*; **F.** *Rhynchotechum discolor*; **G.** *Aeschynanthus irigaensis*; **H.** *Medinilla banahaensis*; **I.** *Dendrobium bullenianum*; **J.** *Gastrodia cajanoae*; **K.** *Piper macropiper*; **L.** *Ardisia warburgiana*; M. *Argostemma solaniflorum*; **N.** *Mycetia cauliflora*; **O.** *Nertera granadensis*; **P.** *Elatostema lagunense*; **Q.** *Poikilospermum erectum*; **R.** *Nothocnide repanda*; **S.** *Alpinia haenkei,* **T.** *Hornstedtia lophophora.*

Noteworthy species were also recorded with one species, *Crepidium purpureum* (Lindl.) Szlach. (Orchidaceae), having an extended range of island distribution to now include Mindanao. Previously, this terrestrial orchid had only been recorded in the Laguna and Rizal provinces in Luzon Island (Pelser et al., 2011 onwards). Three species from the family Gesneriaceae also represent new provincial records for Bukidnon, *viz*., *Aeschynanthus asclepioides* (Elmer) B.L. Burtt & P. Woods, *Cyrtandra pallidifolia* Kraenzl., and *Rhynchoglossum obliquum*.

Conservation status and endemicity

For the conservation assessment, a total of three (3) threatened species were documented (Table 1). Two (2) of these are classified as Endangered (EN): *Medinilla banahaensis*, *Dendrobium bullenianum*, while *Hedychium philippense* is classified as Vulnerable (VU). Twenty-three species (23) were also identified as endemic to the Philippines. Of these, three (3) are further restricted to Mindanao: *Dendrobium butchcamposii*, found only in Bukidnon; *Etlingera dostseiana*, distributed across Bukidnon, Davao Oriental, Davao del Sur, and Misamis Oriental provinces; and *Hornstedtia lophophora*, occurring exclusively in Bukidnon, Davao Oriental, and Davao del Sur (Pelser et al., 2011 onwards).

Ecological threats

The results of the LULC show that the two-kilometre river stretch with a 40-metre buffer on each side for forest easement is comprised of both natural forest (45%) and human-modified lands (55%), highlighting the extent of encroachment into ecologically sensitive zones (Fig. 4).

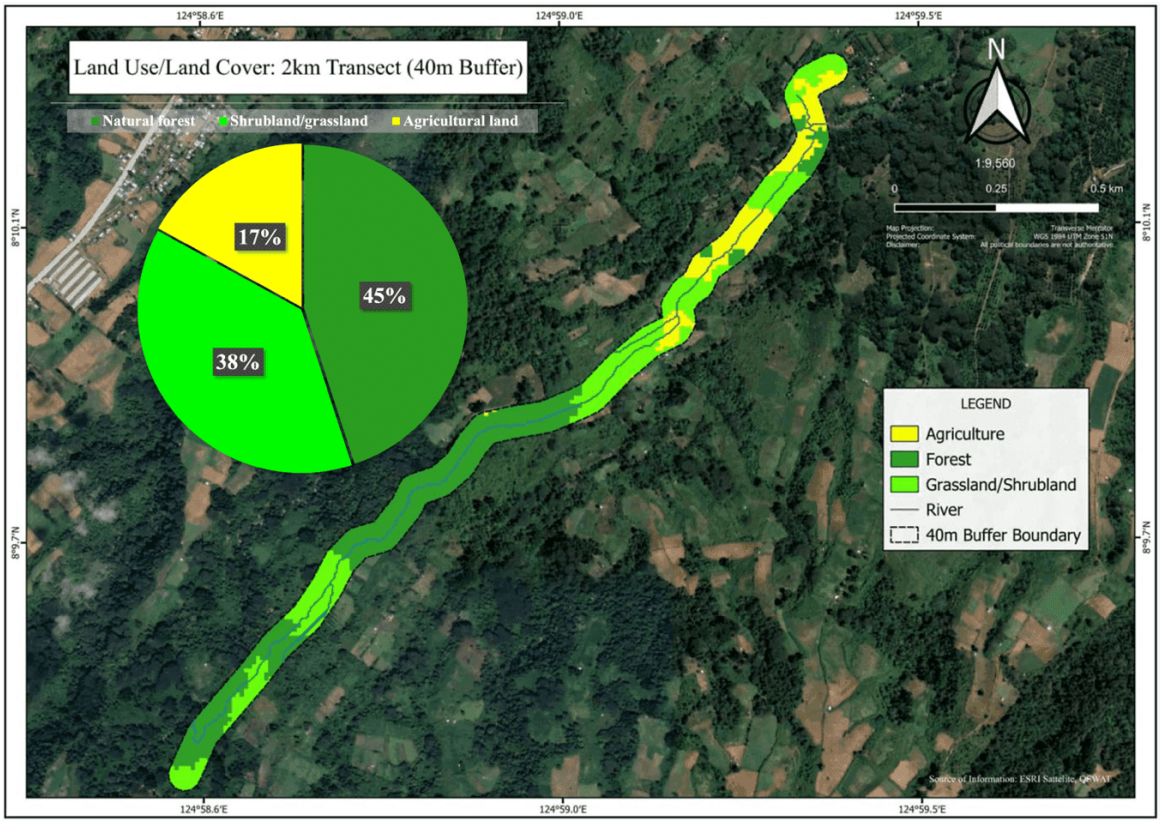


Figure 4: Land use land cover (LULC) of the riparian ecosystem in the upstream Sawaga River, Malaybalay City.

Of the 55%, 38% are shrubland/grasslands as evidences of swidden farming, and 17% are converted into agricultural lands. These human-modified lands pose a high risk for streambank erosion, nutrient runoff, and non-point source pollution.

The KII validates the findings of the LULC where respondents observed that some portions of the forest have been converted into agricultural lands for economically important crops such as abaca, coffee, and potato (Table 2). According to one of the respondents, *"Compared to decades ago, the forest used to be much denser. Now, it has significantly diminished due to the expansion of agriculture. The forest is now interspersed with crops such as coffee and abaca. Some open areas have been extended for planting flowers and sweet potatoes."* This reflects a transition from a previously dense and close canopy to a more open and fragmented forest, with respondents noting an apparent acceleration of these changes in recent decades. Illegal practices, including girdling of trees to kill them and the continued collection of firewood, have also been reported as contributors to forest thinning and degradation.

Along with land-use changes, respondents also observed a marked decline in biodiversity, particularly among native flora and fauna. Notably, the native Philippine oak also known as "ulayan", *Lithocarpus* spp. (Fagaceae), has now become rare in the area. As one respondent explained, *"Ulayan trees are being cut because they burn well as firewood. As a result, most individuals are now found only in protected areas, while in the lower areas, they are already almost absent."* A similar pattern was observed for *Strongylodon* spp. (Fabaceae), which are now largely confined to the protected forests of Mt. Kitanglad, about two kilometres away from the study site. Faunal observations further corroborate these trends, with pigs (*Sus* sp.), deers (*Rusa marianna*), and monkeys (*Macaca fascicularis philippensis*), now becoming a rare sight for locals, as the aforementioned ecological threats continue to expand. As emphasized by another respondent, *"We used to see wild animals frequently because the forest had not yet been opened. Now, it can only be found in areas that not frequented by people."*

Other observations noted by the respondents include soil erosion and minor landslides in some portions, particularly in areas dominated by shrubland and grassland cover along riparian slopes, consistent with the LULC analysis. Dumping of waste by both locals and tourists who go hiking, also evidently remain in some sections of the riparian forest despite existing local ordinances (Table 2).

Table 2: Summary of major anthropogenic and environmental threats in upstream, corresponding field-based evidence and verification methods, and their impacts on understory seed plants.

Major Threat Category	Specific Evidence/Disturbance	Verification Method	Impact on understory seed plants
Land use change	Agricultural expansion (abaca, coffee, vegetables); swidden farming areas forming shrubland/grassland; forest-to-agriculture conversion.	Field observation/ KII/ LULC mapping	Loss of specialized riparian microhabitats and increased soil compaction, reducing germination and establishment of understory seed plants.
Deforestation & Forest Degradation	Illegal tree cutting and girdling; firewood collection.	KII	Canopy opening, increasing light and temperature stress for shade-adapted understory seed plants.
Pollution & Waste	Waste dumping along trails and riverbanks by locals and outsiders; presence of	Field Observation/ KII	Hinders germination and reduces survival particularly for sensitive species.

	plastic trash in forested areas.		
Biodiversity Decline	Decline of native plant species (*Lithocarpus* spp., *Strongylodon* spp.); loss and retreat of wildlife (*Sus* sp., *Rusa marianna*, *Macaca fascicularis*, birds) to upper elevations.	Field Observation/ KII	Limits food and seed sources, disrupting ecological interactions such as seed dispersal, leading to lower germination and simpler understory composition.
Soil & Geomorphological Instability	Increased erosion due to grassland/shrubland and agricultural expansion; small landslides.	Field observation/ KII/ LULC mapping	Removes topsoil and leaf litter important for germination and establishment and reduces nutrient availability.
Climate-related stress	Unpredictable rainfall and temperature shifts; perceived tree dieback linked to climate stress.	KII	Induces physiological stress, disrupting growth, phenology, and overall survival.
Invasive species	Proliferation of invasive species such as *Piper aduncum, Tithonia diversifolia, Lantana camara,* and *Spathodea campanulata* in disturbed areas.	Field observation/ KII	Outcompete native understory seed plants for light, nutrients, and space, suppressing growth and altering species composition.

DISCUSSION

Species composition

The number of species recorded is higher than those reported for riparian areas in Iligan City, with 32 species (Tampus et al., 2012), and the Cagayan de Oro River, with 62 species (Lubos et al., 2015). It is lower than documented species in the Kaliwa River Watershed with 111 species (Malabrigo et al., 2014), the Cabadbaran River with 109 species (Sarmiento et al., 2022), and Molawin River in Mt. Makiling with 107 species (Replan et al., 2023), although these studies also included trees, which indicates that Sawaga River still supports a relatively rich flora even when considering only understory seed plants. Compared to studies that focus specifically on understory seed plants, the upstream Sawaga River has fewer species than the Marilog Forest Reserve in Davao City, with 174 species (Acma et al., 2021), Talangisog Forest in Misamis Oriental, with 128 species (Caballes et al., 2026), and the Balinsasayao Twin Lakes Natural Park (BTLNP) in Negros Oriental, with 101 species (Mendez et al., 2025).

Differences between riparian species richness and composition may be due to factors, such as the level of disturbance and the presence of forested patches. For instance, the study by Tampus et al. (2012), which surveyed two rivers—the Mandulog River and the Iligan City River–with five study areas in each, recorded comparatively fewer species, despite covering a larger total study area. Nine out of 10 surveyed study sites exhibited field biotic index values indicating organic pollution. Further field observations also noted silted banks with little or no vegetation, household wastes, agricultural runoff, and ongoing construction. The two rivers are also situated near urban areas, unlike the upstream Sawaga River, which flows through less developed mountainous areas and retains more natural forest patches. A similar pattern was observed for the study of Lubos et al. (2015) in the Cagayan River where three out of four study areas are polluted. These differences imply that disturbances along the upstream Sawaga River are less extensive than in the two aforementioned rivers, allowing it to still provide

suitable habitat for understory seed plants. This emphasizes the need for stricter protection measures to safeguard the area from further degradation.

Aside from the level of disturbance, differences in the composition, richness, and distribution of understory seed plants in riparian forests may be further influenced by forest vegetation type and landscape position (Ou et al., 2020; Li et al., 2024). Species composition in riverine forests is also affected by altitude, aspect, and slope (Jamtsho & Sridith, 2017). With this, inventories of understory seed plants in Marilog Forest Reserve, Talangisog Forest, and BTLNP encompass ecosystems with more diverse and different microhabitats than the upstream Sawaga River. Marilog Forest Reserve includes both tropical lower montane rainforest and agro-forest ecosystems with clay and limestone substrates, Talangisog Forest consists of a largely intact lowland evergreen rainforest with steep slopes, and the inventory in BTLNP was conducted in a forest-over-rock formation. Further variation in richness could also be attributed to the area surveyed. Both the Kaliwa Watershed (Malabrigo et al., 2014) and the Cabadbaran River (Sarmiento et al., 2022) encompass larger study sites and established plots, which likely captured more understory seed plants. As such, including the midstream and downstream sections of the entire Sawaga River, as well as its tributaries, and employing a plot-based sampling technique for additional comprehensiveness would likely increase the number of species recorded in the area.

The most represented families in the upstream Sawaga River are likewise among the most speciose in other Philippine understory plant inventories. In BTLNP, Orchidaceae and Araceae were also highly represented, each with 11 species, while Zingiberaceae ranked third with 8 species (Mendez et al., 2025). The families Zingiberaceae (26 spp.), Orchidaceae (19 spp.), and Gesneriaceae (14 spp.) were also the most species-rich in the forests of Marilog District in Davao Region in Mindanao (Acma et al., 2021).

Their dominance in understory inventories may reflect the diversity of life forms within these families. Species from Araceae, Orchidaceae, and Gesneriaceae may occur as terrestrial herbs, climbers, or epiphytes (Zhang et al., 2018; Croat & Ortiz, 2020; Legardón & Garcia-Plazaola, 2023). Although Zingiberaceae is predominantly composed of terrestrial herbs, one epiphytic species, *Hedychium philippinense,* was recorded in the study area. Their richness could also be supported by their broad habitat tolerance, with species occurring across land-use types. For instance, *H. flavescens* occurs at forest edges near agricultural land, *Hornstedtia lophophora* in grasslands and shrublands, and others are confined to natural forest fragments. This combination of diverse life forms and habitat flexibility allow these families to occupy different vertical strata and multiple microhabitats, maximizing available ecological niches, and thereby contributing to their high representation in understory plant inventories.

Conservation status and endemicity

The number of threatened and endemic understory seed plants in the upstream Sawaga River is comparable to that of Balinsasayao Twin Lakes Natural Park, Negros Oriental with only two threatened and 18 endemic species (Mendez et al., 2025). Obemio et al. (2016) recorded only one endemic species (*Dendrocnide luzonensis* (Wedd.) Chew) in Mt. Matutum Protected Landscape in South Cotabato, whereas Acma et al. (2021) documented 23 threatened and 54 endemic species of understory seed plants. This suggests that, despite being an unprotected area with altered land-use types and persistent threats, the upstream Sawaga River still supports a significant number of threatened and endemic species, as with those found in formally protected forest ecosystems.

Notably, the three Mindanao endemics (*Dendrobium butchcamposii*, *Etlingera dostseiana, H. lophohora*), along with the new Mindanao record, *C. purpurerum,* were all found exclusively within the remaining natural forest fragments, highlighting the role of these habitats as refugia for rare species. With approximately 55% of the surrounding landscape converted to human-modified land uses, these species face a high risk of local extinction, emphasizing the urgent need to conserve the remaining forest patches along the river.

Ecological threats

In the upstream Sawaga River, the dominance of human-modified lands over natural forest pose significant threat to plant communities. The conversion of natural riparian vegetation with agricultural land and shrubland/grassland results in habitat fragmentation, loss of suitable microhabitats, and altered species composition (Hrkal et al., 2006; Celentano et al., 2017; Dinca et al., 2025). These heighten the extinction risk for threatened species because they have narrow and sensitive ecological requirements and limited dispersal capacity. In this study, all five threatened species were found in forest edges, which make them even more vulnerable to ongoing anthropogenic disturbance and habitat loss.

The same patterns of LULC where human-modified lands dominate over natural forests have been observed in various riparian zones in the Philippines, including the Muleta Watershed in Bukidnon, the Cabadbaran River Sub-watershed in Agusan del Norte, and the Solana River in Misamis Oriental (Amper et al., 2019; Amper et al., 2021; Sarmiento et al., 2022). Given that human-modified lands consistently emerge as problems for riparian forests, these findings highlight the urgent need for local government units and locals to focus on strengthening the regulation and management of land-use activities within riparian buffer zones.

CONCLUSIONS

The upstream Sawaga River is home to a relatively rich assemblage of understory seed plants, comprising 75 species belonging to 61 genera, and 27 families. Of these, three species are threatened, while 23 are endemic to the Philippines. *Crepidium purpureum* is herein reported as a new record for Mindanao, while *Aeschynanthus asclepioides*, *Cyrtandra pallidiifolia*, and *Rhynchoglossum obliquum* are newly recorded for Bukidnon province. Despite this biological significance, the upstream Sawaga River is a biodiversity hotspot at risk, with land use change, deforestation, pollution, biodiversity decline, soil and geomorphological instability, climate-related stress, and invasive species identified as ecological threats. The co-existence of a significant number of threatened, endemic, and rare taxa alongside persistent environmental threats indicates the high conservation value of the upstream Sawaga River. However, this also highlights the vulnerability of the area to continued disturbance, which may drive the loss of sensitive species.

To mitigate these impacts, strict enforcement of the 40-m riparian buffer must be mandated. Disturbed habitats and areas illegally converted to agriculture should be restored using native species. Existing local ordinances must also be revisited and rigorously implemented, and awareness campaigns must be strengthened. Lastly, existing biodiversity monitoring programmes, particularly for threatened and endemic species, must be consistent and done on a long-term basis.

ACKNOWLEDGEMENTS

The authors would like to thank the Malaybalay City Environment and Natural Resources Office for their unwavering support and assistance during the conduct of this study, the Central Mindanao University and the Center for Biodiversity Research and Extension in Mindanao for allowing the first author to participate in the field reconnaissance and BMS sampling, and Mr. Derek Cabactulan for identifying Orchidaceae species. KBMC would also like to extend his gratitude to the following: the Barangay Local Government Unit of Dalwangan, Bukidnon; the Daraghuyan Tribe of Dalwangan; and the DOST-STRAND for funding support.

DECLARATIONS

Research permit(s). A Wildlife Gratuitous Permit (WGP number R10-2025-09-522) was obtained from the Department of Environment and Natural Resources (DENR) Region X.
Ethical approval/statement. An institutional ethics permit (0965 s. 2025) was obtained for the conduct of the Key Informant Interview.
Generative AI use. I/we declare that generative AI was not used in this study nor in the writing of this article.

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