Report No: IGSC WP 2022-002

SUNWAY INSTITUTE for GLOBAL STRATEGY & COMPETITIVENESS

2022

Terrestrial Biodiversity and Protected Areas in Southeast Asia

Hui Hui Teow

Shirlyn Tang

Pervaiz K. Ahmed

Mahendhiran Sanggaran Nair

Santha Vaithilingam

WORKING PAPER

Author Information

1. **Dr. Hui Hui Teow**, *Postdoctoral Research Fellow*
Sunway Institute for Global Strategy and Competitiveness,
Sunway University, Jalan Universiti,
Bandar Sunway, 47500, Petaling Jaya, Malaysia
Email: huihuit@sunway.edu.my

2. Ms. Shirlyn Tang, *Research Analyst*
Sunway Institute for Global Strategy and Competitiveness,
Sunway University, Jalan Universiti,
Bandar Sunway, 47500, Petaling Jaya, Malaysia
Email: shirlynt@sunway.edu.my

3. Professor Pervaiz Khalid Ahmed, *Director*
Sunway Institute for Global Strategy and Competitiveness,
Sunway University, Jalan Universiti,
Bandar Sunway, 47500, Petaling Jaya, Malaysia
Email: pervaiz@sunway.edu.my

4. Professor Mahendhiran Sanggaran Nair, *Pro-Vice Chancellor (Research Engagement & Impact)*
Sunway University, Jalan Universiti,
Bandar Sunway, 47500, Petaling Jaya, Malaysia
Email: mahendhiransn@sunway.edu.my

5. Professor Santha Vaithilingam, *Deputy Director*
Sunway Institute for Global Strategy and Competitiveness,
Sunway University, Jalan Universiti,
Bandar Sunway, 47500, Petaling Jaya, Malaysia
Email: santhaav@sunway.edu.my

Abstract

This working paper aims to provide a comprehensive understanding on terrestrial biodiversity and protected areas in Southeast Asia. Southeast Asia consists of a wide array of terrestrial biomes that comprise natural ecosystems rich in biodiversity, such as lowland evergreen forests, montane evergreen forests, tropical rainforests, semi-deciduous forests, limestone karst formations, mossy forests, pine forests, heath forests, monsoon forests, and grasslands. These ecosystems are situated within the four key globally important biodiversity hotspots in Southeast Asia, namely Indo-Burma, Sundaland, the Philippines, and Wallacea, which house around 20% of the world's flora and fauna species. However, these biodiversity hotspots have already lost more than 90% of their original habitats to anthropogenic activities such as deforestation for socio-economic development and unsustainable use of natural resources. To minimize the anthropogenic impacts, terrestrial protected areas have long been designated to conserve biodiversity and protect biologically important terrestrial areas in Southeast Asia. Nevertheless, despite being protected, some protected areas are not efficiently managed. For example, many have failed to protect and conserve certain endemic species. Poor representation of habitats and lack of connectivity between terrestrial protected areas also serve as other problems with the current terrestrial protected area. Furthermore, some terrestrial protected areas are less effective than other unprotected areas at reducing deforestation and conserving biodiversity. As such, remedial measures are urgently needed to address the shortfalls of these protected areas to ensure the sustainability of biodiversity and ecosystem services.

Keywords: Southeast Asia, Biodiversity hotspots, Biodiversity loss, Terrestrial biodiversity, Terrestrial protected areas,

Table of Contents

1. Terrestrial Ecosystem in Southeast Asia

1.1 Background

Covering an area of about 44.6 million km^2 and a population of over 650 million, Southeast Asia is geographically divided into the Mainland Southeast Asia (also known as Indochina) and Maritime Southeast Asia (Malay Archipelago), which comprise eleven countries of rich biodiversity: Singapore, Brunei, Timor-Leste, Cambodia, Laos, Philippines, Vietnam, Malaysia, Thailand, Myanmar, and Indonesia, all of which represent 3% of the world's total land area (Yale, 2022) (see Table 1 for the respective terrestrial areas of Southeast Asia countries). Southeast Asia is situated within the tropical and subtropical climatic zones. These zones encompass four types of landforms, including mountains, hills, plateaus, and plains (Leinbach & Frederick, 2020).

Table 1. *Terrestrial Area (km^2) of Countries in Southeast Asia*

Countries	Total Terrestrial Area (km^2)
Singapore	605
Brunei	5,962
Timor-Leste	15,007
Cambodia	182,511
Laos	231,276
Philippines	298,775
Vietnam	329,880
Malaysia	331,701
Thailand	517,787
Myanmar	673,079
Indonesia	1,906,555

Source: Protected Planet (2022)

The terrestrial ecosystem is a land-based ecosystem that involves interactions between living organisms and non-living elements. It includes the taiga, tundra, grasslands, deserts, and rainforests. The types of ecosystems found in a particular terrestrial area are dependent upon

the climate, type of soil, amount of soil minerals and nutrients, presence of endemic species, level of rainfall, elevation, and availability of sunlight (McHaughton, 2021). Southeast Asia consists of a wide array of terrestrial biomes that comprise natural ecosystems rich in biodiversity, such as lowland evergreen forests, montane evergreen forests, tropical rainforests, semi-deciduous forests, limestone karst formations, mossy forests, pine forests, heath forests, monsoon forests, and grasslands (CEPF, 2014; 2020). These ecosystems are situated within four key globally important biodiversity hotspots in Southeast Asia, which will be discussed in detail in the section that follows.

2. Biodiversity hotspots in Southeast Asia

The Convention of Biological Diversity (CBD) defines biodiversity as: "the variability among living organisms from all sources including, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems" (Mcgill & Magurran, 2011, p. 292). According to Myers et al. (2000, p. 853), biodiversity hotspots can be defined as "the exceptional concentrations of endemic species and the exceptional loss of habitat." Conservationists and environmentalists have long been using biodiversity hotspots to measure the richness of biodiversity and the degree of habitat loss in certain regions (Mcgill & Magurran, 2011, p. 292). Two strict criteria need to be taken into account when qualifying certain terrestrial regions as biodiversity hotspots. First, the hotspot areas must encompass more than 1,500 species of vascular plants endemic to the regions and cannot be found elsewhere. Secondly, the regions should have lost more than 70% of their original habitat (Critical Ecosystem Partnership Fund [CEPF], 2022). To date, there are 36 biodiversity hotspots, which are rich in biodiversity but heavily threatened by habitat loss (CEPF, 2022). Of which, four biodiversity hotspots can be found in Southeast Asia: Indo-Burma, Sundaland, the Philippines, and Wallacea, which house

around 20% of the world's flora and fauna species (Myers et al., 2000). These four biodiversity hotspots deserve immediate conservation efforts as they consist of a copious amount of endemic species yet have already lost more than 90% of their original habitats (Nilsson, 2019). The details of these biodiversity hotspots will be discussed in the following sections.

Figure 1a. *Indo-Burma Biodiversity Hotspot*

Source: Conservation International/Wikimedia Commons (2005a)

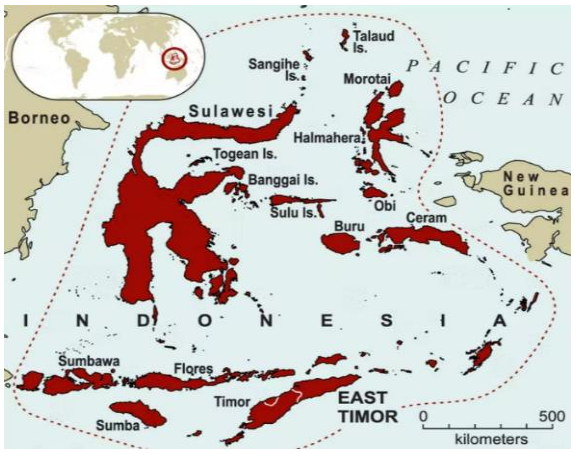
Figure 1b. *Sundaland Biodiversity Hotspot*

Source: Conservation International/Wikimedia Commons (2005)

Figure 1c. *The Philippines Biodiversity Hotspot*

Source: Conservation International/Wikimedia Commons (2005b)

Figure 1d. *The Wallacea Biodiversity Hotspot*



Source: Conservation International/Wikimedia Commons (2005d)

2.1 The Indo-Burma biodiversity hotspot

2.1.1 Terrestrial ecosystems in the Indo-Burma biodiversity hotspot

As shown in Figure 1a, the Indo-Burma biodiversity hotspot covers all land regions in Thailand, Vietnam, Myanmar, Laos, Cambodia, and part of southern China (IUCN, 2020a). As the largest biodiversity hotspot, it covers a total terrestrial area of 2,308,815 km^2 and includes several mountain ranges, such as the Annamite Mountain and parts of the Himalayas. The hotspot is rich in various types of species-rich terrestrial ecosystems, including lowland evergreen forests, montane evergreen forests, semi-evergreen and mixed deciduous forests, limestone karst formations, grasslands, seasonally inundated swamp forests, and freshwater ecosystems. Specifically, lowland evergreen forests (at elevations less than 1,000m) in this hotspot can be found in the lowlands of Thailand, Myanmar, and Vietnam (Mongabay, 2012). However, a large portion of the forests has been substantially exploited due to agricultural expansion and the lucrative market of timber species in these forests (CEPF, 2020). On the other hand, montane evergreen forests (at elevations between 1,000 to 2,500m), which span the Cardamom Mountains of Cambodia, the Annamite Mountains of Laos and Vietnam, mountainous areas of Cambodia, part of southern China, and northern Thailand, are less exploited as compared to lowland forests in this hotspot (CEPF, 2020). Semi-evergreen and mixed deciduous forests, which harbor lesser flora and fauna, are situated within lowland and hill areas across the biodiversity hotspot. Deciduous dipterocarp forest, which is characterized by an open canopy with 50 – 80% canopy cover and grassy forest floor, is the most prevalent type of forest in Indo-Burma (Rundel, 2009). Consisting primarily of calcium carbonate, limestone karsts are landforms that feature complex terrains such as fissured cliffs and caves and house a large number of unique endemic species such as cave geckos, scorpions, and blind fish (Dreybrodt & Loveridge, 2021). Nevertheless, the need for economic development has put limestone karst biodiversity in this hotspot at risk. For instance, limestone quarrying for cement

production has further exacerbated the extinction rate of certain hyperendemic invertebrates, reptiles, fish, and plant species endemic to the hotspot (Lim, 2016).

The grassland ecosystem refers to large open land mainly dominated by different species of grasses with very few trees (Earth Reminder, 2020). There has been a substantial decline in the grassland ecosystem across the Indo-Burma hotspot due to conversion to agriculture, aquaculture, and forestry (CEPF, 2020). Freshwater swamp forests or peat swamp forests are seasonally inundated with shallow freshwater (Rundel, 2009). This type of forest is mainly distributed around the Great Lake of Tonle Sap in Cambodia and the Irrawaddy Delta in Myanmar (CEPF, 2020). Some critically endangered large waterbirds can be found in swamp forests in this ecoregion, such as the Black-Headed Ibis, the Milky Stork, and the Grey-Headed Fish Eagle (Aqua Expedition, 2021). Nonetheless, swamp forests in this hotspot have also been substantially degraded due to their optimal conditions for plantation agriculture (CEPF, 2020). On the other hand, natural freshwater ecosystems involve "the terrestrial phases of the global hydrological cycle and include permanent rivers, streams, lakes, ponds, wetlands as well as groundwaters" (Reid et al., 2020, p. 270). The Tonle Sap in Cambodia is one of the largest freshwater ecosystems in the world (Dempsey, 2014). Specifically, the lake houses 149 fish species from four families, namely Cyprinidae, Bagridae, Siluridae, and Pangasiidae. Furthermore, it is also home to 11 globally endangered species (Campbell et al., 2006). These freshwater areas are essential for communities that rely on their natural resources for livelihoods. Yet, human activities such as unsustainable fishing, overexploitation for human consumption, and hydropower dam construction have caused irreversible damage to freshwater ecosystems in the Indo-Burma hotspot (CEPF, 2020; Dempsey, 2014). Clearly, a vast land area (including freshwater systems) of the Indo-Burma biodiversity hotspot has been degraded and exploited, threatening the various ecosystems and key biodiversity areas across the region

(CEPF, 2020; Tordoff et al., 2012). In fact, only 5% of the original natural habitats are left intact in this biodiversity hotspot (Mittermeier et al., 2004).

2.1.2 Biodiversity in the Indo-Burma hotspot

The Indo-Burma hotspot is biologically rich and threatened at the same time. It is home to more than 15,000 species of vascular plants, 470 mammal species, 1,330 bird species, 670 reptile species, 380 amphibian species, and 1,440 species of fish (CEPF, 2020). In fact, there are around 1,300 globally threatened species in the Indo-Burma hotspot, of which 17% are critically endangered, 36% are endangered, and 47% are vulnerable (CEPF, 2020) (see Table 2). To be more specific, 20% of mammal species, 8% of bird species, 20% of reptile species, 25% of the amphibian species, and 9% of the fish species in the hotspot are registered as globally endangered. Mammal species such as tiger (*Panthera tigris*), Asian elephant (*Elephas maximus*), banteng (*Bos javanicus*), and Lao leaf monkey (*T. laotum*); bird species such as white-throated wren-babbler (*Rimator pasquieri*), reptile species such as Siamese crocodile (*Crocodylus siamensis*), amphibian species such as Hoang Lien moustached toad (*Leptobrachium echinatum*), and fish species such as the Mekong giant catfish (*Pangasianodon gigas*) are some examples of globally threatened vertebrates that inhabit the Indo-Burma hotspot. On the other hand, nearly half of the plant species in the hotspot are listed as globally endangered plant species (CEPF, 2020). As can be seen, the hotspot's biodiversity is declining at an unprecedented rate, and these globally endangered species are at risk of going extinct very shortly if no further actions are taken to protect the biodiversity against deterioration.

Table 2. *Summary of Globally Threatened Species in the Indo-Burma Hotspot*

Taxonomic Group	Global Threat Status				Distribution by Country					
	Critically Endangered	Endangered	Vulnerable	Total	Cambodia	China	Lao PDR	Myanmar	Thailand	Vietnam
Mammals	18	37	42	**97**	38	49	50	47	57	60
Birds	18	32	58	**108**	34	58	31	63	70	57
Reptiles	28	42	54	**124**	24	36	30	34	38	75
Amphibians	3	42	53	**98**	11	41	17	9	8	52
Fish	25	43	66	**134**	30	27	60	21	61	38
Invertebrates	19	41	88	**148**	6	26	25	9	44	60
Plants	116	234	239	**589**	48	253	69	90	189	269
Total	**227**	**471**	**600**	**1,298**	**191**	**490**	**282**	**273**	**467**	**611**

Source: CEPF (2020, p. 43)

Key biodiversity areas (KBAs) are "sites contributing significantly to the global persistence of biodiversity in terrestrial, freshwater, and marine ecosystems" (IUCN, 2022). As of 2020, the Indo-Burma biodiversity hotspot consists of a total of 555 key biodiversity areas (covering 16% of the total area of the hotspot) with many globally threatened species. However, 44% of the KBAs are not situated within protected areas, implying a mismatch between the KBAs and protected areas in the Indo-Burma biodiversity hotspot (CEPF, 2020). As such, there is an urgent need to reassess the locations of these KBAs and identify ways to improve their practicality in conserving globally threatened species (CEPF, 2020).

Table 3. *Summary of Key Biodiversity Areas in the Indo-Burma Hotspot*

Taxonomic Group	Cambodia	China	Lao PDR	Myanmar	Thailand	Vietnam	Total
Mammals	21	25	32	59	59	78	**274**
Birds	39	55	24	82	63	59	**322**
Reptiles	24	18	20	100	32	21	**215**
Amphibians	2	20	1	0	5	13	**41**
Fish	8	2	13	2	9	5	**39**
Invertebrates	1	0	2	16	3	3	**25**
Plants	8	48	8	28	75	36	**203**
All KBAs	**43**	**90**	**47**	**142**	**117**	**116**	**555**

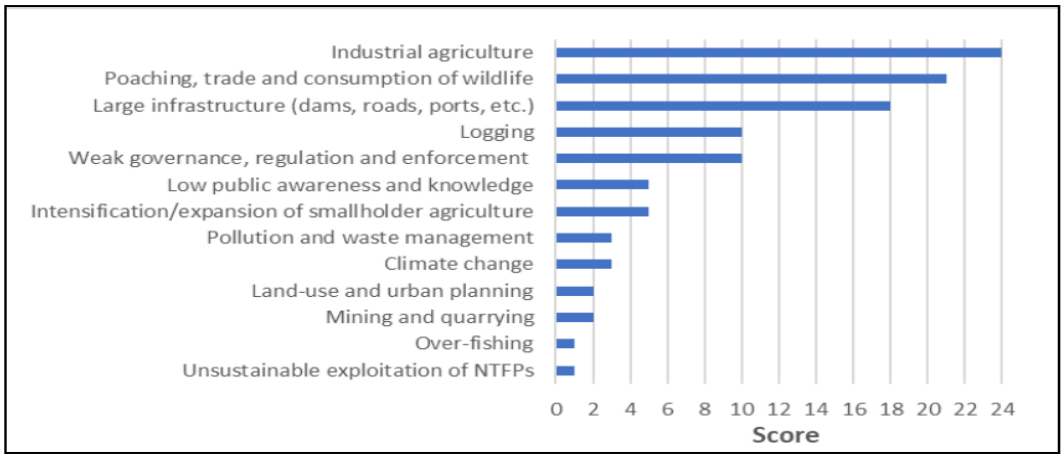
Source: CEPF (2020, p. 47)

2.1.3 Threats to terrestrial biodiversity loss in the Indo-Burma hotspot

The Indo-Burma biodiversity hotspot is threatened with severe biodiversity loss, as it has lost more than 95% of its original natural habitats (CEPF, 2020). Moreover, approximately 120,000 km^2 of forest ecosystems across the Indo-Burma hotspot were destroyed between 2000 and 2017, causing a significant reduction in biodiversity (Foley, 2020). A study conducted by CEPF (2020) reveals that industrial agriculture, poaching, and the construction of large infrastructures serve as the top three drivers of biodiversity loss in the hotspot. Refer to the figure below for other causes of biodiversity loss in the regions.

Figure 2.

Drivers of Biodiversity Loss in the Indo-Burma hotspot



Source: CEPF (2020, p. 74)

2.2 The Sundaland biodiversity hotspot

2.2.1 Terrestrial ecosystems in the Sundaland biodiversity hotspot

As shown in Figure 1b, the Sundaland biodiversity hotspot is dominated by the islands of the Malay Peninsula (encompasses southeastern Mynamar, southwestern Thailand, West Malaysia, and Singapore), Borneo (covers Brunei, western Indonesia, and East Malaysia), Sumatra, and Java, covering around 17,000 equatorial islands and an area of 1.6 million km^2 (CEPF, 2001; Mauldin & Karas, 2016). This hotspot is well-known for its tropical forests and contains around 15,000 endemic plant species (CEPF, 2022). Also, more than 92% of primary

natural vegetation in this biodiversity hotspot has been destroyed (Polgar & Jaafar, 2018). Various types of terrestrial ecosystems are distributed across this hotspot: lowland tropical rainforests, montane tropical rainforests, peat swamp forests, freshwater swamp forests, heath forests, limestone karsts as well as freshwater ecosystems (CEPF, 2001; WWF, 2007). Lowland tropical forests in this hotspot provide an ideal environment and climate for over 10,000 plant species, including 3,000 types of trees and 2,000 types of orchids (Sawe, 2018). Within the Sundaland, Borneo comprises the largest area of heath forest in Southeast Asia (WWF, 2007). In addition, the tropical rainforests in Borneo cover a total area of 24 million hectares, which account for 30% of the Borneo land area, and represent the largest contiguous forest in Southeast Asia (WWF, 2007). Although it only makes up 1% of the world's land area, Borneo harbors more than 6% of global biodiversity in its tropical forests (WWF, 2020). Nonetheless, Borneo has lost around 1.9 million forest areas between 2004 – 2017 to commercial agriculture (The Borneo Post, 2021). Table 4 shows that the area of lowland forests in Borneo had decreased from 19 million hectares in 2005 to 13 million hectares in 2015. Likewise, the areas of limestone forests, heath forests, and swamp forests had also reduced substantially between 2005 to 2015 (Wulffraat et al., 2016). In general, there has been a sharp decline in the area of different terrestrial ecosystems in Borneo alone from 2005 to 2015, signaling an alarming deforestation rate (Wulffraat et al., 2016).

Table 4. *The Area of Different Terrestrial Ecosystems in Borneo from 2005 to 2015*

Terrestrial Ecosystems	**Area (hectares)**	
	2005	**2015**
Lowland rainforest	19,338,952	13,198,700
Upland rainforest	13,118,466	12,348,000
Montane forest	6,655,131	6,461,900
Limestone forest	902,331	675,100
Heath forest	2,930,249	1,624,600
Freshwater swamp forest	1,068,219	534,600
Peat swamp forest	6,490,437	3,951,200

Source: Wulffraat et al. (2016, p. 27)

Sumatra, which covers 470,000 km^2 of land area, consists of the richest yet the most threatened biodiversity in the Sundaland hotspot (CEPF, 2001). It has lost nearly half (approximately 12 million hectares) of its tropical forests in the past decades (WWF, 2020). Similarly, as of 2010, Java comprises slightly more than 10,000 hectares of tropical rainforests. Specifically, 2,500 hectares of forests were cleared annually from 2003 to 2006 on average (Hance, 2010). In fact, more than 95% of the original habitat of this ecoregion has been demolished as the country is densely populated, making it an important biodiversity hotspot to protect (Wikramanayake et al., 2002). On the other hand, most of the remaining forests in Peninsula Malay are located in steep and mountainous areas of the ecoregion. Montane rainforests are the largest terrestrial ecosystems in the Peninsula Malay bioregion, consisting of 1.7 million hectares of land area and occupying the mountainous spine of the peninsula in Malaysia and southern Thailand (Wikramanayake, 2022; Loucks, n.d.). Yet, Peninsula Malaysia is not spared from the forest loss issue; it has lost approximately 50,000 hectares of primary forests in 2019 alone (The Borneo Post, 2021). In general, it is evident that the terrestrial ecosystems in these ecoregions are severely deforested and degraded, which can result in massive biodiversity loss if further preventive and remedial measures are not implemented. In fact, the Sundaland biodiversity hotspot has lost more than 90% of its original primary vegetation, left with 125,000 km^2 as of the year 2000 (Myers et al., 2000).

2.2.2 Biodiversity in the Sundaland hotspot

Sundaland is home to more than 25,000 vascular plant species, of which 15,000 are endemic to the hotspot. In terms of fauna, Sundaland consists of 1,800 species of terrestrial vertebrates, and 2.6% are endemic (Myers et al., 2000). Specifically, this ecoregion houses around 112 endemic mammal species and 128 bird species (Brooks et al., 2002; Eaton et al., 2016). For instance, mammals such as the Borneon orangutans and Sumatran Rhino, and bird species such as the Bali Starling and the Javanese Lapwing are classified as critically

endangered animals in Sundaland (Mauldin & Karas, 2016). In Sumatra, 23% of the reptile and amphibian species and 15% of its freshwater fish species are endemic (CEPF, 2001). Besides that, less than 300 Sumatran rhinos and 400 Sumatran tigers are left in the forests (WWF, 2020). Sumatra also houses some unique mammal species, such as the proboscis monkey, clouded leopard, sun bear, and flying fox bat (WWF, 2020). In the Borneo rainforest, there are more than 15,000 plant species, of which 40% are endemic to the hotspot. Moreover, Borneo harbors approximately 222 mammal species, of which 44 are endemic; 420 bird species with 37 endemic species; 100 amphibians and 394 fish, 19 are endemic (WWF, 2020). Some of these faunas are classified as critically endangered, such as the Borneo pygmy elephant (*Elephasmaximusborneensis*), Borneo Bay cat (*Pardofelis badia*), and the Helmeted Hornbill (*Rhinoplax vigil*) (WWF, 2020).

Located in another part of the Sundaland, the Malay Peninsula also consists of a number of endangered species, such as the Malayan tapir (*Tapirus indicus*), the Asian elephant (*Elephas maximus*), and the gaur (*Bos gaurus*) (WWF, 2022). Besides that, as one of the most actively volcanic islands in the world, the Java rainforests also contain moderately rich biodiversity (WWF, 2022). Specifically, there are more than 100 mammal species in this ecoregion, including five endemic species such as the *Rhinolophus canuti* and the *Otomops formosus.* Some critically endangered mammal species include Javan rhinoceros (*Rhinoceros sondaicus*) and Javan gibbon (*Hylobates moloch*) (IUCN, 2000). In addition, the Java ecoregion also houses more than 350 bird species, of which nine are endemic [e.g., Javan hawk-eagle (*Spizaetus bartelsi*), Javan white-eye (*Zosterops flavus*), Grey-cheeked tit-babbler (*Macronous flavicollis*), etc.]. Also, more than 3,800 plant species can be found here, including the giant Rafflesia species such as *Rafflesia rochussenii* and *Rafflesia padma* (Whitten et al., 1996).

A study discovered that human activities had extensively degraded 70.6% of the Sundaland hotspot, surpassing the global average of 30% due to its high density of population (Jones et al., 2018). Moreover, approximately 63% of the key biodiversity areas in Sundaland were not located within any protected areas of Categories I to IV (Verma et al., 2020). However, the overlapping between key biodiversity areas and protected areas in the Sundaland has increased from 20% in 1993 to 30% in 2009 (Verma et al., 2020). In Sumatra, 54% of the 34 Important Bird Areas (IBA) remain outside protected areas, while 18% are situated in critically threatened lowland forests (CEPF, 2001). As shown in Table 5, except for the montane forest, less than 50% of other terrestrial ecosystems in Borneo are situated within protected areas, respectively. Conversely, more than half of Borneo's montane forest (53.3%) is still protected as these mountainous areas are relatively difficult to access and hence less attractive for agriculture development (Wulffraat et al., 2016).

Table 5. *Percentage of Borneo's Terrestrial Ecosystem Protected*

Ecosystem	% of extent protected
Lowland rainforest	16.2
Upland rainforest	36.0
Montane forest	53.3
Limestone forest	28.5
Heath forest	14.0
Peat swamp forest	38.5
Freshwater swamp forest	30.3

Source: Wulffraat et al. (2016)

2.2.3 Threats to terrestrial biodiversity loss in the Sundaland hotspot

Deforestation and forest degradation are the major factors contributing to terrestrial biodiversity loss in the Sundaland hotspot. The original habitat of the hotspot has been reduced from 1.6 million km^2 to 125,000 km^2 as of the year 2000 (Polgar & Jaafar, 2018). Further, it has lost approximately 773,000 km^2 of tropical lowland forests by 2010, accounting for around 70% of its total area of lowland forests (Wilcove et al., 2013). In fact, Sundaland's tropical

forests face the highest deforestation rate in the world (Hansen et al., 2013), which was mainly driven by rapid agricultural expansion, unsustainable logging activities, and road construction (CEPF, 2001; Wilcove et al., 2013). For instance, palm oil plantations were liable for nearly 40% of deforestation in Sumatra and Borneo, respectively, between the 1980s and 2010s (Guindon, 2021). Moreover, the rapid construction of roads has also catalyzed the deforestation rate in Sumatra (Nilsson, 2019). Specifically, new logging roads provide settlers and logging trucks with easier access to the formerly remote areas of the Sumatran forests, which can eventually result in habitat loss and a decline in biodiversity (Jong, 2021). Coupled with other anthropogenic disturbances such as illegal hunting and wildlife trade, the threat to biodiversity in the Sundaland hotspot is amplified (CEPF, 2001; Haas & Ferreira, 2016). For example, only around 500 critically endangered Sumatran tigers are left in Indonesia, of which only 33 Sumatran tigers are left in North Sumatra due to habitat loss, illegal hunting, and poaching for commercial purposes (Gunawan, 2020; Mangunjaya, 2018).

2.3 The Wallacea biodiversity hotspot

2.3.1 Terrestrial ecosystems in the Wallacea biodiversity hotspot

The Wallacea biodiversity hotspot is located within the central islands of Sulawesi in Indonesia and Timor-Leste, particularly sitting between Maluku, Lesser Sundas, and Sulawesi. As a result of tectonic activities, the land area of this hotspot is fragmented into 1,680 islands (which cover a total terrestrial area of 347,000 km^2) separated by oceanic trenches (CEPF, 2014; Lohman et al., 2011). Nearly half of the land area of the Wallacea hotspot is covered with forests (17.7 million hectares), which are home to more than 1,500 endemic plant species and comprise around 560 globally threatened species (including critically endangered, endangered, and vulnerable categories (CEPF, 2014). Natural habitats in the lowland areas of Maluku & Sulawesi are made up of evergreen and semi-evergreen forests, while monsoon forest is the main type of forest found in Lesser Sundas (CEPF, 2014). Specifically, 56% of the Wallacea's

forests are located in Sulawesi, 24% in Maluku, 19% in Lesser Sundas, and 4% in Timor-Leste. Several types of terrestrial ecosystems can be found in the Wallacea hotspot, including lowland tropical forests, lowland monsoon forests, montane forests, heath forests, grassland, karsts, swamp forests, and as well as freshwater rivers and lakes, all of which serve as important terrestrial ecosystems (CEPF, 2014). Lowland tropical forests are primarily distributed across Maluku and Sulawesi and are dominated by trees of the *Dipterocarpaceae*. Monsoon forests are characterized by a dry period of several months and can be found mainly in regions with seasonal climates. However, a large area of the monsoon forests in this hotspot had been deforested for mining and agriculture expansion. Heath forests are primarily situated in areas with acidic and nutrient-deficient soil, which are covered with drought-tolerant trees, whereas there are relatively lesser tree species in the karst regions due to infertile soil. Swamp forests, such as freshwater swamp forests or peat swamp forests, can be found mainly in Sulawesi (CEPF, 2014). As can be seen, the Wallacea biodiversity hotspot is rich in forested areas. However, mining activities and forest clearing for industrial agriculture are the major threats to these terrestrial ecosystems in the Wallacea hotspot (Gaveau et al., 2021). A study has found that socio-economic development has resulted in 10,231 km^2 of forest loss between 2000 and 2018, and a further 49,570 km^2 of the forest is projected to be cleared by 2053 (Voigt et al., 2021), signaling an alarming deforestation rate.

Like terrestrial ecosystems, freshwater systems (rivers and lakes) located on land areas in the Wallacea hotspot also play significant roles in supporting livelihoods and contributing to socio-economic development. Rivers in the region are generally steep, while the lakes are deep and isolated due to the plate tectonic revolution and volcanic activity (CEPF, 2014). The Malili lake system located on the island of Sulawesi has formed as a result of volcanic activity 1.5 million years ago (Haffner et al., 2001; Russell et al., 2016). As the only hydrologically connected ancient lake system in the world (Vaillant et al., 2011), it consists of five

interconnected lakes: Lake Matano, Lake Mahalona, Lake Towuti, Lake Lontoa, and Lake Masapi, as well as rivers that connect one lake to another in the system, such as Petea River, Tominanga River, and Larona River (von Rintelen & Cai, 2009). The Maliki Lake system is rich in freshwater biodiversity, yet it has been constantly threatened with human activities (e.g., agricultural expansion, mining, illegal logging, etc.) that degraded and polluted the freshwater environment, causing a severe biodiversity loss in the region (IUCN, 2022). All in all, it is clear that the terrestrial ecosystems (forests and freshwater systems) in the Wallacea hotspot are deteriorating at a rate that warrants urgent attention from environmentalists and conservationists, and hence the establishment of the "Wallacea biodiversity hotspot".

2.3.2 Biodiversity in the Wallacea hotspot

The Wallacea hotspot comprises relatively lesser flora and fauna species than other biodiversity hotspots in Southeast Asia due to the fragmented terrestrial areas resulting from the subduction and volcanic activities (CEPF, 2014). Yet, this unique geographical environment has allowed the occurrence of highly endemic species that can only be found in some of the islands in the Wallacea hotspot (Supriatna, 2017). As evidenced, Table 6 shows that 57% of the mammal species, 39% of the bird species, 44% of the reptile species, 50% of birdwing butterflies, 68% of the amphibian species, and 20% of the freshwater fish species are endemic to the Wallacea hotspot. Of the total number of species in this hotspot, a considerable proportion is regarded as globally threatened (see Table 7). For example, mammals species such as the Sunda Pangolin (*Manis javanica*) and Javan Langur (*Trachypithecus auratus*), bird species such as the Timor imperial pigeon (*Ducula cineracea*) and Wetar ground-dove (*Gallicolumba hoedtii*), reptile species such as the Banda Island dtella (*Gehyra barea*) and the Sulawesian tortoise (*Indotestudo forstenii*), amphibian species such as the Djikoro wart frog (*Limnonectes arathooni*) and the Lombok cross frog (*Oreophryne monticola*), and freshwater fishes such as Duckbilled Bunting (*Adrianichthys kruyt*) and Poso Bungu (*Weberogobius amad*) are some of the endangered species

inhabiting the Wallacea biodiversity hotspot. In terms of flora, only 1% of the plant species are classified as threatened species, including species of economic value such as sandalwood (*Santalum album*) and eaglewood (*Aquilaria cumingiana*) (CEPF, 2014). As shown in Table 7, of 336 globally threatened terrestrial species in the hotspot, 28 are classified as critically endangered, 61 are endangered, and 157 are vulnerable.

Table 6. *Summary of Terrestrial Species Diversity and Endemism in the Wallacea Biodiversity Hotspot*

Taxonomic Group	Total No. of Species	No. of endemic species (%)	# of threatened species (%)
Plants	10,000	>1,500 (15)	66 (1)
Mammals	222	127 (57)	64 (29)
Birds	711	274 (39)	61 (9)
Reptiles	222	99 (44)	10 (5)
Amphibians	48	33 (68)	8 (17)
Freshwater fishes	250	50 (20)	37 (15)

Source: CEPF (2014, p. 21)

Table 7. *Summary of Globally Threatened Terrestrial Species in the Wallacea*

Taxonomic Group	Global Threat Status				Species Distribution by Bioregion		
	Critically Endangered	Endangered	Vulnerable	Total	Sulawesi	Maluku	Lesser Sundas
Plants	5	7	54	66	36	23	18
Mammals	5	23	36	64	40	13	15
Birds	12	20	29	61	28	16	20
Reptiles	2	3	5	10	6	2	7
Amphibians	0	4	4	8	6	1	1
Freshwater fishes	4	4	29	37	37	0	0
Total	**28**	**61**	**157**	**336**	**153**	**199**	**61**

Source: CEPF (2014, p. 32)

The Wallacea hotspot consists of a total of 251 terrestrial key biodiversity areas (KBAs), which are situated within the three biogeographic regions and cover a total land area of 9.5 million hectares (see Table 8). In Indonesia, 88% of the terrestrial KBAs are situated within the national forest estate. However, only 31% of the terrestrial KBAs are within legally

protected areas such as national parks, strict nature reserves, wildlife reserves, and other conservation reserves, while the remaining 69% of the KBAs are outside the protected area network (CEPF, 2014). However, a more recent study claims that there are 227 terrestrial KBAs in the Wallacea, of which around 45% are partially protected, 6.2% are completely protected, and 37% are not protected at all (Voigt et al., 2021). In Timor-Leste, 12 terrestrial KBAs are designated as protected areas, of which 11 are Important Bird Areas (IBAs). As can be seen, these statistics show that a large area of the terrestrial KBAs in the Wallacea hotspot remains outside the protected area network. In fact, less than 6% of the Wallacea biodiversity hotspot is within protected areas (Hernani, 2018).

Table 8. *Summary of the Number of Terrestrial KBAs in the Wallacea Hotspot*

	Terrestrial Key Biodiversity Areas	
	Total	**Area (ha)**
Sulawesi	95	5,266,204
Maluku	51	2,146,217
Lesser Sundas	105	2,098,638
Total	**251**	**9,511,059**

Source: CEPF (2014)

2.3.3 Threats to terrestrial biodiversity loss in the Wallacea hotspot

Some of the major threats to terrestrial biodiversity loss in the Wallacea include overexploitation of natural resources (e.g., unsustainable logging and hunting for commercial purposes) and large-scale deforestation for the expansion of agriculture, mining, urbanization, and infrastructure development (CBD, 2022; CEPF, 2014; Voigt et al., 2021). The top driver of terrestrial biodiversity loss in the Wallacea hotspot is the conversion of lowland forests for oil palm plantations (CBD, 2022; CEPF, 2014). As part of the Wallacea hotspot, Indonesia supplied nearly half of the global palm oil between 2010 and 2011, making it a profitable business (CEPF, 2014). The table below shows that the oil palm plantation size has increased tremendously from 9.6 million hectares in 2012 to 11.8 million hectares in 2016, generating

USD 18.6 billion for Indonesia in 2016 (Indonesia Investment, 2017). Although oil palm plantation is the key industry to the country's economy, it has further exacerbated the loss of terrestrial biodiversity in the Wallacea hotspot (CBD, 2022; CEPF, 2014; Voigt, 2021).

Table 9. *Indonesian Palm Oil Production and Export Statistics from 2012 to 2016*

	2012	2013	2014	2015	2016
Production (million tons)	26.5	30.0	31.5	32.5	32.0
Export (USD billion)	21.6	20.6	21.1	18.6	18.6
Plantation size (million hectares)	9.6	10.5	10.7	11.4	11.8

Source: Indonesia Investment (2017)

2.4 The Philippines biodiversity hotspot

2.4.1 Terrestrial ecosystems in the Philippines biodiversity hotspot

As a country of more than 7,000 islands that amount to 300,780 km^2 of terrestrial area, the Philippines is another vital biodiversity hotspot in Southeast Asia, with more than 6,500 endemic plant species and 700 threatened species (Convention on Biological Diversity, n.d.; Goldman, 2010). In fact, the Philippines has lost more than 93% of its original vegetation since the 1900s (Biodiversity Management Bureau [BMB] - Department of Environment and Natural Resources [DENR], 2016). Despite its species richness, the Philippines is severely threatened with biodiversity loss due to anthropogenic activities, making it a biodiversity hotspot that requires intensive conservation efforts (CEPF, 2001; Mona, 2016). Covering almost 24% of the total land area, the terrestrial ecosystems in the Philippines are mainly dominated by tropical evergreen rainforests, montane rainforests, ultramafic forests, limestone karsts, and freshwater swamp forests (CEPF, 2001; Convention on Biological Diversity, n.d.). Several biodiversity corridors can be found in the Philippines, of which the Sierra Madre Corridor, Palawan Corridor, and the Eastern Mindanao Corridor cover most of the terrestrial ecosystems

and hold more than 70% of plant species in the Philippines (CEPF, 2001). Biodiversity corridors involve areas of vegetation that connect fragmented habitats, enabling species to move from one patch of forest to another and enhancing biodiversity (ForestrySA, 2022). In particular, the Sierra Madre covers 1.8 million hectares of land area in ten provinces, including Batanes, Cagayan, Isabela, Nueva Vizcaya, Quirino, Nueva Ecija, Aurora, Bulacan, Rizal, and Quezon. Furthermore, this corridor covers 40% of the country's primary forests and encompasses the most terrestrial protected areas, such as natural parks, forest reserves, and natural monuments. The largest protected area in the Philippines, namely the Northern Sierra Madre Natural Park, can be found in the northern range of the Sierra Madre mountains (CEPF, 2001). Several types of terrestrial forests can be found in the Sierra Madre Corridor, including tropical evergreen rainforests, montane rainforests, limestone forests, and ultramafic forests (CEPF, 2001). Being the largest province in the Philippines, the Pahlawan Corridor is covered with approximately 690,000 hectares of terrestrial forest, which involves a variety of forests similar to those in the Sierra Madre Corridor, such as tropical lowland evergreen forests, moist deciduous forests, and upper montane rainforests (CEPF, 2001; WWF, 2022). On the other hand, the Eastern Mindanao Corridor covers 2 million hectares of land, and nearly half of the areas are covered with forests (Philippine Eagle Foundation, 2008). The terrestrial ecosystems in the corridor are mainly dominated by lowland forests (63%), while the remaining comprises montane forests, with Mount Kampalili (2,499 m) as the highest peak in the region (Philippine Eagle Foundation, 2008). Nevertheless, anthropogenic causes such as commercial logging and mining activities have resulted in habitat degradation and biodiversity loss in the region (CEPF, 2001; Paz et al., 2013).

2.4.2 Biodiversity in the Philippines hotspot

The Philippines is home to more than 53,000 species, of which nearly 50% of its terrestrial vertebrates and around 60% of its vascular plants are endemic to the hotspot (Mona,

2016; Smith, 2017). Being one of the mega-diverse countries, it comprises more than 60% of the world's biodiversity and around 80% of flora and fauna in the world (Convention on Biological Diversity, n.d.). Specifically, the Philippines harbors around 1,500 terrestrial vertebrate species, including more than 200 mammal species, 690 bird species, 419 reptile species, and 120 amphibian species, of which nearly half of the terrestrial species are endemic to the region (BMB, 2016). In addition, 42 terrestrial mammal species, 127 bird species, 24 reptile species, and 14 amphibian species are classified as endangered in the Philippines (CBD, n.d.). For example, the Philippine eagle (*Pithecophaga jefferyi*), Philippine cockatoo (*Cacatua haematuropygia*), Tamaraw (*Bubalus mindorensis*), and the Philippine tarsier (*Tarsius syrichta*) are some examples of threatened species in the Philippines (BMB-DENR, 2016). There are a number of endemic species residing within the Sierra Madre Corridor, including 12 amphibian species, 21 mammal species, and 16 reptile species (CEPF, 2001). In another part of the Philippines, the Palawan Corridor hosts 11 amphibian species, 18 mammal species, 24 reptile species, and 25 bird species endemic to the Philippines. Moreover, more than 60% of the threatened species identified in the corridor are endemic (CEPF, 2001). A large proportion of the Philippines' flora and fauna can also be found in the Eastern Mindanao Corridor. Specifically, it encompasses more than 2,300 plant species, accounting for 31% of the Philippines' total number of plant species. The Eastern Mindanao Corridor also houses more than 370 vertebrate species, of which 180 are endemic to the Philippines (Philippine Eagle Foundation, 2008). In addition, 69 globally threatened flora and fauna are found in the corridor. For example, the Philippine eagle, the Philippine cockatoo, and the Philippine crocodile are some of the critically endangered species residing in the Eastern Mindanao Corridor (Philippine Eagle Foundation, 2008).

Key biodiversity areas (KBAs) also play a significant role in protecting and conserving biodiversity in the Philippines. This biodiversity hotspot comprises 228 key biodiversity areas,

101 of which are terrestrial KBAs, 77 are marine KBAs, and the remaining 50 are a combination of terrestrial and marine KBAs (BMB-DENR, 2016). These KBAs harbor more than 850 species of plants and animals, of which 196 are categorized as globally threatened species (Ambal et al., 2012). Nevertheless, less than 40% of the KBAs are situated within protected areas (see Table 10). Specifically, only 22% of the KBAs are completely protected, and 18% are partially protected, implying that more appropriate conservation initiatives are needed to preserve the KBAs in the Philippines.

Table 10. *Key Biodiversity Areas in the Philippines*

KBAs by Ecosystem Coverage	Area (km^2)	No. of KBAs	% of KBAs	No. of KBAs Protected	No. of KBAs Partially Protected
Terrestrial	51,249	101	44	27	25
Marine	19,601	77	34	8	6
Terrestrial + Marine	35,702	50	22	15	10
Total	106,552	228	100	50	41

Source: BMB-DENR (2016, p.35)

2.4.3 Threats to terrestrial biodiversity loss in the Philippines hotspot

Similar to other biodiversity hotspots in Southeast Asia, there has been a significant decline in biodiversity in the Philippines. Habitat loss and degradation, overexploitation, the introduction of invasive alien species, and rapid urbanization are the main pressures leading to biodiversity loss in the Philippines (Antonio et al., 2013; BMB-DENR, 2016). Habitat loss due to deforestation is not uncommon, especially within a biodiversity hotspot rich in tropical forests. In fact, the Philippines had lost approximately 1.3 million hectares of tree cover to deforestation between 2001 to 2020, resulting in 753 metric tons of carbon dioxide emissions (Global Forest Watch, 2021). Terrestrial biodiversity loss in the Philippines is also caused by rapid urbanization due to the burgeoning human population in the region. In this sense, forest areas are cleared for socio-economic development involving agricultural expansion,

plantations, forest products extraction, and infrastructure expansion (Antonio et al., 2013; BMB-DENR, 2016; CBD, n.d.). Furthermore, mining is another key factor causing habitat loss and degradation in the region (BMB-DENR, 2016). The Philippines is rich in metallic minerals, such as nickel, copper, and gold, yet many of the mineral reserves are located within key biodiversity areas (BMB-DENR, 2016; Philippine Council for Industry, Energy, and Emerging Technology Research and Development [PCIEERD], 2017). Although the mining industry has contributed significantly to the economic development in the Philippines, it has led to irreversible environmental impacts (PCIEERD, 2017). For instance, a large area of forests in Mindanao has been cleared for mining purposes, resulting in forest fragmentation and severe habitat loss (PCIEERD, 2017). Overexploitation is another anthropogenic cause of biodiversity loss in the Philippines. As evidence, the bird population (e.g., hornbills, parrots, cockatoos, etc.) in the Philippines forests, especially Mindanao and Palawan, is threatened by overhunting and illegal wildlife trading (BMB-DENR, 2016; Mayuga, 2021). Socio-economic development is inevitable, but humans are exploiting natural resources in an unsustainable manner, causing irrevocable damage to the terrestrial ecosystems and biodiversity in the Philippines.

3. Main anthropogenic causes of biodiversity loss in Southeast Asia terrestrial areas

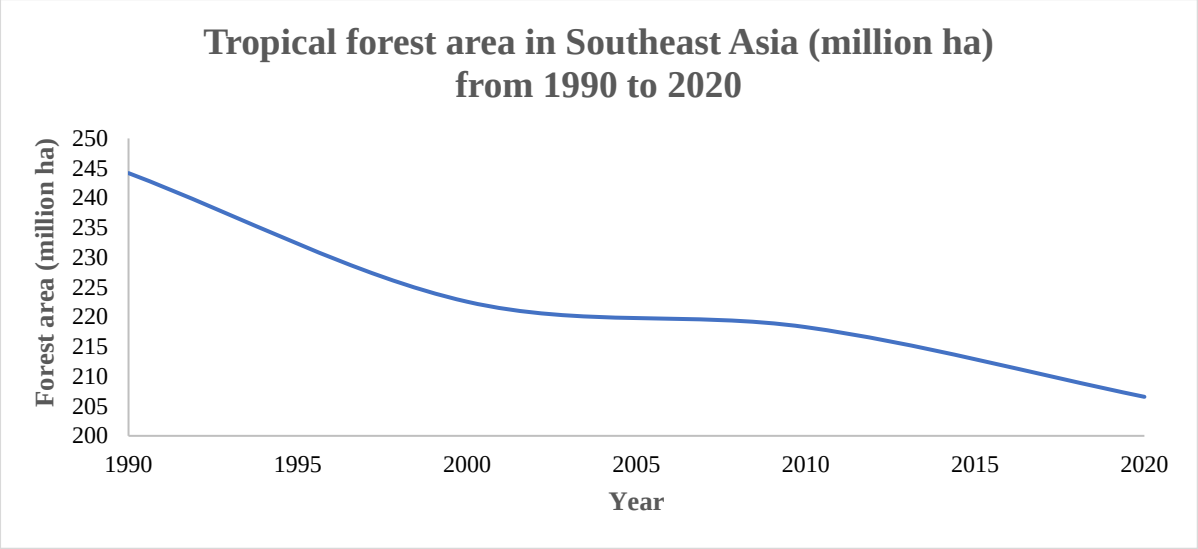
In Southeast Asia, the four main biodiversity hotspots mentioned above are in danger of losing more biodiversity if no further actions are taken to preserve and protect the biodiversity in the region. Correspondingly, research has discovered that Southeast Asia is severely threatened with biodiversity loss (Sodhi et al., 2010). Furthermore, the region is at risk of losing around 40% of its biodiversity by 2100 (Sodhi et al., 2004). Biodiversity loss in terrestrial areas in Southeast Asia is mainly driven by anthropogenic activities such as deforestation for socio-economic development and unsustainable use of natural resources (e.g., Burkmar & Bell, 2015; Convention on Biological Diversity, 2020b; Slingenberg et al., 2009). The details of each anthropogenic factor will be discussed in the following sections.

3.1 Deforestation

In addition to protecting natural habitats and conserving biodiversity, tropical forests in Southeast Asia also contribute to local communities' livelihoods and socio-economic development. 15% of the world's tropical forests are situated in Southeast Asia (Stibig et al., 2014), consisting of 207.5 million hectares of forest area. Of these forest areas, 92% were covered by natural forests, and the remaining areas were covered by plantation forests (FAO, 2020). However, Southeast Asia has the highest deforestation rate compared to other regions in the world (Russell, 2020). As evidence, the United Nations Food and Agriculture Organization (FAO) (2022) reported that Southeast Asia registered a loss of approximately 37 million hectares of tropical forest area from 1990 to 2020 (refer to Figure 3). Moreover, research purports that Southeast Asia will lose more than 70% of its tropical forests by 2100 if the rate of deforestation remains high (Achard et al., 2002).

Figure 3.

Tropical Forest Area in Southeast Asia from 1990 to 2020



Source: FAO (2020)

Of the Southeast Asia countries, Indonesia and Myanmar face the largest magnitude of deforestation, losing about 26 million ha and 10 million ha of forests within 30 years (1990 – 2020) (FAO, 2022). In other countries, such as Brunei, Timor Leste, and the Philippines, the areas of forest loss are comparatively small. On the other hand, encouragingly, some Southeast Asia countries have made tremendous efforts in expanding their forest areas, such as Singapore, Vietnam, and Thailand (see Table 11) (FAO, 2022). Deforestation in Southeast Asia has been largely driven by urbanization, agriculture (e.g., oil palm plantations), wildfire, forestry, and logging (Russell, 2020). The reasons for deforestation vary among different countries. For example, in Indonesia, the main drivers of deforestation involve oil palm plantation, timber plantation, conversion of forests to grasslands, mining activities, and commercial logging. Of which, oil palm plantation is the main driver of deforestation in Indonesia, resulting in 2.08 million hectares of forest loss, which accounted for a quarter of deforestation nationwide between 2001 to 2016 (Austin et al., 2019). In fact, Indonesia is the largest exporter of palm oil in the world, with an export volume of around 28 million metric tons in 2021 (Shahbandeh,

2022). Despite being a profitable industry, it has resulted in severe deforestation and habitat destruction, damaging the health of the natural ecosystems and causing biodiversity loss in Indonesia (Rifin, 2020). Furthermore, clearing forests for grasslands was another culprit of deforestation in Indonesia, which has led to 1.8 million hectares of forest loss (Austin et al., 2019). In other countries, such as Myanmar and Laos, the primary causes of deforestation include the expansion of agriculture, mining activities, illegal logging, and infrastructure development (Cook, 2018; Ministry of Natural Resources and Environmental Conservation Myanmar, 2020). In contrast to the results shown in Table 11, another study discovers no significant gain in the Philippines forest area despite the implementation of the National Greening Program, which aims to reforest the degraded forestlands in the Philippines from 2011 to 2016 (Perez et al., 2020). Specifically, there has been a decline in forest loss from 2011 to 2015, yet immense deforestation continued from 2016 to 2018. Consequently, deforestation offsets the reforestation efforts, resulting in no significant gain from the National Greening Program (Perez et al., 2020). To achieve more remarkable reforestation outcomes, efforts to curtail deforestation should also be executed simultaneously to complement the effective restoration of forests in the Philippines.

Table 11. *Forest Area in Southeast Asia Countries from 1990 to 2020*

	Forest area (hectares)	
Countries	**1990**	**2020**
Singapore	14,830	15,570
Brunei	413,000	380,000
Timor Leste	963,000	921,100
Philippines	7,778,810	7,188,590
Vietnam	9,375,900	14,643,090
Cambodia	11,004,790	8,068,370
Laos	17,843,000	16,595,500
Thailand	19,361,000	19,873,000
Malaysia	20,618,000	19,114,040
Myanmar	39,218,480	28,543,890
Indonesia	118,545,000	92,133,200

Source: FAO (2022)

3.1.1 Deforestation on mountains

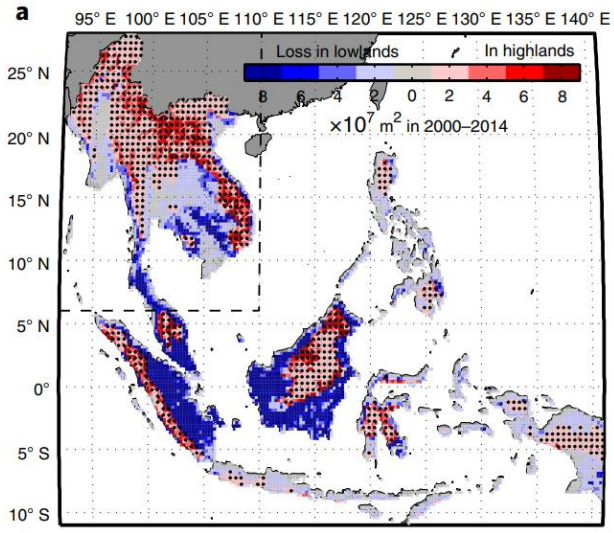
Studies have suggested that tropical deforestation usually occurs in lowland areas and is rarely observed in mountainous areas with relatively richer biodiversity and higher carbon stocks (Aide et al., 2019; Song et al., 2018; Zeng et al., 2018a). However, forest loss is gradually shifting to higher elevations and steeper slopes due to rapid croplands expansion and plantations over the past decade (Feng et al., 2021; Zeng et al., 2018b). Specifically, the average altitude of deforestation has escalated by 150 m over the past decade (Cross, 2021). For instance, a case study in Nan Province in Thailand shows that due to the lucrative market of corn, deforestation had begun to move upwards into mountainous areas since 2012 as a result of forest clearing for the cultivation of cornfields (Zeng et al., 2018b). In fact, approximately 18 million hectares of highland forests were cleared for agricultural expansion since the year 2000 (Cowan, 2021). Deforestation in mountainous areas has accounted for around 30% of the total forest loss in Southeast Asia (Cross, 2021). Likewise, another research found that Southeast Asia had lost around 3.22 million hectares annually from 2001 to 2019, of which 31% took place in mountainous areas, which have been converted into croplands and farms (Feng et al., 2021).

More worryingly, the rate of deforestation in highlands across Southeast Asia demonstrated an upward trend, increasing from 24% (the ratio of mountain forest-loss area to total forest-loss area) in 2001 to 42% in 2019 (Feng et al., 2021). As shown in Figure 4, considerable forest loss in highlands is primarily observed in mainland Southeast Asia (Cambodia, Thailand, Myanmar, Laos, and Vietnam), while deforestation of lowland forests is detected mainly in maritime Southeast Asia (Brunei, Timor-Leste, Malaysia, Singapore, Indonesia, and the Philippines), although small patches of forest loss are also evident in highlands (Zeng et al., 2018a). In line with the findings, another study reveals that rubber plantations have gradually expanded into the highland areas across Southeast Asia, including

Cambodia, Laos, Vietnam, Thailand, and Myanmar, indicating the occurrence of large-scale deforestation in mountainous areas (Fox et al., 2018). As aforementioned, highland forests in Southeast Asia generally store more carbon than lowland forests. In fact, forest loss in highland areas has accounted for more than 30% of Southeast Asia's total annual forest carbon loss (Cowan, 2021). Many species of mammals, birds, and amphibians that inhabit the mountains are at risk of going extinct if deforestation continues to accelerate in mountainous areas across Southeast Asia (Cowan, 2021). Hence, forest loss at higher altitudes in mountainous areas across Southeast Asia is a major issue, given these regions are incredibly rich in biodiversity and carbon stocks.

Figure 4.

Spatial Pattern of Forest Loss in Southeast Asia between 2000 – 2014



Source: Zeng et al. (2018, p. 558)

3.1.2 Consequences of deforestation on terrestrial ecosystem and biodiversity

Deforestation in Southeast Asia has compromised the tropical rainforests' capacity to store carbon and reduce carbon emissions, leading to 424 million metric tons of carbon emission annually, resulting in accelerated global warming (Cross, 2021). In fact, Southeast Asia contributed the most carbon emissions from deforestation and forest degradation (Pearson et al., 2017). It is not surprising that Indonesia and Myanmar are the countries that emit the most carbon into the atmosphere as a result of their large-scale deforestation (Sasaki et al., 2021). On the other hand, Vietnam and Thailand had the highest amount of carbon sequestered annually by their terrestrial ecosystems between 2000 and 2020 (Sasaki et al., 2021), which is on par with the increase in their forest areas (see Table 11). Worryingly, Southeast Asia is at heightened risk of losing USD 28 trillion in economic value over the next 50 years if no actions are taken to reduce carbon emissions in the region (Deloitte, 2021). However, if the countries act quickly to limit carbon dioxide emissions, Southeast Asia can gain USD 12.5 trillion, with an average GDP growth rate of 3.5% annually over the next 50 years (Deloitte, 2021). Failing to do so may result in accelerated global warming with an increase in temperature by more than 3ºC by 2070, eventually leading to extreme floods and droughts devastating to the well-being of the planet and human beings (Deloitte, 2021).

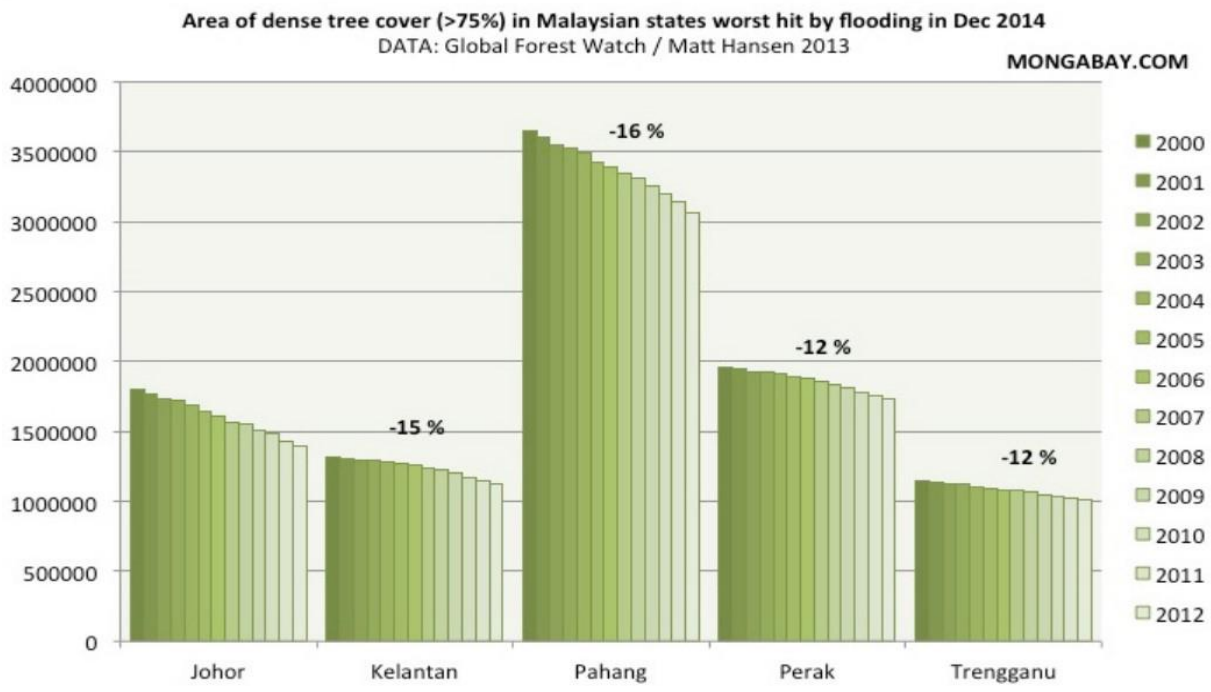
Deforestation and degradation of tropical forests in Southeast Asia have also resulted in significant loss of biodiversity and the extinction of critically endangered endemic species, such as Indochinese tigers, Asian elephants, and Bornean orangutans (Cross, 2021). It is likely that Southeast Asia may lose more than 50% of endemic species if large-scale deforestation continues to expand in the next century (Koh & Sodhi, 2010). In fact, around 85% of species will go extinct by the end of this century if the deforestation rate in Southeast Asia remains high (Sodhi & Brook, 2006). For example, deforestation on the Indonesian island of Sulawesi has resulted in dramatic declines in primate habitats in the past decade. This is partly a result

of habitat fragmentation caused by extensive deforestation in the region (Supriatna et al., 2020). Despite being classified as critically endangered species, the Borneon and Sumatran Orangutan are losing their habitats because of deforestation for palm oil plantations in Indonesia and Malaysia (Orangutan Conservancy, 2021). Without drastic interventions to reduce the deforestation rate in the region, experts believe that Orangutans may face complete extinction in the next ten years (Johnston, 2019). Moreover, habitat destruction resulting from deforestation has also led to a sharp decline in the tiger population in Malaysia (Perera, 2019). Specifically, the tiger populations in Malaysia have declined by more than 88% within 50 years – from more than 3000 in the 1950s to around 340 in the 2000s (Perera, 2019). Similarly, in Indonesia, the IUCN has declared the Balinese tigers (*Panthera tigris balica*) and Javan tigers (*Panthera tigris virgata*) as extinct species in 2003 due to rapid deforestation and habitat fragmentation (Mongabay, 2017). As can be seen, deforestation and forest degradation are evidently threatening the survival of species in Southeast Asia, especially the endangered species on the verge of extinction.

In addition to exerting adverse impacts on wildlife, deforestation can also cause harm to human beings. Floods and landslides are typical examples of calamities caused by massive deforestation (Campion, 2021). Specifically, logging activities cause soil erosion and lower forests' water retention capacity, resulting in increased flash floods in lowland areas (Butler, 2015). As evidence, in recent years, several Malaysian states, namely Selangor, Pahang, Kelantan, Johor, and Terengganu, have suffered serious floods because of the large-scale illegal logging activities in forest areas (Free Malaysia Today, 2021; Haroon, 2022), causing a total loss of RM 6.1 billion (Bedi, 2022). A similar tragedy happened in 2014 when Johor, Kelantan, Pahang, Perak, and Terengganu were hard hit by floods. On average, these states have lost more than 10% of their tree cover within 12 years (from 2000 to 2012) (see Figure 5). Without doubt, forest loss is the critical factor leading to floods in these Malaysian states (Butler, 2015).

Figure 5.

Area of Tree Cover in the Malaysian States between 2000 and 2012



Source: Butler (2015)

In 2014, illegal land clearing for agricultural expansion had led to a devastating landslide in Cameron Highland (situated in Pahang, Malaysia). Consequently, this disaster caused five deaths and displaced dozens of households (The Sun Daily, 2014). Correspondingly, Kalimantan was also struck by massive floods and landslides in 2021 due to immense deforestation for oil palm plantations (Campion, 2021). Unfortunately, 21 individuals were found dead, and more than 70,000 people were displaced by the floods. Simultaneously, damages to the infrastructures and buildings caused by the floods cost Kalimantan a total economic loss of USD 96.1 million (Campion, 2021). Evidently, massive floods and landslides can cause serious damage to physical properties, create unnecessary financial burdens, and endanger human lives. Therefore, it is crucial to take urgent measures to reduce deforestation in Southeast Asia.

3.2 Overexploitation of wildlife

Southeast Asia is one of the global hotspots for wildlife hunting and trading due to its rich biodiversity. Thus, overexploitation of wildlife remains a key threat to biodiversity in the region, which has led to a sharp decline in animal populations across Southeast Asia since the 1980s (Harrison et al., 2016; Hughes, 2017). Animals of more than one kg have greatly decreased in numbers (Harrison et al., 2016), such as the Indochinese tiger, the Burmese star tortoise, and the Javan rhinoceros (Brook et al., 2014; New Straits Times, 2020; Rostro-Garcia et al., 2014). Addressing the overexploitation issue can be more difficult when hunting and trade are conducted illegally. A research study discovers that 48% of amphibian and reptile species traded in Indonesia are listed as endangered, and 17% are fully protected (Natusch & Lyons, 2012). These figures clearly show that wildlife hunting and trading in the region are not properly monitored and reinforced with strict law enforcement, which may eventually result in irreversible biodiversity loss across Southeast Asia (Natusch & Lyons, 2012). In fact, illegal hunting in Southeast Asia is a more severe and immediate threat to biodiversity loss as compared to deforestation and habitat fragmentation (The ASEAN Post, 2019). Shockingly, illegal wildlife trading in Southeast Asia is worth more than USD 20 billion a year, making it one of the most profitable criminal trafficking enterprises in the region (The ASEAN Post, 2019). Furthermore, the Covid-19 pandemic has increasingly moved the illegal trading of wildlife online in recent years. The use of online platforms to facilitate wildlife trading has amplified the poaching issue as traffickers are able to better protect their identities using virtual private networks (VPNs) and fake accounts that are oftentimes not traceable (Fallin, 2021).

The burgeoning demand for traditional Chinese medicinal products, wild meats, and wild animals as pets in Southeast Asia is one of the primary reasons animal species are threatened with extinction (Hall, 2019; Harrison et al., 2016; Natusch & Lyons, 2012). For example, bear bile has been used in traditional Chinese medicine for thousands of years.

Dealers usually acquire bear bile by killing the bears and extracting bile juice from their gallbladders (Hall, 2019). According to a report by the United Nations Office on Drugs and Crime [UNODC] (2013), the estimated prices for bear gallbladders were between USD 50 (in Myanmar) and USD 2,000 (in Hong Kong). Undeniably, the lucrative market of bear bile has further exacerbated the issue of wildlife poaching. Moreover, most of the traditional Chinese medicine shops in Malaysia often sell bear bile openly, which is a prohibited item in the country, further putting the bear species at risk of extinction (Koshy, 2020). As a result of overexploitation and trafficking, the Malayan Sun bears and Asian black bears are listed as Vulnerable to Extinction by the IUCN (Asher, 2016). On the other hand, the presence of Asian elephants has made Indonesia, Vietnam, and Thailand the largest markets for the illegal trade of elephant ivory in Southeast Asia (Indraswari et al., 2020; WWF, 2015). As evidence, the Thai government had seized and destroyed two tonnes of illegal elephant ivory at a solemn ceremony in Bangkok in 2015 (WWF, 2015). Besides that, a study indicates that 8,508 products made from elephant ivories involving elephant tusks, pieces of jewelry, and decorative items were found offered for sale on various social media platforms within just a month across Indonesia, Thailand, and Vietnam (Indraswari et al., 2020).

Figure 6.

Harvested Elephant Ivory

Source: Svetlana Foote/Shutterstock.com

Figure 7.

Bracelet Made with Ivory

Source: Roman Tsymbal/Shutterstock.com

Besides being highly valued in the pet markets, Burmese Star Tortoises in Myanmar were also extensively harvested for food, shells, and medicinal purposes in China (Aung, 2018). More than 15 million turtles and tortoises were illegally hunted and traded each year in Myanmar (Aung, 2018). As a result, this species of tortoises is nearly depleted, eventually being classified as critically endangered by the IUCN (Platt et al., 2011).

Figure 8.

Burmese Star Tortoise

Source: Thanakarn Singto/Shutterstock.com

In addition, the wildlife trade between Myanmar and China has significantly endangered the pangolin species. Over one million pangolins were trafficked in the past ten years, making it

one of the world's most trafficked mammals (Castagnino, 2021). Although being listed as a critically endangered species by the IUCN, the Sunda pangolins are still threatened with poaching for their meats and scales that are believed to have medicinal value (IUCN SSC Pangolin, n.d.). In China, one pangolin was found to be sold for around USD 1,550 in 2007, amounting to more than USD 176 million annually (UNODC, 2013), making it a highly remunerative wildlife crime.

Figure 9.

Pangolin

Source: Vickey Chauhan/Shutterstock.com

Malaysia is also one of the popular hubs of the illegal wildlife trade due to its rich biodiversity (Koshy, 2020). As shown in the figure below, around 3,300 pig-nosed turtles and 29.8 tonnes of pangolin products were seized by relevant authorities in Malaysia (The ASEAN Post, 2019). Furthermore, in 2019 alone, the Thai authorities had seized around 2,730 rats, snakes, cobras, four tiger bones, and 1,666 pieces of bear claws, whereas a total of 25.6 tonnes of pangolin scales were confiscated by the Singapore government (see Figure 10) (The ASEAN Post, 2019). These statistics demonstrate that illegal hunting and trade are occurring at an alarming rate that can result in species extinction across Southeast Asia.

Figure 10.

Wildlife Trafficking Seizures in Southeast Asia

Source: The ASEAN Post (2019)

As can be seen, illegal hunting and trading have caused a substantial decline in the fauna biodiversity in Southeast Asia, putting many unique species into the critically endangered category. Undoubtedly, the trade parties involved in illegal hunting and wildlife trafficking need to come together to collectively and effectively address illegal wildlife hunting and trading in Southeast Asia (Esmail et al., 2020).

Taken together, it is evident that deforestation, forest degradation, and unsustainable hunting serve as the main anthropogenic activities causing deleterious impacts on terrestrial biodiversity and the ecosystems in Southeast Asia. To minimize the anthropogenic impacts, terrestrial protected areas have long been designated to conserve biodiversity and protect biologically important terrestrial areas in Southeast Asia. However, despite being protected, some protected areas are not efficiently managed, resulting in even worse outcomes as compared to non-protected areas. Detailed explanations on terrestrial protected areas will be outlined in the sections that follow.

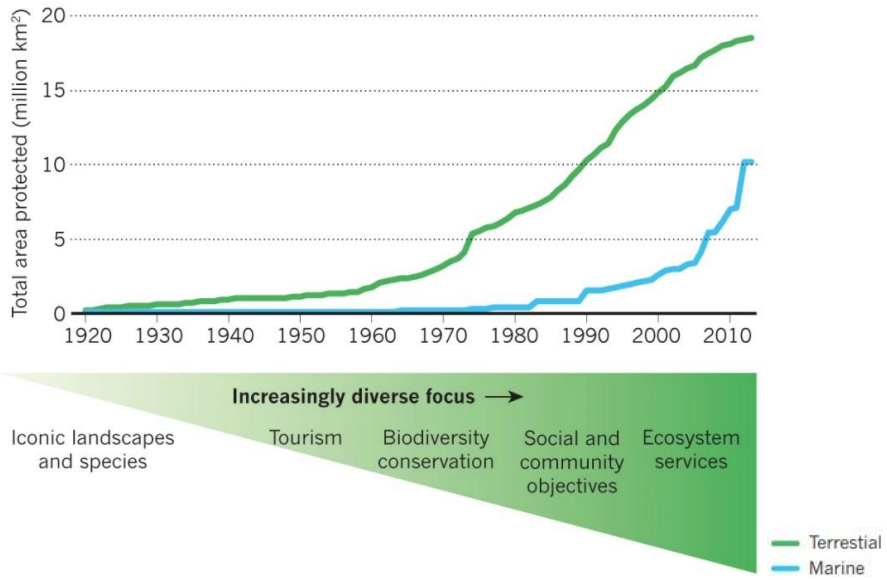
4. Terrestrial Protected Areas in Southeast Asia

4.1 Background

The protected area, one of the area-based measures, plays significant roles in protecting the environment, conserving biodiversity, minimizing habitat loss, and lowering the rate of species extinctions (Gray et al., 2016; Geldmann et al., 2014; Joppa et al., 2008). IUCN defines a protected area as "a clearly defined geographical space, recognized, dedicated, and managed, through legal or other effective means, to achieve long-term conservation of nature with associated ecosystem services and cultural values" (Dudley, 2008). While conserving and minimizing the loss of biodiversity, protected areas also contribute to people's livelihoods, which depend upon nature for sources of food, clean water supply, and protection against natural disasters (Dudley, 2008; Gray et al., 2016). According to a research study, the first official protected area in the world – Yosemite National Park in the United States, was established in 1864 to promote eco-tourism while conserving natural ecosystems (Watson et al., 2014). In later years, protected areas have been designated for increasingly diverse purposes, which include but are not limited to serving social and community objectives (e.g., contributing to the socio-economic development of local communities), and preserving ecosystem services (e.g., food security, clean water supply, climate regulation) essential for human beings (Watson et al., 2014).

Figure 11.

Historical Growth of the Modern Terrestrial and Marine Protected Area



Source: Watson et al. (2014, p. 68)

There are two main types of protected areas, namely terrestrial protected areas and marine protected areas. This paper focuses primarily on the former, which involves land areas that are made up of at least 1,000 hectares of completely or partially protected areas. Specifically, these areas have been selected to serve as scientific and nature reserves in which public access may be restricted partially or completely, protected landscapes, national monuments, national parks, wildlife sanctuaries, and areas that are designated for sustainable use of natural resources (The World Bank, 2022). In addition to government agencies, these protected areas are also managed by non-governmental organizations, private sectors, and local communities (Emerton et al., 2006). Globally, there has been a significant increase in terrestrial protected areas from 10% in 2000 to 15% in 2020 (Convention on Biological Diversity, 2020b). This conservation approach (e.g., the establishment of protected areas) has greatly reduced the extinctions of mammals and birds in the past decade (Convention on Biological Diversity, 2020b).

4.2 Different IUCN categories

To efficiently manage protected areas, IUCN has identified six categories of protected areas, such as Category 1a: Strict Nature Reserve, where human visitation is strictly controlled to preserve ecosystems and conserve biodiversity; Category 1b: Wilderness Area, which involves undisturbed or slightly modified areas that allow a certain extent of human access, with the objectives of preserving the ecological integrity of certain natural areas; Category 2: National Park, which involves natural areas set aside to protect ecosystems and the supporting ecological processes, and to contribute to educational and recreational purposes; Category 3: Natural Monument or Feature, which aims to protect specific natural sites and their cultural values; Category 4: Habitat/Species Management Area, where active management interventions are needed to protect particular species and reinstate habitats; Category 5: Protected Landscape/Seascape, which is managed mainly for biodiversity conservation and recreation purposes, where there is a balanced interaction between human and nature; and Category 6: Protected Area with Sustainable Use of Natural Resources, where biodiversity conservation and sustainable use of natural resources occur simultaneously, which is also vital in promoting socio-economic development of local communities.

Essentially, these six categories of protected areas serve different objectives with respect to particular situations, with the ultimate goal of conserving and protecting biodiversity and natural ecosystems while simultaneously safeguarding human welfare (Dudley, 2008). Refer to Table 12 for the different management objectives of each IUCN protected area management category. Specifically, each protected area category has its own primary and secondary management objectives (IUCN, 2000). See Table 13 for the number of terrestrial protected areas in each IUCN protected area category in Southeast Asia to date. The IUCN categories are not compulsorily applied uniformly across countries (Dudley, 2008). As shown in the table, different countries have taken different approaches to protect their terrestrial

ecosystem. For instance, Malaysia, Indonesia, and Thailand have relatively more terrestrial protected areas placed in category 1a - the strict nature reserves. Bidu-Bidu, Kelawat, and Mount Cochrane are examples of the IUCN category 1a terrestrial protected areas in Malaysia (Protected Planet, 2022). In contrast, little emphasis has been placed on establishing category 1b – wilderness areas across Southeast Asia countries (see Table 13). Based on statistics, Malaysia, Singapore, and the Philippines are the only countries that have established terrestrial protected areas of category 1a (Protected Planet, 2022). A research study has found that protected areas with minimal human footprints are more effective at conserving biodiversity (Gray et al., 2016). Yet, there is no relationship between the strictness of protected areas and species richness and abundance. This indicates that more restrictive protected areas do not imply higher species richness or biodiversity (Gray et al., 2016). Nonetheless, another study found that more strictly protected areas are more effective at conserving larger and threatened mammals (Ferreira et al., 2020). Although the strictness of protected areas varies by country and protection level, these protected areas serve the common goal of preserving biodiversity and the ecosystems in Southeast Asia.

Table 12. *Management Objectives of Each IUCN Protected Area Management Category*

Management objectives	IUCN protected area management categories						
	Ia	Ib	II	III	IV	V	VI
Scientific research	***	*	**	**	**	**	*
Wilderness protection	**	***	**	*	*	-	**
Preservation of species and genetic diversity	***	**	***	***	***	**	***
Maintenance of environmental services	**	***	***	-	***	**	***
Protection of specific natural and cultural features	-	-	**	*	*	***	*
Tourism and recreation	-	**	***	***	*	***	*
Education	-	**	**	**	*	-	-
Sustainable use of resources from natural ecosystems	-	*	*	-	**	**	***
Maintenance of cultural and traditional attributes	-	-	-	-	-	***	**

Source: IUCN (2000, p. 10)

Notes. *** Primary objective; ** Secondary objective; * Potentially applicable objective; - Not applicable

Table 13: *IUCN Terrestrial Protected Area Categories in Southeast Asia Countries in 2021*

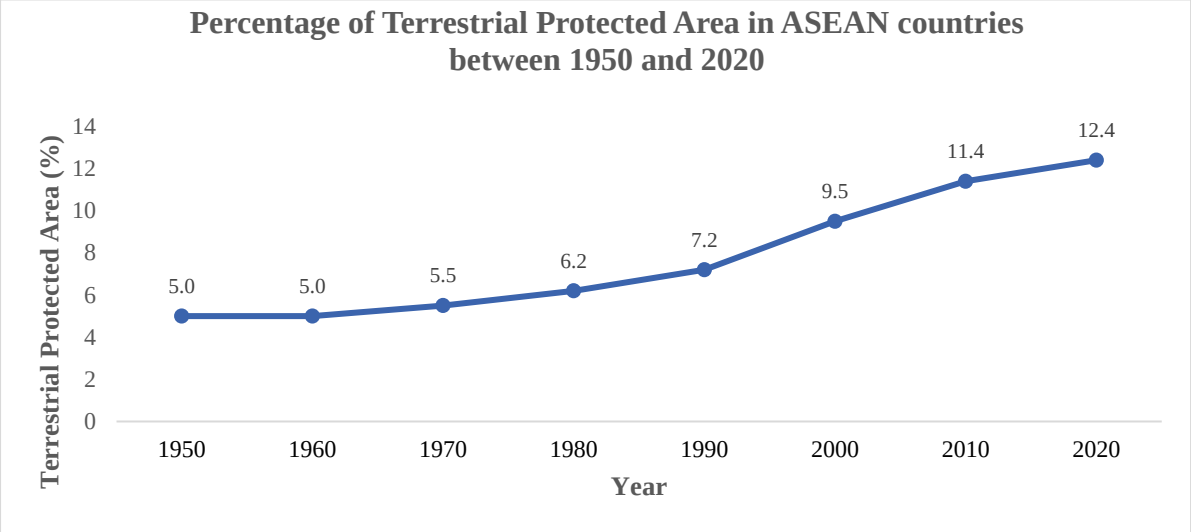
Countries	Terrestrial Protected Area Categories (no.)									
	Ia	**Ib**	**II**	**III**	**IV**	**V**	**VI**	**Not reported**	**Not applicable**	**Not assigned**
Malaysia	170	38	60	1	26	32	103	4	3	0
Singapore	-	3	-	-	-	-	-	-	-	-
Vietnam	-	-	23	-	32	23	-	81	4	-
Cambodia	5	-	11	2	18	14	14	-	1	-
Laos	-	-	3	-	1	-	20	7	-	-
Indonesia	136	-	39	61	56	90	41	105	7	-
Philippines	-	2	27	5	9	36	6	4	6	116
Thailand	58	-	121	12	-	-	1	5	5	-
Brunei	22	-	3	-	-	7	-	12	-	-
Myanmar	1	-	7	2	30	1	-	5	2	-

Source: UN Environment Program-World Conservation Monitoring Centre [UNEP-WCMC] (2022)

4.3 Current trends of marine protected areas in Southeast Asia

Figure 12.

Percentage of Terrestrial Protected Area of Southeast Asia Region between 1950 and 2020



Source: OECD Stat (2021)

Table 14. *Terrestrial Protected Area (%) in Southeast Asia Countries in 2021*

Countries	Total Land Area	Terrestrial Protected Area	
	km^2	km^2	%
Malaysia	331,701	44,205	13.33
Singapore	605	34	5.55
Brunei	5,962	2,794	46.87
Cambodia	182,511	72,527	39.74
Indonesia	1,906,555	231,946	12.17
Laos	231,276	43,220	18.69
Myanmar	673,079	44,289	6.58
Philippines	298,775	47,412	15.87
Thailand	517,787	96,038	18.55
Vietnam	329,880	24,994	7.58
Timor-Leste	15,007	2,401	16
TOTAL	**4,493,138**	**609,860**	**13.57**

Source: Protected Planet (2022)

As shown in Figure 12, terrestrial protected areas in the Southeast Asia region have more than doubled since 1950, increasing from 5% in 1950 to 12.4% in 2020, indicating a positive sign of conservation efforts (OECD Stats, 2021). The current pattern of terrestrial protected areas in each Southeast Asia country is shown in Table 14. Specifically, Southeast Asia's terrestrial protected areas cover 609,860 km^2, accounting for only 13.57% of the total terrestrial realm in Southeast Asia. As shown in Table 14, although Brunei has the highest percentage of terrestrial protected areas (46.87%) among the Southeast Asia countries, it has relatively small total land areas. In contrast, Indonesia has the largest total land area among the Southeast Asia countries, yet only 12.17% are designated as terrestrial protected areas (UNEP-WCMC, 2021). As can be seen, the ratios of total land areas and protected areas in these countries vary greatly. Based on the percentage of terrestrial protected areas, nearly half of the Southeast Asia countries, namely Brunei (46.86%), Cambodia (39.74%), Laos (18.69%), Thailand (18.55%), Timor-Leste (16%), and the Philippines (15.87%), are meeting or have already exceeded the Aichi Biodiversity Target 11. In short, this target calls for at least 17% of the terrestrial areas vital for biodiversity and ecosystem services to be optimally preserved and effectively protected through active conservation efforts (Convention on Biological Diversity [CBD], 2020a).

4.4 The 30 x 30 initiative

Environmentalists have advocated for the protection of 30% of land and ocean areas by 2030 (30 x 30 initiative) using protected areas and other effective area-based conservation measures, with the aims of conserving biodiversity and maintaining ecosystem services while simultaneously preserving the welfare of local communities (IUCN, 2021). However, although the Southeast Asia countries are rich in biodiversity (contains almost 20% of the world's biodiversity), Cambodia is the only Southeast Asia country participating in the 30 x 30 initiative, implying a lack of conservation efforts in other Southeast Asia countries (Taylor,

2021). The reluctance of other Southeast Asia countries to join the 30 x 30 initiative is probably because conservation initiatives are still regarded as a stumbling block to rapid economic development in these Southeast Asia countries (Taylor, 2021). According to the Southeast Asia Centre for Biodiversity (2017), Southeast Asia countries risk losing 70 to 90 percent of natural habitats as well as 13 – 42 percent of flora and fauna species by the year 2100 if no further preventive measures are taken to protect the biodiversity in the region. Furthermore, the recent outbreak of the COVID-19 has hindered the conservation efforts in Southeast Asia countries. This is mainly due to the restriction of non-essential economic activities, which include biodiversity conservation initiatives (Athira, 2020; Lawler et al., 2021). Consequently, this could substantially disrupt conservation efforts in the future.

5. Analysis of Terrestrial Protected Areas in Southeast Asia

5.1 Key benefits of terrestrial protected areas in the Southeast Asia region

The establishment of the Southeast Asia heritage parks, which have been defined as "protected areas of high conservation importance, preserving in total a complete spectrum of representative ecosystems of the Southeast Asia region" (Southeast Asia Centre for Biodiversity, 2015), is one of the collective conservation initiatives among the Southeast Asia countries in protecting biological diversity and recognizing the values of these protected areas. Fifty protected areas have been designated as Southeast Asia Heritage Parks as of 2021 (The Phuket News, 2021). For instance, there are nine Southeast Asia Heritage Parks in the Philippines alone, two of which are also gazetted as UNESCO World Heritage Sites, namely Tubbataha Reefs Natural Park and Mt. Hamiguitan Range Natural Park (The Philippine Clearing House Mechanism, n.d.). Likewise, Myanmar consists of eight Southeast Asia Heritage Parks, such as Inle Lake Wildlife Sanctuary, Alaungdaw Kathapa National Park, Hkakaborazi National Park, etc. (Southeast Asia Centre for Biodiversity, 2015). In essence,

these Southeast Asia Heritage Parks were established to conserve a wide array of ecosystems in the region and generate greater public awareness of the importance of preserving Southeast Asia's rich biodiversity for a sustainable future (Southeast Asia Centre for Biodiversity, 2015).

Effectively managed terrestrial protected areas play an essential role in curtailing the loss of biodiversity, preserving habitats and natural resources, maintaining ecosystem services that serve basic human needs, protecting against natural disasters, and improving climate resilience (Asamoah et al., 2021; Watson et al., 2014). Besides that, they also help reduce the poverty rate, promote eco-tourism, contribute to socio-economic development, and positively impact human well-being (Convention on Biological Diversity, 2008; Naidoo et al., 2019). For example, the Mount Kitanglad Range Natural Park (MKRNP), considered the most well-managed protected area in the Philippines, has contributed to ecosystem services, such as supplying clean water and hydroelectric to the surrounding communities (La Viña et al., 2010). Besides that, MKRNP also provides sustainable livelihood opportunities to the local communities and indigenous people through the eco-tourism industry (BIMP–EAGA, 2017). As another Southeast Asia heritage park, the Khakaborazi National Park, which is situated in northern Myanmar, is also a popular eco-tourism destination for foreign tourists and local travelers, contributing to environmental protection and economic development (Global New Light of Myanmar, 2021). Similarly, serving as the first ecosystem restoration concession in Indonesia, Hutan Harapan Initiative aims to reinstate Indonesia's biodiversity and ecosystem functions while providing the Batin Sembilan community with income-generating opportunities through sustainable use of natural resources in Hutan Harapan (Hutan Harapan, 2018). As a result, these initiatives have led to an increase in the percentage of terrestrial protected areas and reduced natural habitat loss in the Southeast Asia region over time (BIMP–EAGA, 2017).

In another instance, Taman Negara Pahang National Park, the first and oldest terrestrial protected area in Malaysia, also contributes substantially to biodiversity conservation and ecosystem services in the region. This 4,343-hectare national park spreads across Pahang, Kelantan, and Terengganu in Malaysia, with an approximate height of 2,187 meters above sea level (Southeast Asia Centre for Biodiversity, n.d.). It comprises rich biodiversity, housing more than 180,000 fauna, 250 bird species, 50 reptile species, 50 amphibian species, and 100 fish species. Besides serving as the natural habitat for the various species, the establishment of this national park has also promoted eco-tourism activities in the region, including river cruises, jungle trekking, bird watching, canoeing, and visitation to the Orang Asli settlement (Southeast Asia Centre for Biodiversity, n.d.). In addition, the Department of Wildlife and National Parks has taken steps to involve the local communities in preserving and managing the national park. As a result, the majority of indigenous people – the Orang Asli – engage in eco-tourism activities that reconcile the conservation of biological diversity with economic development. In other words, it helps improve the livelihoods of the indigenous people and protect the natural habitats simultaneously. Moreover, the indigenous knowledge of medicinal plants is useful for pharmaceutical companies searching for new drugs vital to public health (Bakar, 2018). As can be seen, terrestrial protected areas such as national parks are beneficial for both biodiversity conservation and the socio-economic development of local communities.

5.2 Shortfalls of terrestrial protected areas in the Southeast Asia region

Prior to the COVID-19 pandemic, there were already many challenges associated with managing terrestrial protected areas in the Southeast Asia region. There is no rose without a thorn. Despite the increasing number of terrestrial protected areas in the Southeast Asia region and their encouraging biodiversity outcomes mentioned earlier, there are some controversial issues to these terrestrial protected areas. In fact, 70% of terrestrial protected areas in the Southeast Asia region are under intense human pressure, signifying that the degree of

protection provided by these terrestrial protected areas is not up to expectation (Jones et al., 2018). In particular, terrestrial protected areas under intense human pressure have increased by 55.2 % from 1993 to 2009 (Verma et al., 2020). Moreover, some of these protected areas are not effectively managed to safeguard the natural habitats and species residing in these areas (WWF, 2020). For example, Indonesia consists of more than 220,000 km^2 of terrestrial protected areas, yet 10% of the regions have been degraded. In addition, there was a significant reduction in the forest cover in most of Indonesia's terrestrial national parks between 2012 and 2017 due to rapid infrastructure development, land transformation, and increasing human population in these regions (Dwiyahreni et al., 2021). In fact, the rate of deforestation in the terrestrial protected areas in Sumatra (one of the largest islands in Indonesia) is similar to that in other production forest areas in Indonesia, overthrowing the conservation purposes of the terrestrial protected areas (Dwiyahreni et al., 2021). In addition to stimulating socio-economic development, the deforestation issue also intensifies due to a lack of appropriate forest management resources (Gaveau et al., 2012). More worryingly, deforestation within the terrestrial protected areas in Indonesia, especially the Sebangau National Park, has also contributed to tons of carbon emissions every year, resulting in global warming (Benji, 2017). Realizing the detrimental impacts of carbon emissions, the Krombacher Climate Protection Project was established by WWF to reduce carbon emissions and curtail forest degradation in Sebangau National Park (WWF Deutschland, 2019).

Besides that, while there are a considerable number of terrestrial protected areas in the Southeast Asian countries, many have failed to protect and conserve certain endemic species. For example, Sumatran primates and tigers residing in the terrestrial protected areas in Indonesia have declined significantly due to the high deforestation rates (Supriatna et al., 2017; Wibisono & Pusparini, 2010). These endemic species are less likely to survive in highly fragmented and disturbed habitats where illegal logging, hunting, land conversion, and other

human activities occur frequently. A study discovered that a species of the Sumatran primates, namely *Macaca Tonkeana*, had lost 4% of their forest habitats in terrestrial protected areas to deforestation between 2000 and 2017 (Supriatna et al., 2020). Other than that, illegal hunting in terrestrial protected areas has also put Sumatran tigers' lives in danger. As evidence, recent news reported that three Sumatran tigers were found dead in a protected area in Banda Aceh (a province in Indonesia) as a result of poaching activities (Daniel, 2021). Although tiger poaching is an offense punishable with hefty fines and imprisonment in Indonesia, many are still involved in poaching activities to make money by selling the Sumatran tigers or their parts to wildlife traffickers (WWF, 2011). In fact, tiger poaching for commercial trade is an extremely lucrative business in Indonesia. Tiger bones are allegedly high in medical value and are usually exported to neighboring countries at sky-high prices to supply the demand for traditional Chinese medicine (Wibisono & Pusparini, 2010). Additionally, Bornean banteng (*Bos javanicus lowi*), a critically endangered wild bovid in Sabah, is also at risk of extinction due to continuous habitat loss, forest fragmentation, and intense poaching within the terrestrial protected areas (Kristy, 2017; Lim et al., 2019). As of 2021, there are only 320 Bornean bantengs left in the forest in Sabah (Paul, 2021). To protect these critically endangered species against extinction, well-trained forest guards are needed to prevent further poaching and illegal logging activities within the terrestrial protected areas.

Poor representation of habitats also serves as another problem with the current terrestrial protected area. In particular, the Southeast Asia region's terrestrial protected areas are mainly located in mountainous areas. As a result, some of the key biodiversity areas are left unprotected as they are primarily located in biologically diverse lowland forests (Verma et al., 2020). The placement of protected areas at high altitudes is largely due to the low economic value of the less-accessible mountainous areas (Singh et al., 2021). For instance, the majority of terrestrial protected areas in Thailand are in areas of high altitudes, which are less likely to

cover a good range of altitudes to preserve a wide array of endemic species (Singh et al., 2021). Correspondingly, some of the key natural habitats remain outside the terrestrial protected areas in Indonesia (Supriatna et al., 2017). Sumatra endemic primates, such as the Pagai langur (*Presbytis potenziani*) and the Pagai macaque (*Macaca pagensis*), reside in lowland forests, which are not represented in any of the terrestrial protected areas and national parks in Indonesia. Clearly, there is an apparent discrepancy between the government-declared terrestrial protected areas and the areas that environmentalists have designated for biodiversity conservation. Nevertheless, these biodiversity conservation issues have been largely ignored by the government and the private sector (Supriatna et al., 2017). This may be due to the fact that Indonesia's Government still sees biodiversity conservation as impeding economic development (Dwiyahreni et al., 2021). Analogous to Indonesia, the Philippines' terrestrial protected areas fail to achieve the requirements of the Aichi Target 11 established by the Convention on Biological Diversity (CBD), which urges Southeast Asia nations to conserve and effectively manage land areas that are of utmost importance for biodiversity and ecosystem services (Mallari et al., 2016). As shown in Figure 2, although the Philippines is reaching the Aichi Target 11, 64% of its key biodiversity areas in the Philippines are still not covered in the system of protected areas such as national parks and reserves (Mallari et al., 2016). For example, most of the endemic bird areas in the Philippines are not located within the terrestrial protected areas (Mallari et al., 2016). As can be seen, many of the terrestrial protected areas in the Philippines are not appropriately located to protect sites essential for biodiversity conservation, signifying a mismatch between key biodiversity distribution and terrestrial protected areas in the Philippines.

Some terrestrial protected areas are less effective than other unprotected areas at reducing deforestation and conserving biodiversity. For example, there has been a substantial forest loss (97,007 hectares) within the terrestrial protected areas in the Philippines in recent

decades (Apan et al., 2017), which has resulted in immense forest fragmentation and biodiversity loss (Estoque et al., 2018). Moreover, poorly implemented environmental legislation has driven illegal logging even within the protected areas in the Philippines. Yet, the government authorities turn a blind eye to these logging activities as the surrounding poor rural villagers rely heavily on timber revenue for their sources of income (Ploeg et al., 2011). Infuriatingly, illegal logging activities persist in Sierra Madre Mountain Range, the largest terrestrial protected area in the Philippines, despite the COVID-19 pandemic in recent years (Jonathan, 2020). Furthermore, almost half of the terrestrial protected areas in the Philippines lack proper management systems and capacities, which are vital for biodiversity conservation (Mallari et al., 2016). In particular, only 15% of the terrestrial protected areas have finalized management plans approved by the Protected Area Management Boards. The shortage of budget, staffing, and research activities is another critical issue leading to poor biodiversity conservation management in the Philippines' terrestrial protected areas (Mallari et al., 2016). Terrestrial protected areas in Indonesia are also faced with deforestation issues. For instance, the Tesso Nilo National Park, which forms the largest lowland rainforest in Sumatra, experienced substantial habitat loss due to illegal logging and rapid road construction within the protected areas. In fact, a study found that the level of human footprint within Category 1a terrestrial protected areas (strict nature reserve) is significantly higher than other categories of protected areas within the Southeast Asia region (Verma et al., 2020). This finding contrasts the main objectives of IUCN Category 1a protected areas, which insinuates that the protected areas are strictly set aside for biodiversity conservation and where human activities are strictly limited (Dudley, 2008). For instance, one of the strict nature reserves in Indonesia suffers from higher deforestation rates than other logging concessions, suggesting that logging concessions provide a higher success rate of halting deforestation compared to terrestrial protected areas in Category 1a (Brun et al., 2015). If deforestation and degradation persist in these terrestrial

protected areas, it can eventually result in the extinction of endangered endemic species that inhabit the forest and accelerate climate change (Poor et al., 2019). The ineffective management of these protected areas might be due to the low budget allocated for biodiversity management. Based on calculations of funding requirements, Indonesia lacks approximately USD 522 million of conservation funding per year from 2010 through 2020 (Ministry of National Development Planning of the Republic of Indonesia, 2016 – see Table 16).

Table 16. *Conservation Fund Deficiency for Protected Area Management in Indonesia between 2010 to 2020*

Description	Value
Lack of conservation cost per hectare	USD 1,352
Lack of conservation cost	USD 521, 930

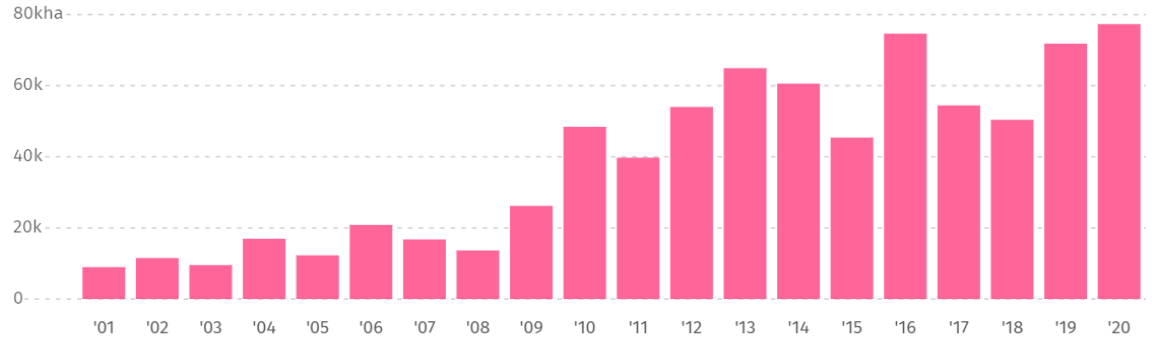
Source: Ministry of National Development Planning of the Republic of Indonesia (2016)

Clearly, expanding terrestrial protected areas alone is not enough to address biodiversity loss; sufficient funding and proper law enforcement are much needed to address the shortcomings of these poorly managed terrestrial protected areas. Besides that, community engagement and the involvement of local communities in the terrestrial protected areas management are also necessary to protect the forest areas against all forms of exploitation (Poor et al., 2019).

In another example, Cambodia had lost approximately 770,000 hectares of tree cover in the protected areas between 2001 and 2020, representing a 14% loss of tree cover since 2001 (see Figure 12). In particular, there has been a significant increase in tree cover loss since 2010 throughout 2020. The bulk of tree cover loss has led to 480 metric tons of carbon emissions in Cambodia within these 20 years (Global Forest Watch, 2020). Moreover, one of the protected areas has been de-gazetted due to substantial deforestation, leaving a devastating impact on the socio-economic development of the indigenous people and local communities who primarily depend on the forest resources for their livelihoods (Global Initiative Against Transnational Organized Crime [GIATOC], 2021).

Figure 12.

Tree Cover Loss in Protected Areas in Cambodia from 2001 to 2020



Source: Krasek (2019)

Paradoxically, some of the government-sanctioned territorial concessions, including economic and social land concessions, are placed within the protected areas in Cambodia. As of 2012, 113 economic land concessions inside protected areas have been approved by the Cambodia Ministry of Environment (GIATOC, 2021). Alarmingly, illegal logging also occurs outside the logging concessions boundary within the protected areas. However, government officials' negligence and lack of action have further allowed logging companies (e.g., Think Biotech, Angkor Plywood, etc.) to carry out large-scale deforestation in the protected areas with assistance from local communities. In particular, these companies outsourced the logging tasks to local communities and stayed aloof from the actual task of logging itself. Moreover, the logging companies also involved local communities in selling resin trees and allowed them to reap benefits from the deals (GIATOC, 2021). For instance, tonnes of trees in some of the wildlife sanctuaries in Cambodia (e.g., Prey Lang, Prey Preah Roka, etc.) have been extensively harvested and then traded illegally (GIATOC, 2021). As can be seen, the rate of deforestation in the protected areas is comparable to other unprotected areas nationwide, creating controversial issues to the protected area approach (Theilade & De Kok, 2015).

Lack of connectivity between terrestrial protected areas also serves as another problem facing the effectiveness of protected area management (Convention on Biological Diversity,

2020a; WWF, 2020). Some countries fail to take into account the structural connectivity between terrestrial protected areas when expanding their terrestrial protected area networks (Ward et al., 2020). In fact, only 9.7% of global terrestrial protected areas are structurally linked, and on average, around 11% of each country's protected areas are connected (Ward et al., 2020). Furthermore, none of the terrestrial protected areas are found interconnected in some Southeast Asia countries, such as Thailand, Myanmar, Vietnam, and Laos, indicating a severe shortfall in the protected area management (Ward et al., 2020). Structurally connected landscapes are crucial in enabling seasonal animal migrations and enhancing ecosystem resilience (Lundberg & Moberg, 2003; Tucker et al., 2018). Some species tend to migrate to other landscapes seasonally to look for food and water, as well as more favorable living and breeding conditions. Climate change has also prompted some temperature-sensitive species to move away from their ancestral lands and seek new habitats in other areas with more suitable temperatures (Heller & Zavaleta, 2009; Ward et al., 2020). Nonetheless, fragmentation of terrestrial protected areas has limited the possibility of animal migration, which can result in species extinctions due to their inability to adapt to climate change (Heller & Zavaleta, 2009). Besides that, species extinctions often occur in small, fragmented habitats rather than large connected habitats. This is because some large animal species, such as bears and big cats (e.g., lions, tigers, leopards, etc.), require larger areas of natural habitat for food hunting and reproduction (WWF, 2020). For example, studies state that the survival of critically endangered species such as saola (*Pseudoryx nghetinhensis*) and Indochinese tigers (*Panthera tigris Linnaeus*) is heavily dependent upon the structural connectivity between terrestrial protected areas in Southeast Asia (Lynam, 2010; Stone, 2006). Undoubtedly, a high level of connectivity between terrestrial protected areas is one of the key solutions to ensure effective conservation and the survival of many species, especially under anthropogenic climate change in the 21st century (Convention on Biological Diversity, 2020b; Ward et al., 2020). Thus, more corridors between the terrestrial

protected areas must be established to enable the movement of species from one protected habitat to another, which is also vital in enhancing biodiversity conservation.

6. Moving Forward

Although Southeast Asia countries have devised and implemented strategic plans to manage their terrestrial protected areas, there are many challenges halting the effective management of these protected areas. Therefore, remedial measures are urgently needed to address the shortfalls of these protected areas to ensure the sustainability of biodiversity and ecosystem services. Several preventive and restorative measures that can help monitor and ensure the effectiveness of terrestrial areas in the Southeast Asia region are discussed in the following paragraphs.

6.1 Inclusion of local communities in the protected area management

Government and NGOs such as WWF should encourage indigenous people and local communities to actively involve themselves in the protected area decision-making process. Indigenous peoples hold primary responsibilities for managing natural habitats and protecting 80% of biodiversity worldwide (Gleb, 2018). They inhabit at least 38 million km^2 of land that spans 87 countries and overlap with 40% of all terrestrial protected areas (Garnett et al., 2018). Local indigenous knowledge and practices are essential in contributing to sustainable ecosystem management and simultaneously safeguarding the livelihoods of local communities (UNEP, 2020). Furthermore, it is relatively easier to enforce conservation policies and implement sound initiatives when the knowledge and opinions of local communities are regularly taken into consideration in protected area management (Andrade & Rhodes, 2012). The inclusion may promote a sense of ownership, which encourages the local communities to jointly protect their homelands against exploitation and sustainably utilize natural resources (Andrade & Rhodes, 2012). Moreover, studies have shown that indigenous lands are more

successful in halting deforestation and conserving biodiversity than protected areas (Barrow et al., 2016; Tauli-Corpuz et al., 2020). Indigenous people are more adept at utilizing traditional conservation strategies and systems to protect the lands in a sustainable manner, owing partly to the traditions and spiritual beliefs that these sacred lands and forests are where the natural gods/spirits belong (Chunhabunyatip et al., 2018). For example, the Lua people, who were the first colonizers in Chiang Mai (Thailand) 1,300 years ago, tend to manage and preserve natural resources based on their beliefs in the spirits of the forests. As a result, they have demonstrated the ability to protect essential natural resources and sustain ecosystem services in ways that contribute to biodiversity conservation and the livelihoods of local communities (Chunhabunyatip et al., 2018). Success stories involving the inclusion of indigenous communities in protected area management also happened in the Jawa Bali bioregion in Indonesia. Jawa Bali successfully maintained and even gained forest cover despite the highest human footprint within and outside its terrestrial protected areas. This is because the Balinese believe that cutting trees on a daily basis is taboo. Instead, they adhere strictly to the Brubuh system, a traditional seasonal logging practice that only allows communities to cut down trees on a seasonal basis. As a result, these cultural customs have contributed significantly to forest preservation and biodiversity conservation (Dwiyahreni et al., 2021). As such, policymakers and conservationists are encouraged to actively engage indigenous communities in protecting and managing terrestrial protected areas in the Southeast Asia region – for instance, involving them in forest patrolling to combat illegal activities (e.g., illegal logging, poaching, timber smuggling, etc.) in the protected areas. Incentives such as income and recognition are crucial to encourage indigenous communities to be involved in managing terrestrial protected areas. In fact, this remedial measure is in line with the Aichi Target 18 set by the CBD, which asserts that the local and traditional knowledge, innovations, and practices should be incorporated into

biodiversity conservation and ecosystem management, alongside the active participation of indigenous and local communities, by 2020 (CDB, 2020).

6.2 Reforestation and afforestation within protected areas

As aforementioned, some terrestrial protected areas suffer from higher deforestation rates than logging concessions and other unprotected areas, compromising the effectiveness of protected areas in conserving biodiversity (Brun et al., 2015; Verma et al., 2020). Thus, reforestation and afforestation within protected areas are urgently needed to restore biodiversity and ecosystem services in the long run. For example, Vietnam has successfully increased its forest coverage from 32% in 1998 to 39.5% in 2010 through the Five Million Hectare Reforestation Program (5MHRP). In this project, local communities such as upland farmers were subsidized to afforest and reforest the mountainous areas. Moreover, 5MHRP has also helped create ample employment opportunities and improved the livelihoods of local communities (OECD, 2018). Likewise, AstraZeneca has recently launched the AZ Forest Programme in Indonesia, pledging to plant 20 million trees by 2025. The first 1.5 million trees were planted in Tanjung Puting National Park, Kalimantan, while another 600,000 trees were planted in the Citarum River Basin, West Java, in 2020. This program will likely contribute to various sustainability benefits: species biodiversity enrichment, natural habitat maintenance, rainforest restoration, forest fires prevention, more effective flood management systems, climate change mitigation, job opportunities, and greater socio-economic development (AstraZeneca, 2020). To further ramp up reforestation and afforestation efforts, the Southeast Asia Green Initiative, a region-wide conservation initiative established by Southeast Asia, was introduced in 2021 with the goal of planting at least 10 million native trees within ten years (Joyce Ann, 2021). This greening project takes a whole-of-society approach through collaborative efforts among the Southeast Asia countries to reinstate degraded lands and curb biodiversity loss for a sustainable future (Joyce Ann, 2021).

Clearly, reforestation and afforestation play significant roles in restoring the ecosystem and biodiversity. As such, urgent actions are needed to reforest and afforest certain terrestrial protected areas where rapid deforestation and fragmentation take place to reinstate biodiversity and the ecosystem.

6.2 Other effective measures in improving the effectiveness of terrestrial protected areas in Southeast Asia

In addition to reforestation and involvement of local communities in protected area management, long-term maintenance of protected areas relies heavily on sustainable revenue streams from diverse sources (Emerton et al., 2006; Watson et al., 2014). In fact, terrestrial protected areas regularly suffer from inadequate budgets and investments from the public and private sectors, leading to ineffective management (IUCN, 2020c). A large proportion of the public funding often goes into supporting other development objectives, such as education, public health, and infrastructure development, leaving only a small amount of budget to enhance the effectiveness of the country's protected areas (IUCN, 2000). Furthermore, in recent years, governments have reallocated funding to health-related services and industries to help curb the spread of the Covid-19, leading to a further reduction in the amount of funding set aside for biodiversity conservation (Lawler et al., 2021). Some protected areas have been closed to tourists and visitors in response to the Covid-19 pandemic, causing a substantial decline in the revenues generated from eco-tourism, which also plays an essential role in sustaining the effective management of protected areas (Gokkon, 2020; IUCN, 2020b). Undeniably, adequate financial resources are tremendously important, especially in recruiting and training management staff (e.g., site maintenance managers, anti-poacher patrols, park rangers, etc.), purchasing necessary equipment, and building infrastructures essential to effectively managing and protecting terrestrial protected areas (O'Flynn et al., 2021). In addition, with sustainable sources of funding, conservationists can better plan and design the

expansion of terrestrial protected area networks in Southeast Asia (Bruner et al., 2004; Watson et al., 2014). Therefore, conservationists should actively seek diversified and sustainable financing resources to sustainably support the effective management of these protected areas.

Other than that, Southeast Asia countries should also continue expanding their terrestrial protected area networks to achieve the Aichi Target 11, which calls for at least 17% of terrestrial areas of particular importance for biodiversity and ecosystem services to be effectively protected and managed (CBD, 2020). As shown in Table 14, nearly half of the countries in Southeast Asia are far from achieving the Aichi Biodiversity Target 11, including Malaysia, Singapore, Indonesia, Myanmar, and Vietnam. Hence, these countries need to ramp up their efforts in expanding their terrestrial protected areas to achieve the Aichi Biodiversity Target 11, which is essential in preserving biodiversity in Southeast Asia. Furthermore, it is also crucial to take into account the structural connectivity between protected areas (Ward et al., 2020), the representation of different species within proposed protected areas (Arabian et al., 2019), and the costs of protected areas expansion and management when deciding whether to expand the protected area networks (Watson et al., 2014). Lastly, the extent to which the expansion of terrestrial protected areas in Southeast Asia countries achieves other biodiversity targets (e.g., Aichi Target 5 – reduce habitat loss, Aichi Target 12 – reduce species extinctions, Aichi Target 14 – safeguard ecosystem services, etc.) should also be considered when expanding terrestrial protected area networks in order to achieve synergies between different biodiversity targets and subsequently enhance management effectiveness of terrestrial protected areas (Di Marco et al., 2016).

7. References

Aide, T. M., Grau, H. R., Graesser, J., Andrade-Nunez, M. J., Araoz, E., Barros, A. P., … Zimmerer, K. S. (2019). Woody vegetation dynamics in the tropical and subtropical Andes from 2001 to 2014: Satellite image interpretation and expert validation. *Global Change Biology, 25*(6), 2112–2126. https://doi.org/10.1111/gcb.14618

Ambal, R. G. R., Duya, M. V., Cruz, M. A., Coroza, O. G., Vergara, S. G., … Tabaranza, B. (2012). Key biodiversity areas in the Philippines: Priorities for conservation. *Journal of Threatened Taxa, 4*(8), 2788–2796. https://doi.org/10.11609/JoTT.o2995.2788-96

Andrade, G. S. M., & Rhodes, J. R. (2012). Protected areas and local communities: An inevitable partnership toward successful conservation strategies? *Ecology and Society, 17*(4), 14. http://dx.doi.org/10.5751/ES-05216-170414

Antonio, P. C., Bugayong, L. A., Dolom, P. C., Garcia, L. N., Villanueva, M. B., & Espiritu, N. O. (2013). *Analysis of key drivers of deforestation and forest degradation in the Philippines.* Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. https://forestry.denr.gov.ph/redd-plus-philippines/publications/Analysis%20of%20key%20drivers%20of%20deforestation%20and%20forest%20degradation%20in%20the%20Philippines.pdf

Apan, A., Suarez, L. A., Maraseni, T. & Castillo, J. A. (2017). The rate, extent, and spatial predictors of forest loss (2000–2012) in the terrestrial protected areas of the Philippines. *Applied Geography, 81,* 32–42. https://doi.org/10.1016/j.apgeog.2017.02.007

Arabian, J., Currie, J., & Snider, J. (2019). *Terrestrial analysis of ecological representation.* WWF. https://wwf.ca/wp-content/uploads/2020/06/Terrestrial-Analysis-of-Ecological-Representation.pdf

Asher, C. (2016, August 1). Malayan Sun bear: Bile trade threatens the World's smallest bear. *Mongabay.* https://news.mongabay.com/2016/08/malayan-sun-bear-bile-trade-threatens-the-worlds-smallest-bear/

AstraZeneca. (2020, December 16). *AZ Forest Indoensia: 20 million trees to be planted by 2025.* https://www.astrazeneca.com/media-centre/articles/2020/az-forest-indonesia-20-million-trees-to-be-planted-by-2025.html#:~:text=To%20commence%20the%20reforestation%20programme,end%20of%20the%202020%20season.

Athira, N. (2020, September 14). Protecting nature in a pandemic. *The Southeast Asia Post.* https://theSoutheast Asiapost.com/article/protecting-nature-pandemic

Aung, M. M. (2018, July 23). Myanmar's 27 turtle species 'facing extinction'. *Myanmar Times.* https://www.mmtimes.com/news/myanmars-27-turtle-species-facing-extinction.html

Austin, K. G., Schwantes, A., Gu, Y. F., & Kasibhatla, P. S. (2019). What causes deforestation in Indonesia? *Environmental Research, 14,* 024007. www.sciencedaily.com/releases/2019/02/190201130603.htm

Bakar, A. N. (2018). Community participation in the management of protected area (PA): A case of Pahang National Park, Malaysia. In M. N. Suratman (Eds.), *National Parks - Management and Conservation.* IntechOpen. https://doi.org/10.5772/intechopen.73048

Barrow, E., Kamugisha-Ruhombe, J., Nhantumbo, I., Oyono, R., & Savadogo, M. (2016). Who owns Africa's forests? Exploring the impacts of forest tenure reform on forest ecosystems and livelihoods. *Forests, Trees and Livelihoods, 25*(2), 132–156. https://doi.org/10.1080/14728028.2016.1159999

Bedi, R. S. (2022, January 28). Malaysia massive floods result in RM6.1 billion losses, Selangor worst hit. *Channel News Asia.* https://www.channelnewsasia.com/asia/malaysia-floods-2021-2022-losses-statistics-department-2465656

Brun, C., Cook, A. R., Lee, J. S. H., Wich, S. A., Koh, L. P., & Carrasco, L. R. (2015). Analysis of deforestation and protected area effectiveness in Indonesia: A comparison of Bayesian spatial models. *Global Environmental Change, 31*, 285–295.

Brunei Darussalam-Indonesia-Malaysia-Philippines - East Southeast Asia Growth Area (BIMP–EAGA). (2017). *Case studies on sustainable eco-tourism, agriculture, and fisheries in BIMP–EAGA.* https://bimp-eaga.asia/sites/default/files/publications/case-studies-sustainable-6th.pdf

Butler, R. A. (2015, January 19). High deforestation rates in Malaysian states hit by flooding. *Mongabay*. https://news.mongabay.com/2015/01/high-deforestation-rates-in-malaysian-states-hit-by-flooding/

Campbell, I. C., Poole, C., Giesen, W., & Valbo-Jorgensen, J. (2006). Species diversity and ecology of Tonle Sap Great Lake, Cambodia. *Aquatic Sciences, 68*(3), 355–373.

Castagtino, R. (2021, October 22). Critically endangered Sunda pangolin caught on camera trap. *Mongabay*. https://news.mongabay.com/2021/10/critically-endangered-sunda-pangolin-caught-on-camera-trap-candid-animal-cam/

Chunhabunyatip, P., Sasaki, N., Grünbühel, C., Kuwornu, J., & Tsusaka, T. (2018). Influence of indigenous spiritual beliefs on natural resource management and ecological conservation in Thailand. *Sustainability (Basel, Switzerland), 10*(8), 2842. https://doi.org/10.3390/su10082842

Conservation International/Wikimedia Commons (2005). *The Indo-Burma Biodiversity Hotspot* [Image]. https://commons.wikimedia.org/w/index.php?search=indo-burma+biodiversity+hotspot&title=Special:MediaSearch&go=Go&type=image

Conservation International/Wikimedia Commons (2005). *The Philippines Biodiversity Hotspot* [Image]. https://commons.wikimedia.org/w/index.php?search=philippines+biodiversity+hotspot&title=Special:MediaSearch&go=Go&type=image

Conservation International/Wikimedia Commons (2005). *The Sundaland Biodiversity Hotspot* [Image]. https://commons.wikimedia.org/w/index.php?search=sundaland+biodiversity+hotspot&title=Special:MediaSearch&go=Go&type=image

Conservation International/Wikimedia Commons (2005). *The Wallacea Biodiversity Hotspot* [Image]. https://commons.wikimedia.org/w/index.php?search=wallacea+biodiversity+hotspot&title=Special:MediaSearch&go=Go&type=image

Convention on Biological Diversity. (2008). *Protected areas in today's world: Their values and benefits for the welfare of the planet* (Technical Series no. 36). https://www.cbd.int/doc/publications/cbd-ts-36-en.pdf

Convention on Biological Diversity. (2020a). *Aichi biodiversity targets*. https://www.cbd.int/sp/targets/

Convention on Biological Diversity. (2020b). *Global Biodiversity Outlook 5.* https://www.cbd.int/gbo/gbo5/publication/gbo-5-en.pdf

Convention on Biological Diversity. (n.d.). *Philippines – Main details.* https://www.cbd.int/countries/profile/?country=ph#:~:text=The%20Philippines%20is%20also%20one,the%20top%20global%20conservation%20areas

Cook, E. (2018, January 6). *With its environmental crisis, is Laos missing the forest for the trees?* The Diplomat. https://thediplomat.com/2018/01/with-its-environmental-crisis-is-laos-missing-the-forest-for-the-trees/

Cowan, C. (2021, June 28). Forest loss in mountains of Southeast Asia accelerates at 'shocking' pace. *Mongabay.* https://news.mongabay.com/2021/06/forest-loss-in-mountains-of-southeast-asia-accelerates-at-shocking-pace/

Critical Ecosystem Partnership Fund [CEPF]. (2001). *Sumatra forest ecosystems of the Sundaland biodiversity hotspot – Indonesia.* https://www.cepf.net/sites/default/files/final.sundaland.sumatra.ep__0.pdf

Critical Ecosystem Partnership Fund [CEPF]. (2014). *Wallacea biodiversity hotspot.* https://www.cepf.net/sites/default/files/wallacea-ecosystem-profilesummary-english.pdf

Critical Ecosystem Partnership Fund [CEPF]. (2020). *Indo-Burma biosiversity hotspot.* https://www.cepf.net/sites/default/files/ep_indoburma_2020_update_final-sm_0.pdf

Critical Ecosystem Partnership Fund [CEPF]. (2022). *Biodiversity hotspots defined.* https://www.cepf.net/our-work/biodiversity-hotspots/hotspots-defined

Cross, D. T. (2021, July 13). *Creeping deforestation is threatening alpine environments across Southeast Asia.* Sustainability Times. https://www.sustainability-

times.com/environmental-protection/creeping-deforestation-is-threatening-alpine-environments-across-southeast-asia/

Cruz, E. D. (2021, April 15). Philippines lifts nine-year ban on new mines to boost revenues. *Reuters.* https://www.reuters.com/business/energy/philippines-lifts-nine-year-old-ban-new-mines-boost-revenues-2021-04-15/

Cumming, T., Seidl, A., Emerton, L., Spenceley, A., Kroner, R. G., Uwineza, Y., & Zyl, H. (2021). Building sustainable finance for resilient protected and conserved areas: Lessons from COVID-19. *Parks, 27 (special issue),* 149–160. https://parksjournal.com/

Daniel, T. C. (2021, September 2). The poaching of Sumatra's endangered tigers remains an acute problem. *Sustainability Times.* https://www.sustainability-times.com/environmental-protection/the-poaching-of-sumatras-endangered-tigers-remains-an-acute-problem/

Danilina, N. R., & Kopylova, S. L. (2011). Protected area staff training: Guidelines for planning and management. *IUCN.* https://www.iucn.org/content/protected-area-staff-training-guidelines-planning-and-management-0

Deloitte. (2021, August 23). *Leading on climate action is a US$12.5 trillion opportunity for Southeast Asia* [Press Release]. https://www2.deloitte.com/sg/en/pages/cxo-programs/articles/leading-on-climate-action-is-a-us-12-5-trillion-opportunity-for-pr.html

Dempsey, C. (2014, June 10). *Tonle Sap Lake – One of the World's Most Productive Freshwater Ecosystems.* Geography Realm. https://www.geographyrealm.com/tonle-sap-lake-one-worlds-productive-freshwater-ecosystems/

Di Marco, M., Butchart, S. H. M, Visconti, P., Buchanan, G. M., Ficetola, G. F., & Rondinini, C. (2016). Synergies and trade-offs in achieving global biodiversity targets. *Conservation Biology, 30*(1), 189–195. https://doi.org/10.1111/cobi.12559

Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E… & Saleem, M. (2017). An ecoregion-based approach to protecting half the terrestrial realm. *Bioscience, 67*(6), 534–545. https://doi.org/10.1093/biosci/bix014

Down To Earth. (2021). *Climate crisis: Deforestation in Southeast Asia mountains on the rise.* https://www.downtoearth.org.in/news/climate-change/climate-crisis-deforestation-in-southeast-asia-mountains-on-the-rise-77920#:~:text=The%20shifts%20have%20resulted%20in,a%20year%20during%202001%2D2019.

Dreybrodt, J., & Loveridge, F. (2021). Karst and cave conservation in Myanmar. *Myanmar Cave Documentation Project.* https://www.researchgate.net/publication/350810641_Karst_and_Cave_Conservation_in_Myanmar

Dudley, N. (2008). *Guidelines for applying Protected Area Management Categories* (Best Practice Protected Area Guidelines Series No. 21). IUCN. https://portals.iucn.org/library/sites/library/files/documents/PAG-021.pdf

Dwiyahreni, A. A., Fuad, H. A. H., Muhtar, S., Soesilo, T. E., Margules, C., & Supriatna, J. (2021). Changes in the human footprint in and around Indonesia's terrestrial national parks between 2012 and 2017. *Scientific Reports, 11*(1), 4510–4514. https://doi.org/10.1038/s41598-021-83586-2

Earth Reminder. (2020). *Grassland ecosystem – Types of grassland ecosystem and characteristics.* https://www.earthreminder.com/grassland-ecosystem-types-characteristics/

Emerton, L., Bishop, J., & Thomas, L. (2006). *Sustainable financing of protected areas: A global review of challenges and options* (Best Practice Protected Area Guidelines Series No. 13). IUCN. https://portals.iucn.org/library/efiles/documents/PAG-013.pdf

Estoque, R. C., Murayama, Y., Lasco, R. D., Myint, S. W., Pulhin, F. B., Wang, C., Ooba, M., & Hijioka, Y. (2018). Changes in the landscape pattern of the La Mesa Watershed – The last ecological frontier of Metro Manila, Philippines. *Forest Ecology and Management, 430,* 280–290. https://doi.org/10.1016/j.foreco.2018.08.023

Fallin, D. (2021, December 13). Time to confront Southeast Asia's online wildlife trafficking. *The Diplomat.* https://thediplomat.com/2021/12/time-to-confront-southeast-asias-online-wildlife-trafficking/#:~:text=If%20not%20properly%20addressed%2C%20however,up%20to%207%20percent%20annually

Feng, Y., Ziegler, A. D., Elsen, P. R., Liu, Y., He, X. Y., Spracklen, D. V., … Zeng, Z. Z. (2021). Upward expansion and acceleration of forest clearance in the mountains of Southeast Asia. *Nature Sustainability,4,* 892–899.

Ferreira, G. B., Collen, B., Newbold, T., Oliveira, M. J. R., Pinheiro, M. S., de Pinho, F. F., Rowcliffe, M., & Carbone, C. (2020). Strict protected areas are essential for the conservation of larger and threatened mammals in a priority region of the Brazilian Cerrado. *Biological Conservation, 251,* 108762. https://doi.org/10.1016/j.biocon.2020.108762

Fleming, S. (2020, August 11). *These scientists are listening to the Borneo rainforest to protect biodiversity.* World Economic Forum.

https://www.weforum.org/agenda/2020/08/scientists-listen-to-rainforest-biodiversity-safe/#:~:text=The%20Borneo%20rainforest%20is%20a,and%203%2C000%20species%20of%20trees

Food and Agriculture Organization (FAO). (2020). *Global forest resources assessment 2020.* https://www.fao.org/documents/card/en/c/ca9825en

ForestrySA. (2022). *Biodiversity corridors.* https://www.forestrysa.com.au/conservation/biodiversity-corridors/

Fox, J., Castella, J. C., & Hurni, K. (2018). *As rubber plantations expand in the highlands of Southeast Asia, what happens to local farmers?* East-West Center. https://www.eastwestcenter.org/system/tdf/private/ewwire014foxetal.pdf?file=1&type=node&id=36769

Free Malaysia Today. (2021, December 30). *Effects of logging on floods can't be denied, says Ramasamy.* https://www.freemalaysiatoday.com/category/nation/2021/12/30/effects-of-logging-on-floods-cant-be-denied-says-ramasamy/

Garnett, S. T., Burgess, N. D., Fa, J. E., Fernández-Llamazares, Á., Molnár, Z., Robinson, C. J., Watson, J. E. M., … Leiper, I. (2018). A spatial overview of the global importance of Indigenous lands for conservation. *Nature Sustainability, 1*(7), 369–374. https://doi.org/10.1038/s41893-018-0100-6

Gaveau, D. L. A., Curran L. M., Paoli, G. D., Carlson, K. M., Wells, P., Besse-Rimba, A., Ratnasari, D., & Leader-Williams, N. (2012). Examining protected area effectiveness in Sumatra: Importance of regulations governing unprotected lands. *Conservation Letters, 5,* 142–148. https://doi.org/10.1111/j.1755-263X.2011.00220.x

Gleb, R. (2018, November 17). Indigenous peoples defend Earth's biodiversity, but they're in danger. *National Geographic.*

https://www.nationalgeographic.com/environment/article/can-indigenous-land-stewardship-protect-biodiversity-

Global Forest Watch. (2022). *Forest change.* https://www.globalforestwatch.org/dashboards/global/

Global Initiative Against Transnational Organized Crime [GIATOC]. (2021). *Forest crimes in Cambodia: Rings of illegality in Prey Lang Wildlife Sanctuary.* https://globalinitiative.net/wp-content/uploads/2021/03/Forest-crimes-in-Cambodia-Rings-of-illegality-in-Prey-Lang-Wildlife-Sanctuary-GITOC-2021.pdf

Global New Light of Myanmar. (2021). *Biodiversity of Khakaborazi National Park, Hponkanrazi Wildlife Sanctuary heightens eco-tourism in high season.* https://www.gnlm.com.mm/biodiversity-of-khakaborazi-national-park-hponkanrazi-wildlife-sanctuary-heightens-ecotourism-in-high-season/

Gokkon, B. (2020, March 20). COVID-19 prompts closure of Indonesian parks, and a chance to evaluate. *Mongabay.* https://news.mongabay.com/2020/03/indonesia-national-parks-covid19-environment-komodo-rinjani-way-kambas-leuser/

Goldman, L. (2010, August 10). *A biodiversity hotspot in the Philippines.* WWF. https://www.worldwildlife.org/blogs/good-nature-travel/posts/a-biodiversity-hotspot-in-the-philippines

Google Site. (n.d.). *What is Sundaland? A hotspot.* https://sites.google.com/site/sundalandhotspots/what-is-sundaland

Gray, C. L., Hill, S. L. L., Newbold, T., Hudson, L. N., Börger, L., Contu, S., Hoskins, A. J., Ferrier, S., Purvis, A., & Scharlemann, J. P. W. (2016). Local biodiversity is higher inside than outside terrestrial protected areas worldwide. *Nature Communications, 7*(1), 12306–12306. https://doi.org/10.1038/ncomms12306

Guindon, M. (2021, February 8). *Deforestation is slowing, but palm oil still major driver.* China Dialogue. https://chinadialogue.net/en/nature/palm-oil-and-deforestation-today/#:~:text=Significant%20deforestation%20has%20been%20caused,Borneo%20between%201973%20and%202015

Gunawan, A. (2020, September 1). Malnourished Sumatran tiger evacuated from village following conflicts with humans. *The Jakarta Post.* https://www.thejakartapost.com/news/2020/08/31/malnourished-sumatran-tiger-evacuated-from-village-following-conflicts-with-humans.html

Haas, T. C., & Ferreira, S. M. (2016). Combating rhino horn trafficking: The need to disrupt criminal networks. *PloS One, 11*(11), e0167040–e0167040. https://doi.org/10.1371/journal.pone.0167040

Hall, J. (2019, February 28). Traditional Chinese medicine and wildlife. *National Geographic.* https://www.nationalgeographic.com/animals/article/traditional-chinese-medicine

Hance, J. (2010, January 24). Little more than 10,000 hectares of rainforest remains on Java. *Mongabay.* https://news.mongabay.com/2010/01/little-more-than-10000-hectares-of-rainforest-remains-on-java/

Haroon, R. (2022, January 2). Do we want to continue facing the wrath of Mother Nature? *New Straits Times.* https://www.nst.com.my/opinion/columnists/2022/01/759567/do-we-want-continue-facing-wrath-mother-nature

Heller, N. E., & Zavaleta, E. S. (2009). Biodiversity management in the face of climate change: A review of 22 years of recommendations. *Biological Conservation, 142*(1), 14–32. https://doi.org/10.1016/j.biocon.2008.10.006

Hernani. (2018, February 5). *The Wallacea hotspot of endemism*. HFMO Conservation and Science. https://hfmoconservationandscience.weebly.com/education-ecology-and-conservation/the-wallacea-hotspot-of-endemism

Hutan Harapan. (2018). Handicrafts for the European market. *Hutan Harapan Newsletter.* https://www.uni-goettingen.de/de/document/download/f9a3c6d3cd9bb4104f260df9f7b27bf6.pdf/Hutan%20Harapan%20Newsletter%20January%202018.pdf

Indonesia Investment. (2017). *Palm oil.* https://www.indonesia-investments.com/business/commodities/palm-oil/item166#:~:text=According%20to%20data%20from%20Indonesia's,used%20for%20palm%20oil%20plantations

Indraswari, K., Leupen, B. T. C., Nguyen, M. D. T., & Phassaraudomsak, M. (2020). *Trading faces: A snapshot of the online ivory trade in Indonesia, Thailand and Viet Nam in 2016 with an update in 2019.* TRAFFIC. Petaling Jaya, Selangor, Malaysia. https://www.traffic.org/site/assets/files/12981/three-country-ivory-report.pdf

IUCN SSC Pangolin. (n.d.). *Threats.* https://www.pangolinsg.org/pangolins/threats/

IUCN. (2013). *IUCN and CEPF launch new funding for Indo-Burma biodiversity hotspot.* https://www.iucn.org/content/iucn-and-cepf-launch-new-funding-indo-burma-biodiversity-hotspot

IUCN. (2015). *On the verge of extinction: A look at endangered species in the Indo-Burma Hotspot*. https://www.iucn.org/content/verge-extinction-a-look-endangered-species-indo-burma-hotspot

IUCN. (2020a). *Indo-Burma Biodiversity Hotspot 2020 Update.* https://www.iucn.org/sites/dev/files/content/documents/indo-burma-ecosystem-profile-executive-summary-2020-english.pdf

IUCN. (2020b). *Conserving Nature in a time of crisis: Protected Areas and COVID-19.* https://www.iucn.org/news/world-commission-protected-areas/202005/conserving-nature-a-time-crisis-protected-areas-and-covid-19

IUCN. (2020c). *Protected areas need better and more diversified funding.* https://www.iucn.org/news/protected-areas/202006/protected-areas-need-better-and-more-diversified-funding

IUCN. (2021). *We need to protect and conserve 30% of the planet: But it has to be the right 30%.* https://www.iucn.org/crossroads-blog/202108/we-need-protect-and-conserve-30-planet-it-has-be-right-30#:~:text=The%20target%20of%20protecting%20and,(OECMs)%20should%20be%20established.

IUCN. (2022). *Malili Lakes, Indonesia*. https://www.iucn.org/theme/species/our-work/freshwater-biodiversity/what-we-do/malili-lakes-indonesia

Johnston, I. (2019, April 24). Orangutans face complete extinction within 10 years, animal rescue charity warns. *Independent.* https://www.independent.co.uk/climate-change/news/orangutans-extinction-population-borneo-reasons-palm-oil-hunting-deforestation-rainforest-a7199366.html

Jones, K. R., Venter, O., Fuller, R. A., Allan, J. R., Maxwell, S. L., Negret, P. J., & Watson, J. E. (2018). One-third of global protected land is under intense human pressure. *Science, 360,* 788–791. https://doi.org/10.1126/science.aap9565

Jong, H. N. (2021, January 14). Deforestation spurred by road project creeps closer to Sumatra wildlife haven. *Mongabay.* https://news.mongabay.com/2021/01/karo-langkat-leuser-national-park-unesco-world-heritage-road-deforestation-encroachment/

Joyce Ann, L. R. (2021, August 6). Southeast Asia launches region-wide greening project. *Philippine News Agency.* https://www.pna.gov.ph/articles/1149647

Koh, L. P., Kettle, C. J., Sheil, D., & Lee, T. M. (2013). Biodiversity state and trends in Southeast Asia. In S. Levin (Eds.), *Encyclopedia of Biodiversity* (pp.509–527). Elsevier Inc.

Koshy, E. (2020, March 1). Malaysia and Southeast Asia at the heart of massive wildlife trade. *New Straits Times*. https://www.nst.com.my/lifestyle/sunday-vibes/2020/03/570621/malaysia-and-southeast-asia-heart-massive-wildlife-trade

Krasek, K. (2019, September 26). *What's happening in Cambodia's forests?.* Global Forest Watch. https://www.globalforestwatch.org/blog/data-and-research/whats-happening-in-cambodias-forests/

Kristy. (2017, November 29). Saving the banteng, the most endangered large mammal in Sabah. *New Straits Times*. https://www.nst.com.my/news/nation/2017/11/308571/saving-banteng-most-endangered-large-mammal-sabah

La Viña, A.G.M., Kho, J. L., & Caledo, M. J. (2010). *Legal framework for protected areas: Philippines.* https://www.iucn.org/downloads/philippines.pdf

Lawler, O. K., Allan, H. L., Baxter, P. W. J., Castagnino, R., Tor, M. C., Dann, L. E., … Kark, S. (2021). The COVID-19 pandemic is intricately linked to biodiversity loss and ecosystem health. *The Lancet. Planetary Health, 5*(11), e840–e850. https://doi.org/10.1016/S2542-5196(21)00258-8

Leinbach, T. R., & Frederick, W. H. (2020). Southeast Asia. *Encyclopedia Britannica*. http://www.britannica.com/place/Southeast-Asia.

Lim, F. (2016, July 19). *Vietnam risks losing endemic species as quarrying booms.* Sci Dev Net. https://www.scidev.net/asia-pacific/features/vietnam-risks-losing-endemic-species-quarrying-booms/

Lim, H., Gardner, P., Abram, N., Yusah, K., & Goossens, B. (2021). Identifying habitat and understanding movement resistance for the Endangered Bornean banteng Bos javanicus lowi in Sabah, Malaysia. *Oryx, 55*(1), 122–130. https://doi.org/10.1017/S0030605318001126

Loucks, C. (n.d.). *Peninsular Malaysian montane rain forests.* WWF. https://www.worldwildlife.org/ecoregions/im0144#:~:text=The%20Peninsular%20Malaysian%20Montane%20Rain,spectacular%20and%20endemic%20crested%20argus

Lundberg, J. & Moberg, F. (2003). Mobile link organisms and ecosystem functioning: implications for ecosystem resilience and management. *Ecosystems, 6,* 87–98. https://doi.org/10.1007/s10021-002-0150-4

Lynam, A. J. (2010). Securing a future for wild Indochinese tigers: Transforming tiger vacuums into tiger source sites. *Integrative Zoology*, *5*(4), 324–334. https://doi.org/10.1111/j.1749-4877.2010.00220.x

Mallari, N. A., Collar, N. J., McGowan, P. J., & Marsden, S. J. (2016). Philippine protected areas are not meeting the biodiversity coverage and management effectiveness requirements of Aichi Target 11. *Ambio*, *45*(3), 313–322. https://doi.org/10.1007/s13280-015-0740-y

Mangunjaya, F. M. (2018). *To protect Sumatran tigers, we mapped villages in Indonesia with high-risk human-tiger conflicts.* The Conversation. https://theconversation.com/to-protect-sumatran-tigers-we-mapped-villages-in-indonesia-with-high-risk-human-tiger-conflicts-103442

Margono, B. A., Potapov, P. V., Turubanova, S., Stolle, F., & Hansen, M. C. (2014). Primary forest cover loss in Indonesia over 2000–2012. *Nature Climate Change, 4,* 730–735. https://doi.org/10.1038/nclimate2277

Mauldin, A., & Karas, Z. (2016). *Sundaland.* Lincoln Community School. https://sites.google.com/a/lincoln.edu.gh/biodiversity-hotspots-lcs-ess/sundaland

Mayuga, J. L. (2021, June 13). *Illegal wildlife trade threatens PHL birds*. BusinessMirror. https://businessmirror.com.ph/2021/06/13/illegal-wildlife-trade-threatens-phl-birds/

McNaughton, S. J. (2021). *Terrestrial ecosystem.* AccessScience. https://doi.org/10.1036/1097-8542.685500

Ministry of Environment Cambodia. (2017). *National Protected Area Strategic Management Plan 2017-2031.* https://redd.unfccc.int/uploads/54_2_cambodia_nat_protected_area_strategic_plan_eng_27_jul_2017.pdf

Ministry of National Development Planning of the Republic of Indonesia. (2016). *Indonesian biodiversity strategy and action plan 2015–2020.* file:///C:/Users/user/Dropbox%20(Old)/My%20PC%20(LAPTOP-14PHM7BN)/Downloads/4.DokumenIBSAP2015-2020EnglishVersion.pdf

Ministry of Natural Resources and Environmental Conservation Myanmar. (2020). *Forestry in Myanmar 2019-2020.* https://www.forestdepartment.gov.mm/sites/default/files/Documents/Forestry_in_Myanmar_2020_0.pdf

Mongabay. (2017). *Indonesia abuzz over possible finding of extinct tiger.* https://news.mongabay.com/2017/09/indonesia-abuzz-over-possible-finding-of-extinct-tiger/

Morse, I. (2019, August 7). Indonesian flooding disaster bears the hallmarks of agriculture and mining impacts. *Mongabay*. https://news.mongabay.com/2019/08/in-sulawesi-floods-bear-the-hallmarks-of-agriculture-and-mining-impacts/

Naidoo, R., Gerkey, D., Hole, D., Pfaff, A., Ellis, A. A., Golden, C., … Fisher, B. (2019). Evaluating the impacts of protected areas on human well-being across the developing world. *Science Advances, 5*(4), eaav3006.

National Biodiversity Steering Committee. (2014). *National protected area system strategic management framework.* file:///C:/Users/user/Dropbox%20(Old)/My%20PC%20(LAPTOP-14PHM7BN)/Downloads/engnationalprotectedareasystemstrategicframework.pdf

National Geographic. (n.d.). *Sunda pangolin.* https://www.nationalgeographic.com/animals/mammals/facts/sunda-pangolin

Natusch, D. J. D., & Lyons, J. A. (2012). Exploited for pets: The harvest and trade of amphibians and reptiles from Indonesian New Guinea. *Biodiversity Conservation, 21,* 2899–2911. https://doi.org/10.1007/s10531-012-0345-8

New Straits Times. (2020). *New hatching method a lifesaver for Burmese star tortoises.* https://www.nst.com.my/world/region/2020/01/552982/new-hatching-method-lifesaver-burmese-star-tortoises#:~:text=The%20International%20Union%20for%20Conservation,for%20its%20meat%20and%20shell.

Nilsson, L. (2019). *The biodiversity loss crisis in Southeast Asia.* https://www.diva-portal.org/smash/get/diva2:1483969/FULLTEXT01.pdf

OECD. (2018). *Mainstreaming biodiversity for sustainable development.* https://www.oecd.org/environment/resources/Policy-Highlights-Mainstreaming-Biodiversity-for-Sustainable-Development.pdf

Paul, M. (2021, August 2). Bornean banteng faces extinction if poaching not eradicated. New Straits Times. https://www.nst.com.my/news/nation/2021/08/714146/bornean-banteng-faces-extinction-if-poaching-not-eradicated

Paz, S. L., Ngoprasert, D., Nuneza, O. M., Mallari, N. A. D., & Gale, G. A. (2013). Philippine-endemic and Mindanao-endemic Bird Communities on Canticol and Mt. Hilong-hilong, Philippines. *Asian Journal of Biodiversity, 4,* 135–168. file:///C:/Users/user/Dropbox%20(Old)/My%20PC%20(LAPTOP-14PHM7BN)/Downloads/191-article-pdf.pdf

Pearson, T. R. H, Brown, S., Murray, L., & Sidman, G. (2017). Greenhouse gas emissions from tropical forest degradation: An underestimated source. *Carbon Balance and Management, 12*(1), 1–11. https://doi.org/10.1186/s13021-017-0072-2

Perera, L. (2019, May 24). Impact of habitat loss on animals. *New Straits Times.* https://www.nst.com.my/opinion/letters/2019/05/491174/impact-habitat-loss-animals

Perez, G. J., Comiso, J. C., Aragones, L. V., Merida, H. C., & Ong, P. S. (2020). Reforestation and deforestation in Northern Luzon, Philippines: Critical issues as observed from space. *Forests, 11*(10), 1–20. https://doi.org/10.3390/f11101071

Philippine Council for Industry, Energy, and Emerging Technology Research and Development (PCIEERD). (2017). *Terrestrial biodiversity assessment in selected key areas in Mindanao as policy mainstream for responsible mining* (Policy Brief December 2017). https://pcieerd.dost.gov.ph/images/article/policy2.pdf

Philippine Eagle Foundation. (2008). *The Eastern Mindanao biodiversity corridor conservation framework.* file:///C:/Users/user/Dropbox%20(Old)/My%20PC%20(LAPTOP-14PHM7BN)/Downloads/EMBCframework_50res_BW.pdf

Polgar G., & Jaafar Z. (2018). *Endangered Forested Wetlands of Sundaland.* Springer.

Poor, E. E., Jati, V. I. M., Imron, M. A., & Kelly, M. J. (2019). The road to deforestation: Edge effects in an endemic ecosystem in Sumatra, Indonesia. *PLoS ONE, 14*(7), e0217540. https://doi.org/10.1371/journal.pone.0217540

Reid, A. J., Carlson, A. K., Hanna, D. E. L., Olden, J. D., Ormerod, S. J., Cooke, S. J. (2020). Conservation challenges to freshwater ecosystems. *Encyclopedia of the World's Biomes, 4,* 270–278. https://doi.org/10.3389/fenvs.2021.664313

Rifin, A., Feryanto, H., & Harianto. (2020). Assessing the impact of limiting Indonesian palm oil exports to the European Union. *Journal of Economic Structures, 9*(1), 1–13. https://doi.org/10.1186/s40008-020-00202-8

Rundel, P. W. (2009). Vegetation in the Mekong Basin. In I. C. Campbell (Eds.), *The Mekong: Biophysical environment of an International River Basin* (pp. 143–160). Academic Press.

Russell, M. (2021). *Forests in Southeast Asia: Can they be saved?* (PE 652.068). European Parliamentary Research Service. https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/652068/EPRS_BRI(2020)652068_EN.pdf

Sawe, B. E. (2018, January 12). *What and where is the Sundaland.* WorldAtlas. https://www.worldatlas.com/articles/what-and-where-is-the-

sundaland.html#:~:text=Sundaland%2C%20also%20referred%20to%20as,during%20the%20previous%20ice%20age

Shahbandeh, M. (2022). *Export volume of palm oil worldwide in 2021/22, by leading country.* Statista. https://www.statista.com/statistics/620219/palm-oil-export-volume-worldwide-by-country/

Singh, M., Griaud, C., & Collins, C. M. (2021). An evaluation of the effectiveness of protected areas in Thailand. *Ecological Indicators, 125,* 107536. https://doi.org/10.1016/j.ecolind.2021.107536

Sodhi, N. S., Koh, L.P., Brook, B. W., & Peter, K. L. (2004). Southeast Asian biodiversity an impending disaster. *TRENDS in Ecology and Evolution, 19*(12), 655–660. https://doi.org/10.1016/j.tree.2004.09.006

Song, X. P., Hansen, M. C., Stehman, S. V., Potapov, P. V., Tyukavina, A., Vermote, E. F., & Townshend, J. R. (2018). Global land change from 1982 to 2016. *Nature, 560,* 639–643. https://doi.org/10.1038/s41586-018-0411-9

Southeast Asia Centre for Biodiversity. (2015). *The AHP Programme.* https://www.Southeast Asiabiodiversity.org/the-ahp-programme/

Southeast Asia Centre for Biodiversity. (2017). *Southeast Asia Biodiversity Outlook 2.* https://Southeast Asia.chm-cbd.net/sites/acb/files/2020-03/Southeast Asia%20Biodiversity%20Outlook%202.pdf

Southeast Asia Centre for Biodiversity. (n.d.). *Taman Negara Pahang National Park - Malaysia's first and oldest protected area.* https://Southeast Asia.chm-cbd.net/taman-negara-pahang-national-park-malaysias-first-and-oldest-protected-area

Stibig, H. J., Achard, F., Carboni, S., Rasi, R. & Miettinen, J. (2014). Change in tropical forest cover of Southeast Asia from 1990 to 2010. *Biogeosciences, 11,* 247–258. https://doi.org/10.5194/bg-11-247-2014

Stone, R. (2006). The Saola's Last Stand. *Science (American Association for the Advancement of Science), 314*(5804), 1380–1383. https://doi.org/10.1126/science.314.5804.1380

Supriatna, J. (2017). *Wallacea: A living laboratory of evolution.* The Conversation. https://theconversation.com/wallacea-a-living-laboratory-of-evolution-85602

Supriatna, J., Dwiyahreni, A. A., Winarni, N., Mariati, S., & Margules, C. (2017). Deforestation of primate habitat on Sumatra and adjacent islands Indonesia. *Primate Conservation, 31*(1), 71–82. http://www.primate-sg.org/primate_conservation/

Tauli-Corpuz, V., Alcorn, J., Molnar, A., Healy, C., & Barrow, E. (2020). Cornered by PAs: Adopting rights-based approaches to enable cost-effective conservation and climate action. *World Development, 130,* 104923. https://doi.org/10.1016/j.worlddev.2020.104923

Taylor, M. (2021, June 29). *Southeast Asian nations missing from push to protect 30% of planet.* Thomson Reuters Foundation News. https://news.trust.org/item/20210628224959-r82ol/

The ASEAN Post. (2019). *ASEAN wildlife under threat from illegal hunting.* https://theaseanpost.com/article/asean-wildlife-under-threat-illegal-hunting

The Borneo Post. (2021). *Saving our forests for the future.* https://www.theborneopost.com/2021/03/14/saving-our-forests-for-the-future/

The Philippine Clearing House Mechanism. (n.d.). *Southeast Asia Heritage Parks.* http://www.philchm.ph/Southeast Asia-heritage-parks/

The Phuket News. (2021, February 18). *Khao Sok National Park named 50th Southeast Asia Heritage Park.* https://www.thephuketnews.com/khao-sok-national-park-named-50th-Southeast Asia-heritage-park-79065.php

The World Bank. (2022). *Metadata glossary.* https://databank.worldbank.org/metadataglossary/world-development-indicators/series/ER.LND.PTLD.ZS#:~:text=Terrestrial%20protected%20areas%20are%20totally,and%20areas%20managed%20mainly%20for

Theilade, I., & De Kok, R. (2015). Editorial - The status of botanical exploration and plant conservation in Cambodia. *Cambodian Journal of Natural History, 2*, 117–120. https://www.fauna-flora.org/publications/cambodian-journal-natural-history/

Tordoff, A. W., Baltzer, M. C., Fellowes, J. R., Pilgrim, J. D., & Langhammer, P. F. (2012). Key biodiversity areas in the Indo-burma hotspot: Process, progress and future directions. *Journal of Threatened Taxa*, 4(8), 2779–2787. https://doi.org/10.11609/JoTT.o3000.2779-87

Tucker, M. A., Böhning-Gaese, K., F, William, F., John, M., Van Moorter, B., Alberts, S. C., Ali, A. H, Allen, A. M, Zwijacz-Kozica, T., … Mueller, T. (2018). Moving in the Anthropocene: Global reductions in terrestrial mammalian movements. *Science (American Association for the Advancement of Science), 359*(6374), 466–472. https://doi.org/10.1126/science.aam9712

UNEP-WCMC. (2022). *World Database of Protected Areas, January 2022*. www.protectedplanet.net

UNEP. (2020). *Indigenous people and the nature they protect.* https://www.unep.org/news-and-stories/story/indigenous-peoples-and-nature-they-protect

United Nations Food and Agriculture Organization (FAO). (2022). *Global forest resources assessment*. https://fra-data.fao.org/THA/fra2020/home/

United Nations Office on Drugs and Crime (UNODC). (2013). *Transnational organized crime in East Asia and the Pacific: A threat assessment.* https://www.unodc.org/toc/en/reports/TOCTA-EA-Pacific.html

Vaillant, J. J., Haffner, G. D., Cristescu, M. E. (2011). The ancient lakes of Indonesia: Towards integrated research on speciation. *Integrative and Comparative Biology*, *51*(4), 634–643. https://doi.org/10.1093/icb/icr101

Verma, M., Symes, W. S., Watson, J. E. M., Jones, K. R., Allan, J. R., Venter, O., Rheindt, F. E., Edwards, D. P., & Carrasco, L. R. (2020). Severe human pressures in the Sundaland biodiversity hotspot. *Conservation Science and Practice, 2*, e169. https://doi.org/10.1111/csp2.169

Voigt, M., Supriatna, J., Deere, N., & Kastanya, A. (2021). Emerging threats from deforestation and forest fragmentation in the Wallacea centre of endemism. *Environmental Research Letters, 16*(9), 094048. https://doi.org/10.1088/1748-9326/ac15cd

von Rintelen, K. & Cai, Y., (2009). Radiation of endemic species flocks in ancient lakes: Systematic revision of the freshwater shrimp *Caridina* H. Milne Edwards, 1837 (Crustacea: Decapoda: Atyidae) from the ancient lakes Of Sulawesi, Indonesia, with the description of eight new species. *Raffles Bulletin of Zoology*, *57*(2), 343–452. https://lkcnhm.nus.edu.sg/publications/raffles-bulletin-of-zoology/

Ward, M., Saura, S., Williams, B., Ramírez-Delgado, J. P., Arafeh-Dalmau, N., Allan, J. R., Venter, O., Dubois, G., & Watson, J. E. M. (2020). Just ten percent of the global terrestrial protected area network is structurally connected via intact land. *Nature Communications*, *11*(1), 4563–4563. https://doi.org/10.1038/s41467-020-18457-x

Watson, J. E. M., Dudley, N., Segan, D. B., & Hockings, M. (2014). The performance and potential of protected areas. *Nature (London)*, *515*(7525), 67–73. https://doi.org/10.1038/nature13947

Wibisono, H. T., & Pusparini, W. (2010). Sumatran tiger (Pantheratigris sumatrae): A review of conservation status. *Integrative Zoology, 5,* 313–323. https://doi.org/10.1111/j.1749-4877.2010.00219.x

Wikramanayake, E. (2022). *Peninsular Malaysian montane rainforests.* One Earth. https://www.oneearth.org/ecoregions/peninsular-malaysian-montane-rainforests/

Wikramanayake, E., Dinerstein, E., Loucks, C. J., Olson, M. J., Morrison, J., Lamoreux, J., McKnight, M., & Hedao, P. (2002). *Terrestrial ecoregions of the Indo-Pacific: A conservation assessment.* Island Press.

Wulffraat, S., Greenwood, C., Faisal, K. F., & Sucipto, D. (2016). *The environmental status of Borneo.* WWF. https://d2d2tb15kqhejt.cloudfront.net/downloads/The_Environmental_Status_of_Borneo_2016_Report.pdf

WWF. (2011). *WWF Indonesia has encouraged authorities to hand down a maximum sentence to a suspected tiger smuggler that was put on trial yesterday in a West Sumatra district court.* https://wwf.panda.org/wwf_news/?201282/WWF-calls-for-maximum-penalty-on-suspected-tiger-

smuggler#:~:text=The%20Indonesia%20law%20on%20biodiversity,Indonesian%20rupiah%20(US%2410%2C000).

WWF. (2015). *Thailand destroys stockpile of illegal ivory.* https://wwf.panda.org/wwf_news/?251412/Thailand-destroys-stockpile-of-illegal-ivory

WWF. (2020). *Protected area problems.* https://wwf.panda.org/discover/our_focus/biodiversity/protected_areas/protected_area_problems/

WWF. (n.d.). *Facts about pangolin.* https://www.worldwildlife.org/species/pangolin#:~:text=Also%20called%20scaly%20anteaters%20because,for%20their%20meat%20and%20scales

Yale. (2022). *Southeast Asia, Malaysia and Singapore*. https://masa.sites.yale.edu/southeast-asia-malaysia-and-singapore

Zeng, Z. Z., Estes, L., Ziegler, A. D., Chen, A. P., Searchinger, T., Hua, F. Y., Guan, K. Y., Jintrawet, A., & Wood, E. F. (2018a). Highland cropland expansion and forest loss in Southeast Asia in the twenty-first century. *Nature Geoscience, 11,* 556–562. https://doi.org/10.1038/s41561-018-0166-9

Zeng, Z. Z., Gower, D. B., & Wood, E. F. (2018b). Accelerating forest loss in Southeast Asian Massif in the 21st century: A case study in Nan Province, Thailand. *Global Change Biology, 24*(10), 4682–4695. https://doi.org/10.1111/gcb.14366

About Sunway IGSC

Sunway Institute for Global Strategy and Competitiveness (Sunway IGSC) is dedicated to extending its research focus beyond the traditional economic boundary of competitiveness and draws into its coverage social and environmental considerations as explicit factors of competitiveness.

Based on a more inclusive and holistic consideration, Sunway IGSC identifies three primary pillars of competitiveness: Economic, Social, and Environment. The three pillars of competitiveness provide direction and focus to the type of questions asked and the work conducted within IGSC:

- **Economic health -** This pillar investigates drivers of competitiveness from the vantage point of firms, industry, and national ecosystems, with a particular focus on policies and drivers of structure and competitive strategies to create positions of sustainable advantage.
- **Social health -** This pillar focuses on issues of distribution of wealth, equity, and unity within ecosystems as a consequence of economic policies and strategies at the firm, industry, and national levels. The lens scrutinizes who creates value, for whom, and how is this value distributed among the diverse stakeholders operating within the ecosystem. It stresses the need for inclusive creation and sharing of value creation to ensure shared prosperity.
- **Environment health -** This pillar scrutinizes how actions of individuals, firms, industry, and government impact the environment and draws into explicit consideration the need to go beyond the simple mantra of firm profit maximization and short-run economic development and competitiveness by holistic consideration of the costs to the natural environment and life of species, including that of the human race over the long run.

The mission of the Sunway IGSC is to conduct meaningful fundamental and translational research exploring global strategy and competitiveness to contribute to the strategic transformation and competitiveness of governments, industries, and society in the context of rapidly changing global dynamics.

Referencing or Use of this Publication

TO REFERENCE TO THIS PUBLICATION:

Teow, H. H., Tang, S., Ahmed, P. K., Nair, M. S., & Vaithilingam, S. (2022). *Terrestrial biodiversity and protected areas in Southeast Asia* (Working Paper No. IGSC WP 2022-002). Sunway Institute for Global Strategy and Competitiveness.