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Review article

Ethnobotanical diversity, phytochemical characterization, and pharmacological validation of medicinal plants used by indigenous communities of Tripura, Northeast India

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ABSTRACT

Tripura, part of the Indo-Myanmar biodiversity hotspot in northeastern India, hosts around 2,400 angiosperm species, many used medicinally by its 19 Scheduled Tribe communities. Its rich ethnomedicinal diversity arises from a favourable subtropical climate, varied topography, and extensive indigenous knowledge. However, a comprehensive multidisciplinary review integrating ethnobotany, phytochemistry, and pharmacology of Tripura's medicinal plants remains lacking.

To provide an integrated review of the ethnobotany, phytochemistry, and documented pharmacological activities of the most therapeutically significant plant species used by indigenous communities in Tripura; to identify critical research gaps; and to assess prospects for phytopharmaceutical development in an ethically and conservationally responsible framework.

A systematic search of PubMed, Scopus, Web of Science, Google Scholar, and Indian botanical and pharmacological journals (1980–2024) was conducted and synthesized with primary ethnobotanical field data collected across all eight districts of Tripura (2019–2024; n = 212 informant interviews). Species selection was based on frequency of citation (FCI), strength of pharmacological evidence, and therapeutic relevance. Quantitative ethnobotanical metrics—use value (UV), informant consensus factor (ICF), and fidelity level (FL)—were calculated using established methods.

Tripura's medicinal flora, represented by fifteen species across diverse families like Zingiberaceae, Lamiaceae, Fabaceae, Moraceae, Euphorbiaceae, Asteraceae, and Menispermaceae, demonstrates significant therapeutic potential, particularly in anti-inflammatory, antidiabetic, antimicrobial, and hepatoprotective activities. This is supported by a rich diversity of phytoconstituents such as alkaloids, flavonoids, terpenoids, phenylpropanoids, and tannins. However, major research gaps and increasing conservation pressures highlight the urgent need for integrated approaches involving phytochemical analysis, pharmacological validation, and collaboration with indigenous communities to fully harness this underexplored resource.

Keywords: Ethnobotany, Tripura, Medicinal plants, Phytochemistry, Pharmacology, Biodiversity hotspot, Indigenous knowledge.

INTRODUCTION

The role of plant-derived medicines in the international therapeutic arena is a decisive factor, with ensuing years of epidemiological, ethnomedical, and pharmacological evidence behind their effectiveness. According to the estimations made by the World

Health Organization (WHO, 2019), about 80 per cent of the global population is dependent on traditional plant-based remedies as the main health resource or even as a supplement to health care - an issue that not only implies economic need, but also the pharmacological validity of botanical medicines, developed over centuries of empirical testing. During 1981-2019, approximately half of the drugs approved were based on or inspired by natural products structurally, highlighting the perpetual central role of plant biodiversity in drug discoveries over time [1].

Special place in this pharmacological picture is taken by biodiversity-based tropical and subtropical areas, which is now a source of chemical richness, as well as of traditional medicine knowledge which is still disproportionately underrepresented in the biomedical literature. Northeastern India, comprising Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura is classified in the Indo-Myanmar biodiversity hotspot, one of 36 internationally recognized hotspots, characterized by an unusual richness of endemic species with a disproportionately high level of habitat threat [2].

In this sub-region, the smallest state in the northeast of India is Tripura (area: 10,486 km2), which supports a floristically diverse group of subtropical moist deciduous forests, semi-evergreen forests, bamboo-dominated secondary growth, wetland communities and complex homestead agroforestry systems that in total support about 2400 angiosperm species, 80 pteridophyte species, and many bryophytes and fungi [3]. These cultures are unique yet overlapping ethnomedicinal practices of the 19 Scheduled Tribe communities, or about 31.8% of the general population, upheld by centuries of practice in observation and intergenerational passage, which contribute to a pharmacological legacy remarkable in depth.

Ethnobotanical surveys have been done on specific communities or geographic regions in isolation [4,5], and pharmacological studies have tended to explore a single species out of context [6,7].

This review fills that gap, incorporating primary field information with the secondary literature to provide a revised evidence-based report on fifteen priority species, as both a synthesis of scientific knowledge and a research gap assessment and a strategic resource guide to future research and conservation planning.

Biodiversity and floristic context of medicinal plant use in Tripura

Vegetation types and botanical richness

There are five main physiognomic communities in Tripura: tropical evergreen wet forests, restricted to the high mountainous Jampui Hill Range of North Tripura and supporting the highest level of plant alpha-diversity in the state: Dipterocarpus turbinatus, Artocarpus chaplasha, Cinnamomum spp.; tropical moist semi-evergreen forests, which form the main cover in the central and southern districts and are also essential to the state; tropical moist deciduous forests; bamboo-dominant secondary growth, which spreads into target areas where shifting cultivation has taken place; wetland communities (beel ecosystems), concentrated in West Tripura [4,5]. The ethnopharmacological spectrum of the tribe has unique assemblages of medicinal species by each vegetation type.

Surveys Tripura Tribal Areas Autonomous District Council (TTAADC) villages record an average 18-24 medicinal plant species found in the household including wild-collected medicinal species introduced to an easy source and domesticated medicinal cultigens maintained during generations of selective cultivation. Other significant species consistently reported in household gardens are Alpinia nigra, Clerodendrum colebrookianum, Oroxylum indicum, Drymaria cordata and Tinospora cordifolia [5,6].

Ethnomedicinal documentation: methodology and scope

The primary ethnobotanical data supporting this review were collected in the context of systematic field survey conducted in all eight administrative districts of Tripura during 2019-24 based on the principles of the systematic ethnobotanical methodology and ethical requirements such as prior informed consent, community level permission, and confidentiality of the information received or shared by the informant [8]. The semi-structured interviews were utilized on 212 informants who were stratified based on taxonomic verification with a standard regional flora [9], and deposited in the Tripura University Herbarium. The calculated quantitative ethnobotanical indices are the use value (UV), frequency of citation index (FCI), fidelity level (FL) and informant consensus factor (ICF) as explained [10,11].

Selected medicinal plants: an integrated review

The fifteen species below were prioritised based on the highest FCI scores of primary field data, the robustness of phytochemical documentation and the therapeutic importance of the fifteen species in the various tribe populations. A synopsis is contained in Table 1; these are elaborated.

Clerodendrum colebrookianum Walp. (Lamiaceae)

Locally designated 'Baghchita' in the Tripuri language and referred to colloquially as 'Hill glory bower' in English, Clerodendrum colebrookianum is a large deciduous shrub attaining 2–5 m in height and occupying the highest FCI among all species surveyed (FCI = 0.91; UV = 3.24). Leaf decoctions are employed for hypertension management by 43 of 47 interviewed healers; topical leaf paste is applied for dermal infections by 38 of 47; root decoctions are prescribed for diabetes mellitus by 29 of 47; and leaf juice is administered for jaundice by 24 of 47 informants [12,13].

Table 1: Comparative summary of fifteen priority medicinal plant species of Tripura

Species (Family)	Family	Traditional Uses	Key Phytoconstituents	Pharmacological Evidence	FCI
Clerodendrum colebrookianum Walp.	Lamiaceae	Antihypertensive, antidiabetic, antimicrobial	Quercetin, luteolin, oleanolic acid, β-caryophyllene	ACE inhibition (IC_{50} = 42.8 µg/mL); BP reduction in SHR	0.91
Centella asiatica (L.) Urb.	Apiaceae	Memory enhancement, wound healing, skin disorders	Asiaticoside, madecassoside, asiatic acid	RCT-confirmed neuroprotective, wound-healing, venous insufficiency	0.88
Alpinia nigra (Gaertn.) B.L.Burtt	Zingiberaceae	GI disorders, rheumatism, respiratory, antimicrobial	ACA, galangin, β-pinene, 1,8-cineole	Anti-inflammatory (NF-κB), antidiabetic (α-glucosidase IC_{50} = 148.6 µg/mL)	0.84
Justicia adhatoda L.	Acanthaceae	Bronchitis, asthma, COPD, tuberculosis	Vasicine, vasicinone, vasicol, apigenin	β_2-adrenergic bronchodilation; bromhexine precursor; clinical RCT support	0.79
Oroxylum indicum (L.) Kurz	Bignoniaceae	Respiratory, rheumatism, anti-inflammatory	Baicalein, chrysin, oroxylin A, scutellarein	NF-κB inhibition (IC_{50} = 8.4 µM); bronchodilatory; hepatoprotective	0.72
Tinospora cordifolia (Willd.) Miers	Menispermaceae	Fever, diabetes, immunostimulant tonic	Berberine, palmatine, tinosporaside, arabinogalactan	Immunomodulatory, antidiabetic, hepatoprotective; clinical evidence in T2DM	0.68
Drymaria cordata (L.) Willd.	Caryophyllaceae	Headache, fever, colds, expectorant	Drymarigenin, vitexin, isovitexin, drymaricine	Antinociceptive (61.4% writhing inhibition); antipyretic; CNS depressant	0.64
Solanum torvum Sw.	Solanaceae	Cough, asthma, fever, liver disorders	Torvosides, solasonine, solamargine, quercetin	Bronchodilatory (comparable to aminophylline); anticancer; hepatoprotective	0.56
Morinda angustifolia Roxb.	Rubiaceae	Fever, diarrhoea, skin diseases	Damnacanthal, morindone, asperulosidic acid	Anticancer (IC_{50} = 0.04 µg/mL in Ras-transformed cells); antimicrobial	0.58
Mikania micrantha Kunth	Asteraceae	Wound healing, hemostasis	Mikanolide, scandenolide, quercetin, germacrene-D	Hemostatic (clotting time −53%); wound contraction 78.4% at day 16	0.52
Dillenia pentagyna Roxb.	Dilleniaceae	Fever, dysentery, tonic	Betulinic acid, ursolic acid, ellagitannins, myricetin	Anticancer (mitochondrial apoptosis); antibacterial; antidiarrhoeal	0.46
Sida rhombifolia L.	Malvaceae	Urinary, rheumatic, nerve disorders	Vasicine, vasicinol, cryptolepine, mucilaginous polysaccharides	Anti-inflammatory (COX-1/2); diuretic; neuromuscular activity	0.43
Callicarpa arborea Roxb.	Lamiaceae	Inflammation, skin diseases, infected wounds	Callicarpalignan, calliterpenone, luteolin, apigenin	Anti-inflammatory (carrageenan edema 62.4%); broad-spectrum antimicrobial	0.39
Vitex peduncularis Wall.	Lamiaceae	Fever, liver disorders, rheumatic pain	Aucubin, agnuside, casticin, vitexilactone	Hepatoprotective (aucubin); antitumor in HCC models (casticin)	0.34
Pterospermum acerifolium (L.) Willd.	Malvaceae	Inflammatory, blood disorders, skin diseases	Vitexin, orientin, proanthocyanidins, triterpenoids	Anti-inflammatory; antioxidant; wound-healing (preliminary)	0.31

ACA = 1′-acetoxychavicol acetate; FCI = frequency of citation index; GI = gastrointestinal;
HCC = hepatocellular carcinoma; RCT = randomised controlled trial; SHR = spontaneously hypertensive rats; T2DM = type 2 diabetes mellitus.

Angiotensin-converting enzyme (ACE) inhibitory activity aqueous leaf extracts show potent cardiovascular effects with an IC50 of 42.8 ug/mL, and oral administration of 400 mg/kg leaves a significant antihypertensive effect, lowering the mean arterial pressure of 186 o 82 0170 0142mmHg (p 0.001) [7]. Other mechanisms are endothelium-dependent vasodilation via the nitric oxide/cyclic GMP pathway and activation of large conductance calcium-activated potassium channel (BKCa) by activation [12]. These mechanistic results offer a solid scientific justification of the plant as the most widely acclaimed antihypertensive medicine of the traditional pharmacopoeia of Tripura.

Centella asiatica (L.) Urb. (Apiaceae)

Centella asiatica aka thankuni in Bangladesh, Manduk parni in Sanskrit, is one of the most commonly used medicinal herbs in the world and is well ingrained in the food and medicine of the entire Tripuri tribes (FCI = 0.88). The fresh entire plant is used as a leafy vegetable (saag) and made into a decoction to enhance memory, cure wounds, treat dermatological problems and stomach upsets. The triterpenoid saponins asiaticoside, madecassoside, asiatic acid and madecassic acid represent the main pharmacologically active proportion, which has well-characterized and clinically confirmed wound-healing capabilities (promotion of dermal collagen generation, fibroblast proliferation), neuroprotective (upregulation of

brain-derived neurotrophic factor, inhibition of amyloid-B aggregation), anti-inflammatory and antioxidant effects [13].

Alpinia nigra (Gaertn.) B. L. Burtt (Zingiberaceae)

The second most commonly mentioned medicinal is Alpinia nigra commonly known in the Tripuri language as Tora Ada and is a sturdy rhizomatous perennial herb that grows to 2-4 m in height and is, by far, the second-most frequently mentioned medicinal species in our survey (FCI = 0.84; UV = 2.84). The predominant phytochemical profile is phenylpropanoid, which is typified by 17-acetoxychavicol acetate (ACA) as the major bioactive compounds, and diarylheptanoid and flavonoid galangin, as well as essential oil represented by 16.8% of 2-pinene, 14.2 of 1,8-cineole, and 16 of 8-caryophyllene [14].

The antidiabetic properties via 1,6-glucosidase inhibition (IC50 = 148.6 1 exploited 1), hepatoprotective, and gastroprotective properties, as well as anticancer property with ACA recording an IC50 value of 4.842.18 g/mL in various cancer cell lines [6,15,16].

Justicia adhatoda L. (Acanthaceae)

Also called Justicia adhatoda in Bengali and as the equivalent in the tribal tongues, Basak (FCI = 0.79), Justicia adhatoda is one of the most widely used medicinal plants, with vasicol (quinazoline alkaloids), adhatonine and (5)- apigenin and luteolin the pharmacodynamically predominant phytoconstituents, used in all population groups surveyed in Tripura using adhatoda (FCI = 0.79) as a recognized folk term [5].

Oroxylum indicum (L.) Kurz (Bignoniaceae)

Indigenous name Oroxylum indicum Oroxylum indicum is a rare small to medium size deciduous tree (612 m) that is mentioned in the indigenous nomenclature of 72.4% of the surveyed healers (FCI = 0.72) in respiratory diseases (primarily bronchitis and asthma) and in rheumatism, diarrhoea and treatment of postinflammatory conditions. The most common types of medicinal preparations are the use of a bark decoction and the use of the young fruit as a vegetable and having anti-inflammatory effect [5,19].

Baicalein is a potent NF -, -blocker (IC50 = 8.4 -) and bronchodilator (guinea pig tracheal preparations) and chrysin is an anxiogenic (partial benzodiazepine receptor agonist) and anti-inflammatory (anticancer) agent.

Tinospora cordifolia (Willd.) Miers (Menispermaceae)

One of the pharmacologically complex species in this review, Tinospora cordifolia depicted as Guduchi or Gilioy according to Ayurvedic tradition and as Gulancha in the tribal populations of Tripura (FCI = 0.68), is a highly complex plant. The stem, which is used in the form of a water decoction or fresh juice, is used to treat fever, diabetes, urinary tract infection, and as a tonic to stimulate the immune system. The chemical details of phytochemical characterization indicate an extraordinary variety of classes of bioactive compounds: alkaloids (berberine, palmatine, magnoflorine, tembetarine, chanderoside), diterpenoid glycosides (tinosporaside, cordioside), polysaccharides (arabinogalactan), and sesquiterpene derivatives (tinosporon, tinosporic acid) [17].

Drymaria cordata (L.) Willd. ex-Schult. (Caryophyllaceae)

Drymaria cordata, termed 'Shatpati' or 'Chicken weed' in common parlance, is a delicate In common language, Drymaria cordata is also known as Shatpati or Chicken weed; it is a fine and tender annual herb that grows in thick mats in wet shady microhabitats and is mentioned in Tripura as an agent of headache treatment when used as a topical whole-plant poultice, as a topical nasal congestant, a topical cold-effect treatment, and as an expectorant (FCI = 0.64) [5].

Mikania micrantha Kunth (Asteraceae)

In a pharmacologically compelling paradox, Mikania micrantha regarded as one of the 100 most destructive invasive species globally and reportedly a danger to forest biodiversity in northeastern India - has become a constituent of MK of the ethnomedicinal practice of Tripuri and Jamatia healers, using the resulting crushed leaves as a topical hemostatic agent and a wound healer to a cut and a soft tissue injury (FCI = 0.52).

Dillenia pentagyna Roxb. (Dilleniaceae)

Native to Tripura, Dillenia pentagyna, also known as ' Harikol' or ' Karambel&#39> is a medium-sized, deciduous tree that is common all over the moist forests of Tripura and widely used because of its antibiotic and febrifuge properties (FCI = 0.46) by Chakma, Mog, and Tripuri people [4].

Solanum torvum Sw. (Solanaceae)

Solanum torvum (also known as T titled Begun Bengali and wild eggplant in English) is a ubiquitous semi-woody shrub, used as a culinary vegetable and in medicine to treat cough, asthma, and fever, as well as liver diseases in the communities of Tripura (FCI = 0.56). The most significant types of therapeutic forms are fruit decoctions and root preparations. The phytochemical composition includes steroidal saponin (torvosides, torvogenin), glycoalkaloid (solasonine, solamargine), flavonoid (quercetin, rutin, kaempferol) and chlorogenic acid [4].

Morinda angustifolia Roxb. (Rubiaceae)

Morinda angustifolia (Tripuri language Achthaichchi) is a marginally forest shrub or a small forest tree commonly found in TTAADC regions and used by Tripuri, Reang, and Jamatia to treat fever, diarrhoea and dermatologic diseases (FCI = 0.58). The main preparations are root and bark decoctions. Phytochemical studies have discovered anthraquinones (damnacanthal, morindone, rubiadin), iridoid glycosides (deacetylasperulosidic acid, asperulosidic acid), and triterpenes (ursolic acid, 2-sitosterol) [5].

Sida rhombifolia L. (Malvaceae)

Sida rhombifolia, which is referred to in Sanskrit as Bala and traditionally used in the communities of Tripura in treatment of urinary tract problems, rheumatic and musculoskeletal diseases, neurological dysfunctions and in Pharmacological studies that verify -anti-inflammatory, anti-bacterial, diuretic, and neuromuscular effects are all in line with the accepted pattern of traditional treatment indication.

Callicarpa arborea Roxb. (Lamiaceae)

Callicarpa arborea known as 'Bormala' in Tripuri language, is a big shrub or small tree of the secondary forests which is used by the Tripuri and Reang healer in treating inflammatory conditions, skin diseases, fever, and wound management with infections (FCI = 0.39). Phytochemical investigations have described phenylnaphthalene lignans (callicarpalignan), pentacyclic diterpenoids (calliterpenone), flavonoid (luteolin, apigenin, eupafolin), and essential oils [5].

Vitex peduncularis Wall. Ex schauer (Lamiaceae)

Vitex peduncularis, which is also referred to as 'Aani' in the Tripuri language, is also a massive oak-like tree that is native to the wet forest areas of the forest humorously utilized in the treatment of fever, liver disorders and pain (FCI = 0.34). Invar Kamprad has used the therapeutic use of Bark and leaf preparations [5].

Pterospermum acerifolium (L.) Wild. (Malvaceae)

Pterospermum acerifolium, or Mucukunda of Bayur, is a big, deciduous tree in the moist forests of Tripura used by traditional healers to treat inflammatory diseases, blood disorders, and skin ills (FCI = 0.31). The major formulations include flower and bark decoceptions. Phytochemical studies have found flavonoid C-glycosides (vitexin, orientin), proanthocyanidins, and triterpenoids.

Cross-cutting phytochemical and pharmacological themes
dominant bioactive compound classes

The systematic examination of the fifteen studied species shows that there are certain common phytochemical themes typical of medicinal flora in Tripura. Terpenoids, triterpenes (oleanolic acid, ursolic acid, betulinic acid, lupeol) and diterpenes (calliterpenone, vitexilactone) are present in several families of plants and are always linked with anti-inflammatory, anticancer, hepatoprotective, and antimicrobial effects.

Alkaloids: J. adhatoda have quinazoline types, - has quinoline types, and Solanum has steroidal glycoalkaloids; Zingiberaceae of Tripura has protoberberine alkaloids. Iridoid glycosides such as those found in Morinda, Vitex, Tinospora, and Centella, are also another structural theme that is associated with hepatoprotective, anti-inflammatory, and neuroprotective effects directly related to the most common ethnomedicinal therapeutic categories.

Ethnomedicinal consensus and pharmacological validation

Assessment of correlation between ethnomedicinal consensuses by the quantified FCI and ICF and strength of pharmacological evidence demonstrates a positive but with flaws correlative relationship among the surveyed species. Plants with the highest FCI scores—Clerodendrum colebrookianum (FCI = 0.91), Centella asiatica (FCI = 0.88), Alpinia nigra (FCI = 0.84), and Justicia adhatoda (FCI = 0.79)—possess the most extensive pharmacological literature and the strongest experimental evidence, consistent with the ethnomedical principle that high informant consensus is positively predictive of pharmacological activity [11,18].

Therapeutic category distribution

An informant consensus factor analysis of the totality of known therapeutic uses indicates the greatest inter-informant agreement: febrile illnesses and how they are managed (ICF = 0.82), gastrointestinal disorders (ICF = 0.79), dermatological conditions and wound management (ICF = 0.76), rheumatic and inflammatory pain states (ICF = 0.74), and respiratory diseases (ICF = 0.71). These five treatment areas each offered by various plant species in various formulations are the main foci of serious pharmacological research not only owing to community health applicability but also due to good ethnomedicinal consensus endorsement. Multi-purposeness, shown by the widespread use of multi-functional plants employed in many of these categories, including notably Clerodendrum colebrookianum, Alpinia nigra and Centella asiatica, highlights the multi-target pharmacological nature of the most commonly used medicinal plants at Tripura [18].

Conservation status and sustainable utilization challenges

A variety of endangered species discussed here have conservation concerns that should be taken seriously. In the Indian Red Data Book, Oroxylum indicum is categorised as 'Vulnerable' and in Schedule VI of the Biological Diversity Act (2002) as needing special conservation protection, due to the harvesting of bark and roots to commercial Ayurvedic production and the loss of forest habitats in countries of use [5].

The medicinal plant resources of Tripura in community biodiversity registers, people biodiversity registers as well as traditional knowledge digital libraries under the supervision of Tripura State Biodiversity Board constitute a critical parallel priority of any serious pharmacological study using the resources [4,19].

Research gaps and future directions

The most promising research investments to fill this translational gap are systematic evaluation of the research space across the surveyed species with known cases of antihypertensive uses of Clerodendrum colebrookianum, wound healing acceleration by Mikania micrantha, and antidiabetic management with Tinospora cordifolia in Tripuris' populations- used in the highest priority.

Most of the reviewed species have not been systematically and thoroughly addressed with regard to phytochemical standardization, which is the key to reproducible pharmacological studies and future regulatory development. The most effective and comprehensive route to creation of chemical quality fingerprints that explain the geographic, seasonal and collection-condition variability of northeastern Indian plant material consists in the deployment of metabolomics-based methods where untargeted profiling is used to develop methods based on LC-HRMS and NMR [19].

DISCUSSION

The surveyed medicinal flora of Tripura is already a pharmacologically diverse, ethnomedically confirmed, and fifteen reviewed species are a scientifically heterogeneous group with plants with strong clinical evidence (Centella asiatica, Justicia adhatoda) to those with well-characterised lead compounds to be no more than glimpsed by clinical evidence (Morinda angustifolia, Callicarpa arborea, Drymaria cordata). This heterogeneity is by way of unequal scientific interest and not disparity within intrinsic pharmacological potential.

The mutual demands of scientific research and conservation mean that the two cannot be divided in any research programme about medicinal plants of Tripura, which offers both legal and institutional frameworks of ethically-based pharmacological studies which indeed should be at hand at the very onset of any serious research project.

CONCLUSION

The ethnomedicine of Tripura and its medicinal plants embedded within the ethnomedicinal tradition of nineteen indigenous peoples and with strong botanical diversity, is an important but underused source of pharmacology.

The key to accessing this potential is to deploy a long-term, cross-disciplinary strategy, including ethnobotanical record-keeping efforts, phytochemical research based on metabolomics or other analytical methods, mechanistic pharmacology, safety analysis and clinical verification. These actions need to be executed in an ethical manner in collaboration with native communities and in accordance with the Nagoya Protocol as well. This integrated approach has the potential to encourage drug discovery and primary healthcare, support knowledge maintenance of indigenous communities, and conservation of biodiversity, based on a solid argument that research agencies, industry, and international conservation agencies should invest in the strategy.

Conflict of interest

The authors do not report any conflict of interest.

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