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Forest ecosystem services and local communities neighboring Biha Resort in Bukit Barisan Selatan National Park, Southern Sumatra, Indonesia

ANGGI MARDIYANTO[1,2,♥], RIYANTO[3], CORINTHIAS P. M. SIANIPAR[1,4], SHOZO SHIBATA[1,4]

[1]Graduate School of Global Environmental Studies, Kyoto University. Kyoto 606-8501, Japan. Tel./fax.: +81-75-753-5932/9167, [♥]email: anggimardiyanto@gmail.com

[2]Department of Landscape Architecture, Institut Teknologi Sumatera. Jl. Terusan Ryacudu, Lampung Selatan 35365, Lampung, Indonesia

[3]Bukit Barisan Selatan National Park. Jl. Ir. H. Juanda No. 19, Terbaya, Tanggamus 35384, Lampung, Indonesia

[4]Graduate School of Agriculture (GSA), Kyoto University. Kyoto 606-8502, Japan

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Abstract. *Mardiyanto A, Riyanto, Sianipar CPM, Shibata S. 2024. Forest ecosystem services and local communities neighboring Biha Resort in Bukit Barisan Selatan National Park, Southern Sumatra, Indonesia. Asian J For 8: 18-30.* The Biha Resort in Bukit Barisan Selatan National Park, Indonesia, provides essential resources for biodiversity conservation and local livelihoods. However, spatial borders between surrounding villages and the resort are improperly mapped, resulting in border disputes and unmonitored exploitation of forest ecosystem services. In this study, spatial mapping of villages home to forest local communities in the resort's buffer area was conducted via face-to-face interviews with key informants and Geographic Information System (GIS) analysis. Focus Group Discussions (FGDs) with several key informants were conducted to clarify the type and locations of forest ecosystem services utilized by the local community and related harvesting schedules, and the results were analyzed thematically. The study found that local communities were distributed among eight villages, with national park land, protected forest land, limited-production forest land and customary forest land providing ecosystem resources. Villagers reported usage for water, food, pets, construction materials, fuel, medicine, raw commercial materials and other items. These services fulfill basic needs and provide a crucial source of income, underlining their critical role in sustaining rural livelihoods. The study highlights interaction between people and diverse forest ecosystems, each with unique ecological characteristics and resource offerings, and consequentially, presents distinct implications for local-community livelihood strategies. The results are expected to support forest management toward a win-win balance between conservation and local-community wellbeing.

Keywords: Biodiversity conservation, customary forests, forest ecosystem services, forest management, rural region

INTRODUCTION

In previous work, Chao (2012) estimated that over 300 million people reside within forest ecosystems globally. In this sense, forests can be seen as social-ecological systems in which people maintain deep connections to their surroundings. Local communities thus share a long-standing symbiotic relationship with the forests where they live, representing a rich ground for research in the field. However, boundary disputes are a key issue in such communities, often leading to local frictions and conflicts. Riggs et al. (2016) and Hettiarachchi et al. (2022) suggested that such disputes are often fueled by the absence of distinct or clear land boundaries; conflicts can intensify due to differing viewpoints, adding another layer of complexity. These disputes, particularly when escalated to actual conflict level, can pose substantial challenges to local governments and authorities in formulating effective policies for natural resource conservation. Such disputes are also barriers to sustainable natural resource management and, more broadly, to socio-economic sustainability in forest local communities (van der Muur 2018). Thus, mapping of clear boundaries for forest areas and communities is critical within the larger efforts of sustainable forest management.

Understanding the precise location of forest local communities and the sources of the services they rely on is necessary for research on forest ecosystem services. Spatial mapping is a vital requirement for this, along with a thorough investigation of interactions between forests and communities and the functions provided by forest ecosystems (Palomo et al. 2013; Paudyal et al. 2015; Damastuti and de Groot 2019). The use of baseline mapping of residential locations and interactions with ecosystem services allows policymakers, researchers, and other stakeholders to have a more precise and complete knowledge of the causes of disputes. This would enable the formulation of conservation plans, particularly for national parks, aimed at striking a delicate balance between biodiversity preservation and the sustainability of local forest populations' livelihoods (Brown and Fagerholm 2015).

Buffer areas around national parks play a pivotal role in preserving internal integrity by providing a barrier between human activity and protected areas (Lynagh and Urich 2002), and such areas are home to communities that rely heavily on park ecosystem services for their livelihoods (Amacher et al. 1998). In Indonesia, Bukit Barisan Selatan

National Park (BBSNP) provides a good example of efforts toward balance between nature conservation and provision of ecosystem services for local communities in buffer areas (Bukit Barisan Selatan National Park Bureau 2019). Within the global conservation movement, BBSNP provides natural habitats for the Sumatran tiger (IUCN 2008), the Sumatran elephant (IUCN 2011) and the Sumatran rhino (IUCN 2020g). Among 17 resorts (sections) across the park, Biha Resort is the most critical habitat for these animals (Arimbi et al. 2021). Local communities neighboring the resort rely on forest ecosystem services for their own consumption and livelihoods in line with needs and culture. However, boundary disputes in the resort remain a problem for both BBSNP and neighboring local communities. In practice, the success of national park management is contingent upon consideration for the livelihoods of local communities, as related efforts form an integral part of holistic conservation work. Given the intimate community understanding of the local ecosystem and individuals' intensive interactions with the park, community members are potential key stakeholders in conservation efforts. Accordingly, they should ideally be involved in the mapping of forest/community boundaries to support forest governance efforts and conflict resolution.

This study was conducted toward inclusive mapping of forest/community and inter-community boundaries in the buffer area of Biha Resort. In addition to usage of satellite imagery, the involvement of local communities neighboring the resort is an essential part of mapping in the field. The authors attempted to determine the utilization of forest ecosystem services by local communities in the resort and surrounding forests with focus on the following research questions (RQs): (i) RQ1: How local communities living neighboring Biha Resort are mapped? (ii) RQ2: What kind of forest ecosystem services utilized by local communities? (iii) RQ3: When and where do communities take or use forest ecosystem services?

MATERIALS AND METHODS

Research design

The study employed a qualitative methodology in three stages (Figure 1). The approach included a preliminary study, sampling and data collection and data analysis. The procedures to respond to the first research question included selecting a case study and key informants, collection of maps, map processing and spatial mapping. Literature reviews and interviews with BBSNP, Indonesia, staff were conducted to select case studies. The key informants (eight local village leaders, one district-level forest management unit representative and two resort managers) were chosen via interviews with BBSNP staff with focus on background diversity to optimize the information gathered (Chaigneau et al. 2019). Maps were collected to illustrate general site situations and clarify the location of local communities neighboring Biha Resort. The mapping approach has been widely used in ecosystem service studies, such as those conducted by Hauck et al. (2013) on the potential benefits and challenges of ecosystem service map production for different levels of decision-making in Germany, Finland, the UK and Poland. Willemen et al. (2013) also highlighted the need for spatial methods to assess ecosystem service trade-offs in the Democratic Republic of Congo. Mapping pre-processing was also carried out to validate and ensure that all maps collected were appropriate for spatial map production. The Geographic Information System (GIS) was used for spatial mapping.

The second and third research questions were answered via questionnaire content and related Focus Group Discussions (FGDs) with key informants. This is a common technique used in qualitative research, especially in evaluation studies (Kaplowitz and Hoehn 2001), with mutual complementing of information and participant data (Doyle et al. 2020). However, caution was applied in relation to the potential for dominant participants to influence others in conveying their own ideas. FGDs are often used in studies related to evaluation of forest ecosystem services (e.g., Cuni-Sanchez et al. (2019) for the Democratic Republic of Congo, Iqbal (2020) for Sundarbans mangrove forest areas in Bangladesh, Chaigneau et al. (2019) for coastal Kenya and Mozambique, and van Oort et al. (2015) for the Koshi river basin in Nepal). FGDs were conducted to clarify the type, locations and collecting time of forest ecosystem services by local communities, with resulting data subjected to thematic analysis.

Study area

Biha Resort plays a vital role in BBSNP conservation efforts, with an area of 19,874.41 ha between 5°10' to 5°24' south latitude and 104°2' to 104°14' east longitude (Figure 2). It is part of Pesisir Barat District, around a six-hour drive from Bandar Lampung (the capital of Lampung) via the *Lintas Barat* road or seven hours via the *Lintas Timur* road.Biha Resort area is covered by a core zone (73%), wilderness zone (22%), rehabilitation zone (3%) and traditional zone (2%). This formation demonstrates how the ecosystem (especially in the core zone) remains natural and ideal as a crucial habitat for the Sumatran tiger, the Sumatran elephant and the Sumatran rhino, whose presence is much higher than in other resorts (Arimbi et al. 2021).

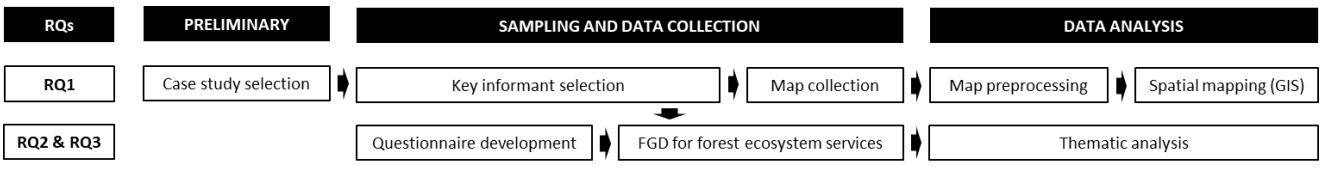

Figure 1. Research design

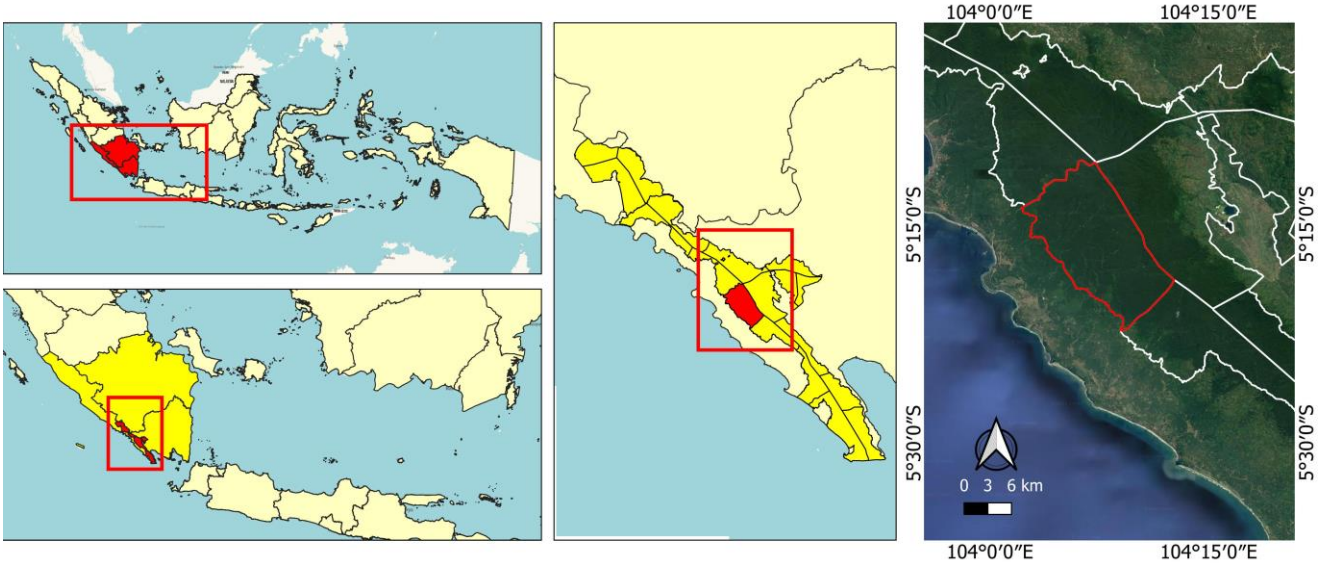

Figure 2. Biha Resort and the surrounding area in Bukit Barisan Selatan National Park, Southern Sumatra, Indonesia

Several villages have communities that interact with forest areas around Biha Resort and use BBSNP for their livelihoods (Arimbi et al. 2021). The map layout in Figure 2 is based on: (i) Land cover data from Sentinel 2 satellite imagery captured on 11 July 2021 (from the USGS website: https://earthexplorer.usgs.gov/) with a kappa accuracy of 77%, (ii) Biha Resort map data from the BBSNP bureau.

Data collection and analysis

Data were collected from May to July 2022, with spatial mapping based on interviews with key informants assumed to be knowledgeable about each site and to have diverse backgrounds to enrich basic information (Sandelowski 2000; Kim et al. 2016). First, BBSNP managers were interviewed regarding villages neighboring Biha Resort, and several studies conducted by BBSNP managers were reviewed. Second, the authors visited and interviewed leaders of adjacent villages to clarify their areas. Third, a representative of the local district-level forest management unit (KPH) of Pesisir Barat was interviewed to clarify Biha Resort buffer areas. Information on the locations of villages, the Biha Resort area, buffer areas and customary forests was obtained to enable mapping forest local community's location in BBSNP's borders.

All base maps were organized into village, BBSNP, Biha Resort, buffer area and approximate customary forest types. Village maps were obtained from *Badan Informasi Geospasial* (BIG), or the Indonesia Geospatial Agency. Buffer area maps were obtained from *Balai Pemantapan Kawasan Hutan* (BPKH), or the Forest Area Consolidation Agency Region XX Bandar Lampung, BBSNP maps and Biha Resort maps were obtained from the BBSNP bureau, and approximate customary forest maps were determined from Sentinel 2 satellite imagery captured on 26 July 2021 and validated by key informants. The information was delineated using ArcGIS 2.7.0 software and overlaid to map the forest local community location and surrounding areas. Identification of customary forests via satellite imagery can be problematic due to tree density, but classification showed moderately dense forest outside the legal boundaries of BBSNP, protected forests and limited production forests.

The questionnaire (asking 1. What items were used or taken by the village community from forest areas, 2. Where and when they were used or taken) was formulated to support FGDs, with key informants clarifying forest ecosystem services utilized by the local communities. Hong and Saizen (2019) used similar techniques to estimate the utilization of forest ecosystem services in Vietnam's Bach Ma National Park forest community. The first question related to current and past utilization of forest ecosystem services. Multiple choices (BBSNP, protected forests, limited production forests and customary forests) to answer the location of forest ecosystem services and questions related to the harvesting calendar in monthly aggregates were provided for the second question.

FGDs were conducted via online Zoom meetings due to the Covid-19 pandemic, as well as to reduce the cost of data collection and provide increased flexibility as compared to face-to-face interviews (Doyle et al. 2020). Data from the discussions were subjected to Thematic Analysis (TA), which is commonly used in qualitative studies to identify, arrange and analyze information (Braun and Clarke 2006). The questions were posed to all group members, with the ability for free-form answers. The responses were reviewed, and clarification was sought where necessary.

Transcripts from the FGDs were sorted by theme, including ecosystem service types, resource types (scientific, common and family), life forms, elements used, usage purpose, collection sites, and the harvesting calendar for monthly aggregates. Animal forest resources were grouped into wild aquatic and wild land types, and plants were classified as wild, semi-wild, semi-cultivated and

cultivated, with elaborated definitions of how plants grow and their environments. A difference between cultivated and naturally growing plants was made, although this was sometimes unclear due to the characteristics of growth sites. Wild plants grew wild in natural environments without human intervention; semi-wild plants grew naturally in environments that had some level of human intervention; semi-cultivated plants grew in cultivated environments with minimized human intervention, and cultivated plants grew in environments with human intervention and intensive maintenance.

RESULTS AND DISCUSSION

Spatial mapping of local communities neighboring Biha Resort

Spatial mapping shows local communities distributed among eight villages (Sukarame, Pelita Jaya, Sumur Jaya, Tanjung Setia, Paku Negara, Tanjung Raya, Marang and Ulok Mukti (Figure 3)) using: (i) the state-managed Bukit Barisan Selatan National Park (*Taman Nasional Bukit Barisan Selatan*; a protected forest variety); (ii) protected forests controlled by *Kesatuan Pengelolaan Hutan* (KPH), or the district-level forest management unit of Pesisir Barat (*Hutan Lindung*; a protected forest variety); (iii) limited-production forests managed by the KPH of Pesisir Barat (*Hutan Produksi Terbatas* (HPT)), and (iv) community-managed customary forests (*Hutan Marga* or *Repong Damar)*.

Customary forest areas are located on *Tanah Marga* land – a local term referring to areas long controlled and managed by community groups. *Repong Damar* also accommodates traditional agroforestry practices dominated by dammar trees (*Shorea javanica*) in customary forests along with fruit, vegetable and medicinal plant growth. Communities use land in limited production forest areas for agroforestry, agriculture (horticulture and staple-food growth) and plantations (e.g., for fruit, palm oil, coconuts and rubber), while land in protected forests is used to grow fruit. These activities are permitted under an agreement between farmers and the authority of *Kesatuan Pengelolaan Hutan* (KPH) – the regency level-forest management unit of Pesisir Barat – in designated areas. In the Biha Resort Area, the community is allowed to collect non-timber forest products (e.g., resin from dammar species, *S. javanica* and durian, langsat, bitter bean and *jengkol* fruit) under a similar agreement with the BBSNP authority in traditional zones. Collection of forest resources and use of BBSNP areas outside the scope of the agreement are illegal.

Three villages (Sumur Jaya, Paku Negara and Ulok Mukti) covered four types of forest, four villages (Sukarame, Pelita Jaya, Tanjung Raya and Marang) covered three types, and one (Tanjung Setia) covered two types. The Biha Resort buffer area consisted of protected forests and a larger area of limited-production forests, as seen in all villages. Protected forests were found only in Sumur Jaya, Paku Negara and Ulok Mukti, while customary forests were seen outside the resort and its buffer area. These were close to community settlements in all villages. There were several ethnic groups in all villages (Lampung, Java, Bali, and other groups from Sumatra), with many long-term migrant residents. There are still differences in perception among local leaders regarding village boundaries and divisions between villages and forests due unclear demarcations.

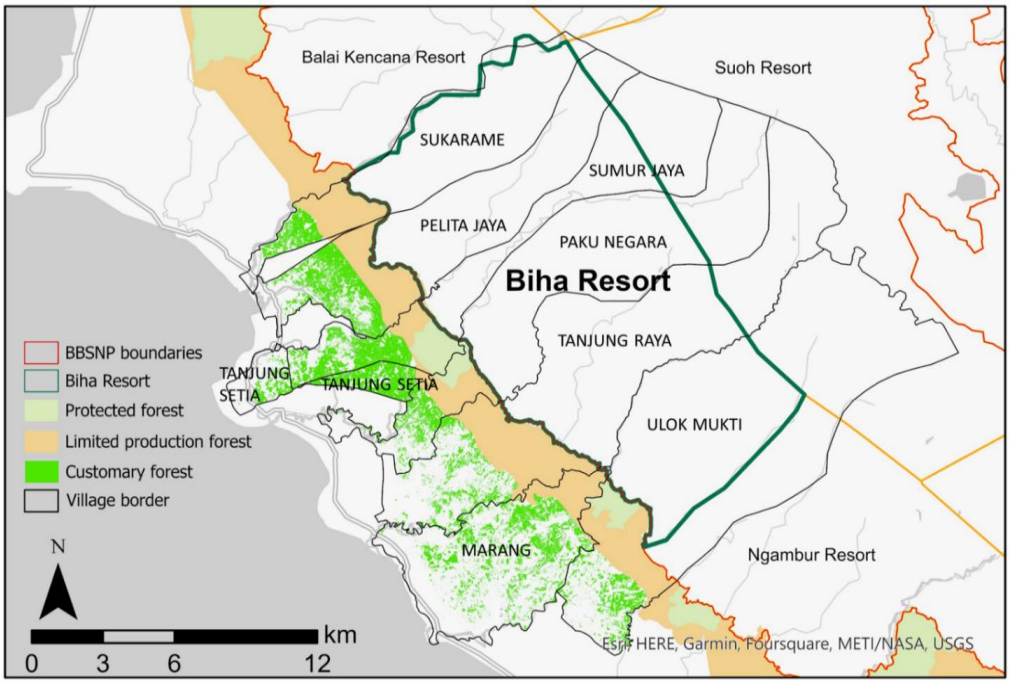

Figure 3. Local communities neighboring Biha Resort in Bukit Barisan Selatan National Park, Southern Sumatra, Indonesia

Table 1. Local river/spring usage

Name		Usage	Sites* and Collectors**			
Common	Local		BBSNP	PF	LPF	CF
Basohan River	Way Basohan	Transportation, sanitation	2, 3	3	2, 3	2, 3
Biha River	Way Biha	Irrigation, transportation, sanitation	5, 6, 8		5, 6, 8	5, 6, 8
Tenumbang River	Way Tenumbang	Transportation, sanitation	1, 2		1, 2	1, 2
Marang River	Way Marang	Transportation, sanitation	7	7	7	7
Ngambur River	Way Ngambur	Irrigation, transportation, sanitation	8		8	8
Way Curug Spring	Mata Air Way Curug	Drinking water			5	

Note: * BBSNP: Bukit Barisan Selatan National Park; PF: protected forests; lpf: limited production forests; cf: customary forests, ** 1: Sukarame; 2: Pelita Jaya; 3: Sumur Jaya; 4: Tanjung Setia; 5: Paku Negara; 6: Tanjung Raya; 7: Marang; 8: Ulok Mukti

Forest ecosystem services

The results from FGDs on forest ecosystem services utilized by the community cover water resources, food, pets, construction materials, fuel, medicine, raw commercial materials and other matter (Table 2). Table 1 shows water resources used by villagers, who also utilized ecosystem services in customary, limited-production, protected and BBSNP forests. Villagers in Sukarame, Pelita Jaya, Tanjung Setia, Paku Negara, Tanjung Raya, Ulok Mukti Sumur Jaya and Marang utilized resources from these four forest types as detailed below.

Water resources

The *Tenumbang*, *Basohan*, *Biha*, *Marang* and *Ngambur* rivers are utilized primarily for sanitation, drinking water and flow through local forests. Locals also use the *Way Curug* spring for drinking water (Table 1). They also used local rivers to collect stones and wooden boat transportation.

Food

Ecosystem services are utilized by villagers in the form of food derived from animals and plants. These are harvested on a monthly basis or as needed. Harvests include fruit (*Artocarpus heterophyllus*, *Artocarpus integer*, *Carica papaya*, *Cocos nucifera*, *Durio oxleyanus*, *Durio zibethinus*, *Garcinia mangostana*, *Lansium parasiticum*, *Mangifera indica*, *Musa paradisiaca*, *Nephelium lappaceum*, *Persea americana*, *Psidium guajava*, *Syzygium queum*), vegetables (*Archidendron bubalinum*, *Archidendron pauciflorum*, *Capsicum annum*, *Capsicum annum* var. annuum, *Capsicum frutescens*, *Gnetum gnemon*, *Parkia speciosa*) and content for drinks such as coffee (*Coffea canephora*) in June and July. The harvest calendar for other fruits is presented in Table 3. Flowering plants are used for vegetable content (*Alpinia galangal*, *C. papaya*, *G. gnemon*, *Musa acuminata*, and *M. paradisiaca*) and spices (*Syzygium aromaticum*), with most available year-round except *G. gnemon* (July) and *S. aromaticum* (May).

Several bamboo species provide year-round vegetable content, such as *Dendrocalamus asper* and *Gigantochloa robusta*. Villagers used stems from the perennial *Saccharum officinarum* for beverages, and numerous leafy vegetables were provided by *C. papaya*, *Diplazium esculentum*, *Manihot esculenta* and *Sauropus androgynus*. Leaves were also used year-round for food coloring (*Pandanus amaryllifolius*), spice (*Syzygium polyanthum*) and wrapping (*M. acuminata* and *M. paradisiaca*). Rhizomes from *A. galanga*, *Curcuma longa*, *Kaempferia galanga*, and *Zingiber officinale* were also consumed.

Pet

Villagers leveraged wild birds as pets and for income. Hunting is illegal in the BBSNP area, protected forests and limited-production forests, with birds protected under the regulation of the Minister of Environment and Forestry of the Republic of Indonesia No. P.92/MENLHK/SETJEN/KUM.1/8/2018 (the great hornbill, the rhinoceros hornbill, the helmeted hornbill, the Javan leafbird and the lesser green leafbird, which are on the IUCN red list of threatened species (IUCN 2020a,b,c,d). Bird hunting was found to be only occasional in the survey.

Construction materials and fuel

Timber from various tree species and bamboo were used to construct houses. Villagers harvested them as needed. Villagers collected fallen leaves, branches, twigs and tree trunks for fuel on a year-round basis. These come from a variety of species and were used for cooking.

Medicine and raw commercial materials

Villagers used various animals and plants for medicinal resources. The Sumatran serow (IUCN 2020e) and the Sunda pangolin (IUCN 2019b) are on the IUCN Red List of threatened species. Wild animals were also occasionally hunted for medicinal purposes. Plant-based medicine comes from plant resources such as rhizomes, roots and leaves perennially, with occasional harvesting. Villagers use various forest resources for sale and as perennial commercial raw materials to get cash. These materials are available every month.

Fodder and other materials

Fodder comes from the several leaves. They were available perennially, with occasional collection. Other forest materials were used for decorations, bird traps, dammar resin harvesting, textile dyes, kitchen utensils and traditional ceremonies. Horns from sambar deer (*Cervus unicolor*), southern red muntjacs (*Muntiacus muntjak*) and Sumatran serows (*Capricornis sumatraensis*) and ivory from Sumatran elephants (*Elephas maximus sumatranus*) were used decoratively, with occasional hunting.

Table 2. Animal and plant resources collected by villagers in Biha Resort, Bukit Barisan Selatan National Park, Southern Sumatra, Indonesia

Scientific Name*	Common Name	Local Name	Family	Lifeform	Element	Usage	Ecosystem Service	Collection Site**
Wild aquatic animals								
Achatina fulica	Giant African land snail	*Sioh, siput*	Achatinidae	Snail	Meat	Protein, income	Food	1, 2, 3, 4
Anguilla spp.	Freshwater eel	*Ikan sidat, pelus, lindung*	Anguillidae	Fish	All	Protein, income	Food	1, 2, 3, 4
Metapenaeus ensis	Greasyback shrimp, Sand shrimp	*Udang batu, urang napal*	Penaeidae	Shrimp	All	Protein	Food	1, 2, 3, 4
Oreochromis mossambicus [VU]	Oreochromine cichlid	*Ikan mujair*	Cichlidae	Fish	All	Protein, income	Food	1, 2, 3, 4
Osteochilus vittatus	Bonylip barb, hard-lipped barb, silver shark minnow	*Ikan palau, nilam*	Cyprinidae	Fish	All	Protein, income	Food	1, 2, 3, 4
Sicyopterus cynocephalus, Sicyopterus micrurus	Cleft-lipped goby	*Ikan lekok*	Gobiidae	Fish	All	Protein, income	Food	1, 2, 3, 4
Tor duoronensis	Ray-finned fish	*Ikan siran*	Cyprinidae	Fish	All	Protein, income	Food	1, 2, 3, 4
Wild terrestrial animals								
Aethopyga temminckii	Temminck's sunbird	*Kolibri*	Nectariniidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Apis dorsata	Giant honeybee	*Lebah madu hutan*	Apidae	Insect	Honey	Food supplement	Food	1, 2, 3, 4
Buceros bicornis [VU]	Great hornbill	*Enggang papan*	Bucerotidae	Bird	All	Pets, income	Pets	1
Buceros rhinoceros [VU]	Rhinoceros hornbill	*Enggang cula*	Bucerotidae	Bird	All	Pets, income	Pets	1
Capricornis sumatraensis [VU]	Sumatran serow, mainland serow	*Kambing hutan*	Bovidae	Mammal	Meat, horns	Protein, traditional medicine, income, decoration	Food, medicine, other materials	1, 2
Cervus unicolor [VU]	Sambar deer	*Rusa sambar*	Cervidae	Mammal	Meat	Protein, income, decoration	Food, other materials	1, 2, 3, 4
Chloropsis cochinchinensis [EN]	Javan Leafbird	*Cucak ranting*	Chloropseidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Chloropsis cyanopogon [NT]	Lesser green leafbird	*Cucak daun*	Chloropseidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Chloropsis sonnerati [EN]	Greater green leafbird	*Cucak hijau*	Chloropseidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Cisticola juncidis	Zitting cisticola	*Ciblek*	Cisticolidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Copsychus malabaricus	White-rumped shama	*Murai batu*	Muscicapidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Copsychus saularis	Oriental magpie-robin	*Kacer*	Muscicapidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Elephas maximus sumatranus [EN]	Sumatran elephant	*Gajah sumatera*	Elephantidae	Mammal	Ivory	Decoration, income	Other materials	1
Enicurus leschenaulti, Enicurus velatus	White-crowned forktail, Sunda forktail	*Meninting air*	Muscicapidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Geopelia striata	Zebra dove	*Perkutut*	Columbidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Hystrix brachyura	Malayan porcupine	*Landak*	Hystricidae	Mammal	Intestines	Traditional medicine, income	Medicine	1, 2, 3, 4
Leptocoma sperata	Purple-throated sunbird	*Konin*	Nectariniidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Manis javanica [CR]	Sunda pangolin	*Trenggiling*	Manidae	Mammal	Meat, scales	Protein, traditional medicine, income	Food, medicine	1, 2, 3, 4
Muntiacus muntjak	Southern red muntjac	*Kijang*	Cervidae	Mammal	Meat	Protein, income, decoration	Food, other materials	1, 2, 3, 4

Platylophus galericulatus [NT]	Crested jay	*Cililin, cucak jambul*	Platylophidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Prinia familiaris [NT]	Bar-winged prinia	*Perenjak*	Cisticolidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Pycnonotus aurigaster	Sooty-headed bulbul	*Kutilang*	Pycnonotidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Pycnonotus goiavier	Yellow-vented bulbul	*Crocokan, cerukcuk*	Pycnonotidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Pycnonotus melanicterus	Black-capped bulbul	*Cucak kuning, kutilang emas*	Pycnonotidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Pycnonotus plumosus	Olive-winged bulbul	*Kapas tembak*	Pycnonotidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Rhinoplax vigil [CR]	Helmeted hornbill	*Rangkong gading*	Bucerotidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Spilopelia chinensis	Eastern spotted dove	*Tekukur*	Columbidae	Bird	All	Pets, income	Pets	1, 2, 3, 4
Sus scrofa	Wild boar	*Babi hutan*	Suidae	Mammal	Meat	Protein, income	Food	1, 2, 3, 4
Tragulus napu	Greater oriental chevrotain	*Napuh pelanduk*	Tragulidae	Mammal	Meat	Protein, income	Food	1, 2, 3, 4
Trigona apicalis	Stingless bee	*Lebah madu klanceng*	Apidae	Insect	Honey	Food supplements	Food	1, 2, 3, 4
Plants								
Albizia chinensis	Chinese albizia	*Sengon merah*	Fabaceae	Tree	Trunks, leaves	Roofs, doors, fodder	Construction materials, fodder	4 [sc]
Aleurites moluccanus	Candlenut	*Kemiri*	Euphorbiaceae	Tree	Fruit	Income, spices	Food	3 [sc], 4 [sc]
Alpinia galanga	Greater galangal	*Lengkuas*	Zingiberaceae	Herb	Flowers, rhizomes	Vegetables, spices, income	Food	1 [sw], 2 [sw], 3 [sc], 4 [sc]
Alstonia scholaris	Blackboard tree	*Pulai*	Apocynaceae	Tree	Trunks, leaves	Domestic construction, fodder	Construction materials, fodder	4 [sc]
Amomum compactum	Java cardamom	*Kapu laga*	Zingiberaceae	Herb	Rhizomes	Traditional medicine, income	Medicine	3 [sc], 4 [sc]
Aquilaria malaccensis [CR]	Agarwood	*Gaharu*	Thymelaeceae	Tree	Bark, trunks, branches, twigs	Cosmetics, income	Raw commercial materials, fuel	1 [sw], 2 [sw], 3 [sc], 4 [sc]
Archidendron bubalinum	Kerdas	*Kuau*	Fabaceae	Tree	Fruit, branches, twigs	Vegetables, income, firewood	Food, fuel	1 [sw], 2 [sw], 3 [sw], 4 [sw]
Archidendron pauciflorum	Djengkol	*Jengkol*	Fabaceae	Tree	Fruit, branches, twigs	Vegetables, income, firewood	Food, fuel	1 [sc], 2 [sc], 3 [sc], 4 [sc]
Areca catechu	Betel palm	*Pinang*	Arecaceae	Tree	Fruit, leaves	Traditional medicine, income, firewood	Medicine, fuel	1 [sc], 2 [sc], 3 [sc], 4 [sc]
Artocarpus elasticus	Terap	*Bendo, kerbang*	Moraceae	Tree	Trunks, sap	Domestic construction, bird traps	Construction/other	4 [sc]
Artocarpus heterophyllus	Jackfruit	*Nangka*	Moraceae	Tree	Fruit, branches, twigs, leaves	Fruit, vegetables, firewood	Food, fuel, fodder	3 [sc], 4 [sc]
Artocarpus integer	Cempedak	*Cempedak*	Moraceae	Tree	Fruit, branches, twigs	Fruit, income, firewood	Food, fuel	1 [sc], 2 [sc], 3 [sc], 4 [sc]
Bambusa arundinacea	Bamboo	*Bambu ori*	Poaceae	Tree	Stems	Roofs, livestock/bird cages	Construction	3 [sw], 4 [sw]
Calamus sp.	Rattan	*Rotan*	Arecaceae	Tree	Stems, fruit	Resin harvesting tools, textile dyes	Other	1 [sw], 2 [sw], 3 [sw]
Canna edulis	Edible canna	*Ganyong*	Cannaceae	Herb	Tubers	Side dishes, income	Food	3 [c], 4 [c]

Capsicum annum	Sweet chilli pepper	*Cabai merah*	Solanaceae	Tree	Fruit	Vegetable	Food	3 [c], 4 [c]
Capsicum annum var. annuum	Green chilli pepper	*Cabai hijau*	Solanaceae	Tree	Fruit	Vegetable	Food	3 [c], 4 [c]
Capsicum frutescens	Tabasco pepper	*Cabai rawit*	Solanaceae	Tree	Fruit	Vegetable	Food	3 [c], 4 [c]
Carica papaya	Papaya	*Pepaya*	Caricaceae	Tree	Fruit, leaves, flowers	Fruit, income, vegetables	Food	3 [sc], 4 [sc]
Cocos nucifera	Coconut	*Kelapa*	Arecaceae	Tree	Fruit, leaves	Fruit, food commerce, income	Food, raw commercial materials, fuel	4 [sc]
Coffea canephora	Coffee	*Kopi*	Rubiaceae	Tree	Fruit, branches, twigs, trunks	Drink, income, firewood, roofs, walls, windows, doors	Food, fuel, construction materials	3 [sc], 4 [sc]
Curcuma longa	Turmeric	Turmeric	Zingiberaceae	Herb	Rhizomes	Spices, food coloring, traditional medicine	Food, medicine	3 [sc], 4 [sc]
Curcuma zanthorrhiza	Temulawak	*Temu lawak*	Zingiberaceae	Herb	Rhizomes	Traditional medicine	Medicine	3 [sc], 4 [sc]
Dendrocalamus asper	Bamboo	*Bambu betung*	Poaceae	Tree	Shoots, stems	Columns, roofs, livestock/bird cages, kitchen utensils	Construction/other	3 [sw], 4 [sw]
Diplazium esculentum	Climbing swamp fern	*Pakis*	Athyriaceae	Fern	Leaves	Vegetables	Food	4 [sw]
Durio oxleyanus	Durian	*Durian*	Malvaceae	Tree	Fruit	Fruit, income	Food	1 [sw,w]
Durio zibethinus	Durian	*Durian*	Malvaceae	Tree	Fruit, branches, twigs	Fruit, income, firewood	Food, fuel	1 [sc], 2 [sc], 3 [sc], 4 [sc]
Elaeis guineensis	African oil palm	*Kelapa sawit*	Arecaceae	Tree	Fruit	Oil palm commerce, income	Raw commercial materials	3 [sc], 4 [sc]
Eurycoma longifolia	Longjack	*Pasak bumi*	Simaroubaceae	Tree	Roots	Traditional medicine, income	Medicine	1 [sw], 2 [sw], 3 [sc], 4 [sc]
Garcinia mangostana	Magosteen	*Manggis*	Clusiaceae	Tree	Fruit, branches, twigs	Fruit, income, firewood	Food, fuel	1 [sc], 2 [sc], 3 [sc], 4 [sc]
Gigantochloa apus	Bamboo	*Bambu apus, bambu tali*	Poaceae	Tree	Stems	Roofs, walls, livestock/bird cages, kitchen utensils	Construction/other	3 [sw], 4 [sw]
Gigantochloa atroviolacea	Bamboo	*Bambu wulung*	Poaceae	Tree	Stems	Columns, livestock/bird cages	Construction	3 [sw], 4 [sw]
Gigantochloa robusta	Bamboo	*Bambu mayan*	Poaceae	Tree	Shoots	Vegetables	Food	3 [sw], 4 [sw]
Gliricidia sepium	Quickstick	*Gamal*	Fabaceae		Branches, twigs, leaves	Firewood, fodder	Fuel, fodder	4 [sw, sc]
Gnetum gnemon	Melinjo	*Melinjo, tangkil*	Gnetaceae	Tree	Fruit, flowers, leaves, branches, twigs	Vegetables, income, firewood	Food, fuel	1 [sw], 2 [sw], 3 [sw], 4 [sw]
Hevea brasiliensis	Pará rubber tree	*Karet*	Euphorbiaceae	Tree	Latex	Rubber commerce, income, bird traps	Raw commercial/other	3 [sc], 4 [sc]
Kaempferia galanga	Aromatic ginger	*Kencur*	Zingiberaceae	Herb	Rhizomes	Traditional medicine, spices	Medicine, food	3 [sw, sc], 4 [sw, sc]
Lansium parasiticum	Langsat, lanzones, longkang	*Duku*	Meliaceae	Tree	Fruit, branches, twigs	Fruit, income, firewood	Food, fuel	1 [sc], 2 [sc], 3 [sc], 4 [sc]
Leea indica	Bandicoot berry	*Handamali*	Vitaceae	Tree	Trunks	Traditional ceremonies	Other	4 [sw]
Maesopsis eminii	Umbrella tree	*Afrika*	Rhamnaceae	Tree	Leaves	Fodder	Fodder	3 [sc], 4 [sc]

Mangifera indica	Mango	*Mangga*	Anacardiaceae	Tree	Fruit, branches, twigs	Fruit, income, firewood	Food, fuel	3 [sc], 4 [sc]
Manihot esculenta	Cassava	*Singkong*	Euphorbiaceae	Tree	Tubers, leaves	Side dishes, vegetables, income	Food	3 [sc], 4 [sc]
Musa acuminata	Banana	*Pisang kepok*	Musaceae	Tree	Fruit, leaves, flowers	Side dishes, vegetables, food wrapping, income	Food	3 [sw, sc], 4 [sw, sc]
Musa paradisiaca	Banana	*Pisang ambon, pisang lilin, pisang muli, raja nangka*	Musaceae	Tree	Fruit, leaves, flowers	Fruit, vegetables, food wrapping, income	Food	3 [sw, sc], 4 [sw, sc]
Myristica fragrans	Nutmeg	*Pala*	Myristicaceae	Tree	Fruit	Spices, income	Food	3 [sc], 4 [sc]
Neolamarckia cadamba	Burflower tree	*Jabon*	Rubiaceae	Tree	Trunks	Walls	Construction	4 [sc]
Nephelium lappaceum	Rambutan	*Rambutan*	Sapindaceae	Tree	Fruit, branches, twigs	Fruit, income, firewood	Food, fuel	4 [sc]
Pandanus amaryllifolius	Pandan	*Pandan*	Pandanaceae	Tree	Leaves	Food coloring	Food	3 [sw, sc], 4 [sw, sc]
Paraserianthes falcataria	Batay	*Sengon putih*	Fabaceae	Tree	Trunks, leaves	Roofs, fodder	Construction/fodder	4 [sc]
Parkia speciosa	Bitter bean	*Petai*	Fabaceae	Tree	Fruit, branches, twigs	Vegetables, income, firewood	Food, fuel	1 [sw, sc], 2 [sw, sc], 3 [sw, sc], 4 [sw, sc]
Pennisetum purpureum	Elephant grass	*Rumput gajah*	Poaceae	Grass	Leaves	Fodder	Fodder	3 [sw, sc], 4 [sw, sc]
Peronema canescens	False elder	*Sungkai*	Lamiaceae	Tree	Trunks, leaves	Roofs, doors, traditional medicine	Construction, medicine	4 [sc]
Persea americana	Avocado	*Alpukat*	Lauraceae	Tree	Fruit	Fruit, income	Food	4 [sc]
Piper nigrum	Black pepper	*Lada*	Piperaceae	Climber	Fruit	Spices, income	Food	3 [c], 4 [c]
Psidium guajava	Common guava	*Jambu biji*	Myrtaceae	Tree	Fruit, branches, twigs	Fruit, firewood	Food, fuel	3 [sc], 4 [sc]
Saccharum officinarum	Sugar cane	*Tebu*	Poaceae	Grass	Stems	Drinks	Food	3 [sc], 4 [sc]
Sauropus androgynus	Katuk	*Katuk*	Phyllanthaceae	Shrub	Leaves	Vegetables	Food	4 [sw, sc]
Schima wallichii	Needlewood tree	*Medang*	Theaceae	Tree	Trunks	Domestic construction	Construction	4 [sc]
Schizostachyum brachycladum	Bamboo	*Bambu lemang*	Poaceae	Tree	Stems	Kitchen utensils	Other	3 [sw], 4 [sw]
Shorea javanica [EN]	White meranti, Dammar	*Damar mata kucing*	Dipterocarpaceae	Tree	Resin, trunks	Income, domestic construction	Raw commercial/ construction materials	1 [sw, sc], 2 [sc], 3 [sc], 4 [sc]
Syzygium aromaticum	Clove	*Cengkeh*	Myrtaceae	Tree	Flowers	Spices, income	Food	3 [sc], 4 [sc]
Syzygium polyanthum	Indonesian bay leaf	*Salam*	Myrtaceae	Tree	Leaves	Spices	Food	1 [sw], 2 [sw], 3 [sw], 4 [sw]
Syzygium queum	Watery rose apple	*Jambu air*	Myrtaceae	Tree	Fruit, branches, twigs	Fruit, firewood	Food, fuel	3 [sc], 4 [sc]
Theobroma cacao	Cacao tree	*Kakao*	Malvaceae	Tree	Fruit, branches, twigs	Income, firewood	Raw commercial materials, fuel	4 [sc]
Vitex pinnata	Round leaf chaste tree	*Laban*	Lamiaceae	Tree	Trunks	Doors	Construction	3 [sc], 4 [sc]
Zingiber officinale	Ginger	*Jahe*	Zingiberaceae	Herb	Rhizomes	Traditional medicine, spices	Medicine, food	3 [sc], 4 [sc]

Note: *IUCN Red List threatened species. NT: near-threatened, VU: vulnerable, EN: endangered, CR: critically endangered; ** Collection site. 1: Bukit Barisan Selatan National Park, 2: protected forests, 3: limited production forests, 4: customary forests; Plant acquisition: w: wild; sw: semi-wild; sc: semi-cultivated; c: cultivated

Table 3. Fruit-harvesting calendar

Scientific Name	Harvest Calendar
Fruit	
Artocarpus heterophyllus	July, August
Artocarpus integer	April, May
Carica papaya	Perennial
Cocos nucifera	Perennial
Durio oxleyanus	June, July
Durio zibethinus	June, July
Garcinia mangostana	July
Lansium parasiticum	February, March
Mangifera indica	March
Musa acuminata	Perennial
Musa paradisiaca	Perennial
Nephelium lappaceum	March, April
Persea americana	January, February
Psidium guajava	Perennial
Syzygium queum	February, March, June, July, September, October
Vegetables	
Archidendron bubalinum	August, September
Archidendron pauciflorum	June, July
Capsicum annum	Perennial
Capsicum annum var. *annuum*	Perennial
Capsicum frutescens	Perennial
Gnetum gnemon	July
Parkia speciosa	June, July

Pará rubber tree (*Hevea brasiliensis*) latex and terap (*Artocarpus elasticus*) sap were used for bird hunting on a perennial basis, rattan (*Calamus* sp.) stems were used as dammar resin harvesting tools, and rattan fruit was used as a textile dye. Bamboo stems from *Gigantochloa apus* and *Schizostachyum brachycladum* were used as kitchen utensils, and bandicoot berry (*Leea indica*) trunks were used ceremonially. Most materials were available perennially, with occasional collection.

Discussion

The spatial map highlights Biha Resort's vital local community and livelihood roles for them, who coexist with multiple forest types in villages overlapping BBSNP areas including Biha Resort and buffer forests. Natural forests and communities have long coexisted in the area, although reliable demarcations of forest and village boundaries (e.g., roads, rivers and mountains (Hettiarachchi et al. 2022)) remain unavailable. This lack of territorial clarity may lead to conflicts of interest in developing villages and BBSNP conservation areas. Boundary disputes in the study area have continued for a long time, especially between communities and state forest managers, regardless of local efforts to determine state forest boundaries, resulting in overlapping boundaries with cultural-heritage *Repong Damar* land (Suporahardjo and Wodicka 2003). To prevent conflicts, the Indonesian government provides access to local communities for management of *Repong Damar* land in state forest areas (BBSNP, protected forests, limited-production forests and protected forests) through a social forestry (*perhutanan sosial*) program, which also allows communities to cultivate plants and collect non-timber forest products in limited-production forest areas and protected forests. In BBSNP areas, communities can collect non-timber forest products.

The study found that BBSNP forest areas and their surroundings exhibited high biodiversity and played significant roles in providing resources for local livelihoods. The majority of forest ecosystem services used by communities were mainly in customary forests, followed by limited-production forests, protected forests and BBSNP areas. Customary forests are more easily accessed due to community control, and tend to be closer to residential areas. Forest ecosystem services in protected forests were only used by Sumur Jaya and Marang villagers. However, the map shows protected forests within Sumur Jaya, Paku Negara, and Ulok Mukti boundaries. This is a result of unclear forest boundaries, highlighting a need for clarification and consideration of how community forests sometimes do not follow legal boundaries.

The findings also show that forests provide ecosystem services relating to water resources, wild animals, plants and similar to support livelihoods and generate income. This demonstrates the importance of forest resources in fulfilling the basic needs of locals, with semi-cultivated and semi-wild types playing essential livelihood roles. Plants were the main forest resource reported, providing more ecosystem services than wild animals (e.g., food, medicine, construction materials). Food is the most important ecosystem service because it fulfils a basic human need, with most coming from plants rather than animals. The study demonstrated the significant contribution of trees to local livelihoods and reserves, reflecting the finding of Reed et al. (2017) that trees play an important role in livelihoods and food resources for people in tropical zones. Provisioning services are the most frequently mentioned forest ecosystem services because they are easy to identify and directly benefit community needs and livelihoods. Our study did not identify other forest ecosystem services such as supporting, regulating and cultural services. However, it enriches information regarding the local community's detailed use of forest resources, especially related to provisioning services. A study by Muhamad et al. (2014) in several households neighboring Gunung Gede Pangrango National Park, West Java, Indonesia, identified the benefits of more various forest-agricultural landscape ecosystem services such as provisioning, supporting, regulating and cultural services, also showing that provisioning services are the most dominant services mentioned by the community, especially food. It aligns with this study's results that food is the ecosystem service most widely used by local communities around forests. A study from Hong and Saizen (2019) on the use of forest ecosystem services by local communities in the buffer area of Bach Ma National Park, Vietnam, also demonstrates that food is the most frequently mentioned by respondents.

The most-hunted animals are generally birds and mammals (Wiratno et al. 2004), and this study highlighted birds as the most popular targets. Villagers hunted for purposes relating to food, livelihoods and pets. To reduce the poaching of protected animals, BBSNP managers educate villagers in door-to-door visits, face-to-face presentations, posters and information boards. However,

illegal hunting is still rife due to information/education limitations. Due to their proximity to and greater influence within the community, local leaders must be involved in the effort to reduce illegal hunting.

Birds on the IUCN Red List of threatened species include the great hornbill (IUCN 2020a), the rhinoceros hornbill (IUCN 2020f), the helmeted hornbill (IUCN 2020b), the Javan leafbird (IUCN 2020c), the lesser green leafbird (IUCN 2020d), the crested jay (IUCN 2019a) and the bar-winged prinia (IUCN 2018b). Protected mammals include the Sumatran serow (IUCN 2020e), the Sambar deer (IUCN 2014), the Sumatran elephant (IUCN 2011) and the southern red muntjac (IUCN 2015). The plant species of agarwood (*Aquilaria malaccensis)* or *gaharu* (IUCN 2018a) and dammar (*S. javanica*) or *damar mata kucing* (IUCN 2018c) are also on the list. Such protected species require special attention in forest resource management, as extinction would adversely affect ecosystem sustainability. Sustaining such resources needs to educate local communities on threatened resources and encourage them to conserve and cultivate them on privately owned or government-prepared land. Cultivating threatened resources can be a way to prevent extinction and improve local economies through work-labor absorption (Bariyah 2020). *Gaharu* is a popular forest product with high global demand (Großmann 2017). This product is a raw material for various cosmetics, medicines, perfumes and jewelry. Several studies note the use of products from *gaharu* by local forest communities in Indonesia, such as wood for bracelets and necklaces (Großmann 2017), resin for sale to get cash (Kamarudin et al.2022) and leaves for cancer and hypertension medicine (Yanti et al. 2020). Education regarding the use of other products from *gaharu*, such as leaves for medicine, can increase the local community's livelihood around Biha Resort. Forest resources may be seasonal or perennial, affecting local utilization and incomes. This situation may be affected by climatic conditions and community needs. The study's findings indicate that forests in BBSNP buffer areas are vital to local livelihoods, as per similar studies in other regions (Poffenberger 2006; Palomo et al. 2013). Attention to the sustainability of forests in such areas helps to reduce BBSNP exploitation. More ecosystem services are derived from customary forests (CFs) than other forest types, demonstrating their benefits in livelihood support and their rich biodiversity. CFs also tend to be closer to residential areas, making them easier to access and cultivate. Such forests (*Repong Damar*) are formed on the basis of traditional ecological management, providing various ecosystem services for community livelihoods with agroforestry techniques (Muhamad et al. 2014).

Repong Damar and surrounding forest types in BBSNP are challenged by the expansion of monoculture farming for crops such as oil palm, coconut and coffee, the latter of which has the most serious effects. Encroachment by non-locals in particular severely threatens BBSNP and surrounding forests. Such operators generally come from neighboring regions, cities and areas outside Sumatra, such as Java, engaging in local cultivation for various reasons such as infertile land in their own areas, a lack of employment opportunities and other economic issues. They mostly work as farm laborers, and have limited educational backgrounds. These conditions threaten ecosystem sustainability, impacting biodiversity and eroding local livelihoods. To address this, management of national parks and forests in buffer areas is required with the involvement of local governments, communities and forest managers in buffer areas as well as non-governmental organizations.

To prevent and reduce land encroachment and poaching of wild animals in forests, the Indonesian government runs a program promoting forest management and involvement from local communities under an agreement that obliges residents to preserve forests and report any encroachment or wild-animal poaching in *perhutanan sosial*. This mitigates negative outsider influence by increasing familiarity of local areas and surroundings. The results of this study show the importance of state forests in providing a source of livelihood for local communities and the need to provide access and legal protection to local communities through *perhutanan sosial* programs. Such training and assistance from experts regarding sustainable forest management to the local community can be embedded in this program to maintain the sustainability of forests for environmental benefit and local community benefit.

Forest has multiple benefits, as shown in these study results that not only fulfill local community needs but also provide livelihoods and have important socio-cultural value. It echoes the study results from Setiawan et al. (2021) in the buffer village communities of Alas Purwo National Park, Banyuwangi, East Java, Indonesia, that forests around buffer village communities provide multiple functions for them, including economic, social and cultural. This study shows that forests in BBSNP and forests in buffer areas provide many ecosystem services to communities around Biha Resort. This study is in line with a study from Palomo et al. (2013) in Don˜ana National Park and Sierra Nevada National Park in Spain, showing that both national parks and their buffer areas provide abundant ecosystem services for local communities. Those highlight that buffer forests have an important role in reducing local pressures and providing livelihoods for local communities around the national park. Additionally, these study results emphasize the importance of buffer area management for the sustainability of national parks and local community's quality of life.

In conclusions, this study examines the mapping of forest-local community and inter-community boundaries in Biha Resort buffer areas, focusing on settlement distribution across eight villages. Differences in community perspectives on these boundaries highlight ongoing issues, leading to potential conflicts and loss of inter-community harmony. Community-participation mapping is encouraged for a more democratic approach, allowing for collective identification and clarification of critical resource boundaries. Forest ecosystem services, such as water, food, and construction materials, are crucial for sustaining rural livelihoods. The study highlights the interdependencies between local communities and surrounding forest ecosystems (BBSNP's forests and buffer forests), emphasizing the importance of context-specific

conservation strategies. Buffer-zone forests play a crucial role in minimizing resource extraction within BBSNP buffer areas, offering alternative resources and relieving pressure on vulnerable areas. The fostering of community-based forest ecosystem management thus becomes a key objective in creating inclusive solutions that balance biodiversity conservation with sustainable community livelihoods. The findings of the study thus provide valuable insights serving as a baseline for rural development in BBSNP buffer areas and other national parks, supporting understanding of the current situation and serving as a foundation for future interventions and strategies.

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