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Review

Can Humans and Elephants Coexist? A Review of the Conflict on Sumatra Island, Indonesia

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Abstract: The high rate of deforestation and fragmentation of elephant habitat on Sumatra Island has triggered human-elephant conflict (HEC) in Sumatra Island, Indonesia. This conflict brings negative impacts on humans and elephants. Despite numerous efforts having been made to solve this problem, the HEC continues to occur in the remaining elephant enclave every year. The harmonious coexistence between humans and elephants could be improved through HEC mitigation programs. The aim of this paper was to review information on HEC in Sumatra Island, investigate the causes and implications of HEC, review existing HEC mitigation methods, and formulate strategies to improve the harmonious coexistence between humans and elephants. The best strategies to create successful human and elephant coexistence are strengthening the institutions and policies, restoring the habitat, developing wildlife corridors, establishing Essential Ecosystem Areas (EEA), community empowerment through ecotourism, providing legal access to forests through Social Forestry (SF), and providing compensation schemes for conflict victims.

Keywords: coexistence; community; corridor; farmer; habitat; Sumatran elephant

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1. Introduction

Elephants are the only surviving representatives of Proboscidea that for the first time appeared in Africa about 55 million years ago [1,2]. Elephants are classified into the African elephant (*Loxodonta africana africana* and *Loxodonta africana cyclotis*) and the Asian elephant (*Elephas maximus*) [3,4]. The Asian elephant has four sub-species: *Elephas maximus indicus* (Malaysia, Thailand, Cambodia, Vietnam, Laos, Myanmar, China, Bhutan, India, and Bangladesh), *Elephas maximus maximus* (Sri Lanka), *Elephas maximus sumatranus* (Sumatra, Indonesia), and *Elephas maximus borneensis* (Kalimantan, Indonesia) [5–7]. The remaining population of Asian elephants across 13 countries is less than 50,000 individuals [8]. The population reduction has invoked the conservation status of Asian elephants including the Sumatran elephant to be critically endangered in 2011 as half of their population was lost in one generation [9,10]. Sumatran elephants are distributed in Aceh, North Sumatra, Riau, Jambi, Bengkulu, South Sumatra, and Lampung provinces in Sumatra Island, and the Sumatran elephant is one of the flagship endemic species to those provinces.

The population of Sumatran elephants started to decrease when the government of Indonesia implemented a transmigration program to reduce the Java population to Sumatra from the 1930s to the 1980s [11–14]. This program had caused a huge forest conversion into a settlement, agricultural, and plantation areas [14]. To improve the economy of the country, in 1970, the Indonesian government started to release forest utilization permits (concession areas) on natural forests through the development of industrial forests and plantations (mostly oil palm) that caused forest loss, degradation, and fragmentation [15,16]. Furthermore, the decentralization policy after the reformation era (in 1999) encouraged the regional expansion in Indonesia (from 27 provinces to 34 provinces and 514 districts) [17]. The regional expansion converted forest areas into settlements, infrastructures, urban areas, industrial areas, public facilities, agricultural and plantations, ports, airports, irrigation, and electricity networks to improve the economic development and public services for the new regions. Forest loss and habitat destruction have forced elephants to get closer to people and have caused competition for space and other resources that triggers human-elephant conflict (HEC) [18,19]. HECs that occur in most of the provinces on Sumatra Island have caused negative impacts on humans and elephants [19–22].

To reduce conflicts, the government of Indonesia has implemented various HEC mitigation programs, such as the translocation of wild elephants from the conflict areas, domestication of elephants, and habitat improvement (e.g., planting and enriching elephant feeds on forests) [23]. However, these programs are considered not to be optimal because the available policies do not strongly support the conservation of species, and there are resources and budget constraints and low participation of parties in the HEC mitigation program [13,24]. Therefore, better and more pragmatic strategies are required in mitigating HEC [22,25]. A proposed concept to reduce HEC is to create a harmonious coexistence between humans and elephants. To develop a harmonious coexistence, it is important to consider elephant ecology, the basic needs of and the interactions between humans and elephants, and existing regulations [26–28]. In this study, we reviewed and collected information on elephant bio-ecology, the main driver of HEC, and the impact of HEC on both humans and elephants. We then formulated several strategies and recommendations for creating a harmonious coexistence between humans and elephants on Sumatra Island (Figure 1).

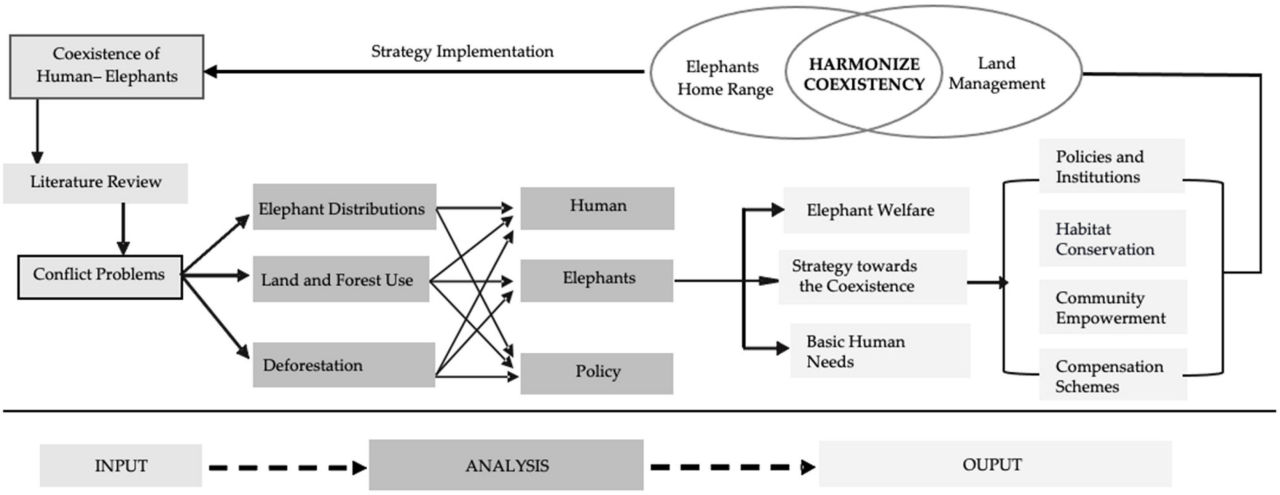


Figure 1. Conceptual framework of the study.

2. Sumatran Elephant Life History and Population Distributions

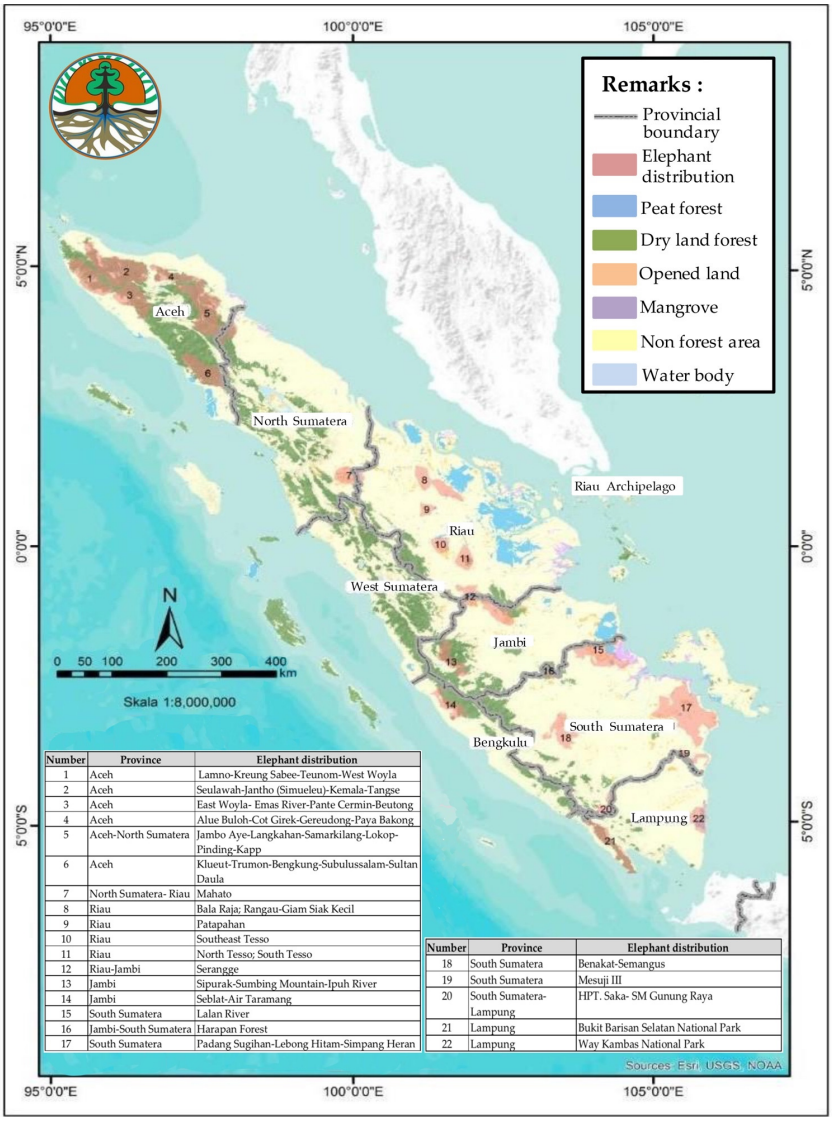
2.1. Distribution of Sumatran Elephants

2.1.1. Wild Elephants

Sumatran elephant habitat ranges from lowland forests to higher elevations. Elephants are generally observed at an altitude range of 300–500 m [29]. Elephants use habitats up

to an altitude of 1600 m, in valleys and foothills with high food resources, and near watersheds [20,30,31]. Previous studies also reported that elephants were once observed at 2329 m above sea level in Mount Ulu Masen, which connects elephant habitats in Aceh Jaya and Pidie, in Aceh Province [32]. In general, the distribution of elephants is highly influenced by topography as elephants avoid areas with slopes above 60% [5,11].

More than 60% of elephants are currently distributed outside conservation areas (natural habitats). Sumatran elephant habitat consists of swamp forests, peat forests, primary and secondary forests, shrubs, and plantations [5,11,33,34]. They are mostly distributed in open areas near water sources with abundant food supplies [35,36]. Figure 2 is the distribution of elephant habitats on Sumatra Island. The elephant's habitats in Sumatra Island include the Leuser Ecosystem or Gunung Leuser National Park (GLNP) (in Aceh, North Sumatra, and West Sumatra), Batang Toru Watershed (North Sumatra, Riau, Jambi, and West Sumatra), Kerinci Seblat National Park (KSNP) (in Bengkulu, South Sumatra and Lampung), and Tesso Nilo National Park (TNNP) in Riau [13,15,16,37–39].



Number	Province	Elephant distribution
1	Aceh	Lamno-Kreung Sabee-Teunom-West Woyla
2	Aceh	Seulawah-Jantho (Simueleu)-Kemala-Tangse
3	Aceh	East Woyla- Emas River-Pante Cermin-Beutong
4	Aceh	Alue Buloh-Cot Girek-Gereudong-Paya Bakong
5	Aceh-North Sumatera	Jambo Aye-Langkahan-Samarkilang-Lokop-Pinding-Kapp
6	Aceh	Klueut-Trumon-Bengkung-Subulussalam-Sultan Daula
7	North Sumatera- Riau	Mahato
8	Riau	Bala Raja; Rangau-Giam Siak Kecil
9	Riau	Patapahan
10	Riau	Southeast Tesso
11	Riau	North Tesso; South Tesso
12	Riau-Jambi	Serangge
13	Jambi	Sipurak-Sumbing Mountain-Ipuh River
14	Jambi	Seblat-Air Taramang
15	South Sumatera	Lalan River
16	Jambi-South Sumatera	Harapan Forest
17	South Sumatera	Padang Sugihan-Lebong Hitam-Simpang Heran

Number	Province	Elephant distribution
18	South Sumatera	Benakat-Semangus
19	South Sumatera	Mesuji III
20	South Sumatera-Lampung	HPT. Saka- SM Gunung Raya
21	Lampung	Bukit Barisan Selatan National Park
22	Lampung	Way Kambas National Park

Figure 2. Source: Ministry of Environment and Forestry [40]. The distribution of Sumatran elephants on Sumatra Island.

The elephant population on Sumatra Island has declined since 1931 [12,13]. In the 1980s, the total population of elephants on Sumatra Island was about 2800 to 5000 individuals, distributed in 44 spots from northern Aceh to southern Lampung (Table 1). In 2017, it

had declined to 1694 to 2038 individuals, almost half of the population. The decrease in the elephant population was mainly caused by forest conversion, hunting, disease, environmental pollution, and HEC [4,41–43]. This condition has encouraged the Government of Indonesia to set the Sumatran elephant as a top priority for species conservation.

Table 1. Estimation of elephant populations on Sumatra Island.

No	Habitat	Year of Assessment	Population Size	References
1	Sumatra Island	1980	2800–4800	Santiapillai and Jackson [12]; Blouch and Haryanto [44]; Blouch and Simbolon [45]
2	Sumatra Island	2014	1724	Directorate General of KSDAE [13]; Azmi and Gunaryadi [46]; World Wildlife Fund (WWF) Indonesia [47]
3	Sumatra Island	2017	1694–2038	Hanafiah [48]
4	Riau Province	1985	1067–1647	Blouch and Simbolon [45]
5	Bengkalis, Riau Province	2005	35–50	Suhandri et al. [49]
6	Riau Province	2007	210	Sitompul et al. [33]
7	Riau Province	2009	34	Santiapillai and Jackson [12]
8	Riau Province	2016	244–338	Desai and Samsuardi [50]
9	Lampung-Bengkulu	2000	9	Hedges et al. [11]
10	Bukit Barisan Selatan National Park	2005	498	Hedges et al. [11]
11	Way Kambas National Park (WKNP)	2005	180	Hedges et al. [11]
12	Tebo Regency, Jambi	2007	117	Sitompul et al. [33]
13	Aceh	2016	500–530	Mustafa et al. [51]

2.1.2. Captive Elephants

The ex-situ elephant conservation program for captive Sumatran elephants was established in 1985. This program was proposed as one of the main solutions to mitigate HEC. Numerous Elephant Training Centers (ETCs) were established in Sumatra Island, such as Way Kambas National Park (WKNP) in Lampung Province; Minas ETC (South Sumatra Province), Seblat ETC (Bengkulu Province), and Tangkahan ETC (North Sumatra Province) [20]. ETCs were built for genetic preservation, breeding, education and tourism, and training for captured elephants [52]. Elephants are now also distributed in several zoos, such as Bali Zoo, Bandung Zoo, Indonesia Safari Park (in Cisarua and Prigen), and Bali Elephant Safari Park. The total number of elephants in captive ETCs is 543 (Table 2). The main problem of ex-situ conservation programs is population structure, limited gene flow, and inbreeding [36].

Table 2. Distribution of captive elephants in different institutions.

Institutions	Elephant Population		
	Male	Female	Total
ETC/Elephant Conservation Center (ECC)	99	116	215
Zoos	17	29	46
Recreational parks, safari parks, nature recreation parks	59	171	230
Companies	25	27	52
Abroad	2	4	6
Total	202	347	543

Source: Directorate General of Natural Resources Conservation and Ecosystem (NRCE) originally named Directorate General of *Konservasi Sumber Daya Alam dan Ekosistemnya* (KSDAE) [13].

2.2. Deforestation and Habitat Loss of Sumatran Elephants

Deforestation is one of the main challenges in preserving the elephant's natural habitat in Indonesia. Deforestation is defined as a one-time permanent conversion of natural forest cover into other land cover categories [53,54]. The forest conversion in Indonesia is caused by direct or indirect factors i.e., transmigration programs, forest concession rights in 1970–1980, and expansion of oil palm plantations [15,16,55]. For many decades, the

nationwide trend of deforestation has been declining every year (Figure 3). For Sumatra, the data in the last two years also followed the same trends (Figure 4). However, the massive forest clearing in the 1990's to 2000's caused huge forest loss in Indonesia, including in Sumatra.

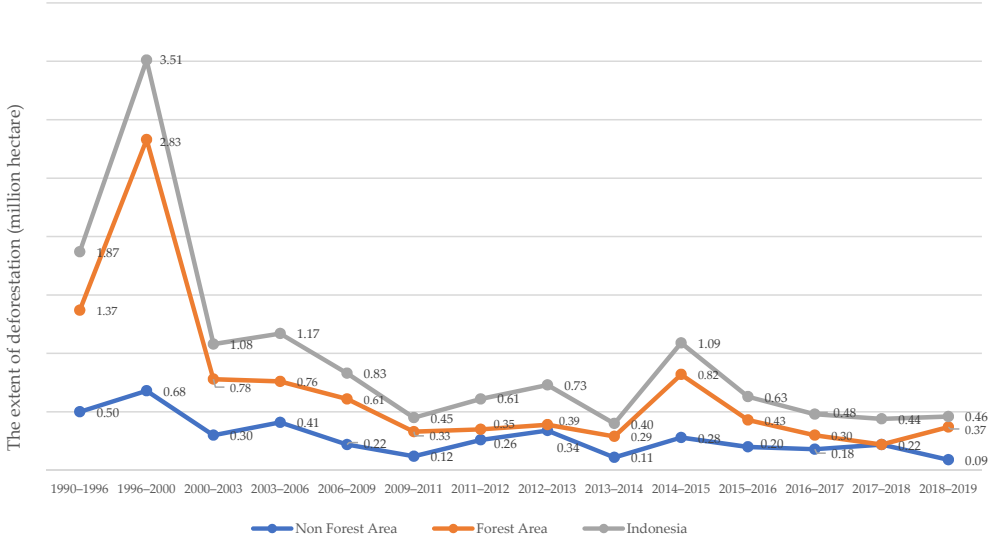


Figure 3. Indonesian deforestation trends in 1990–2019 [53].

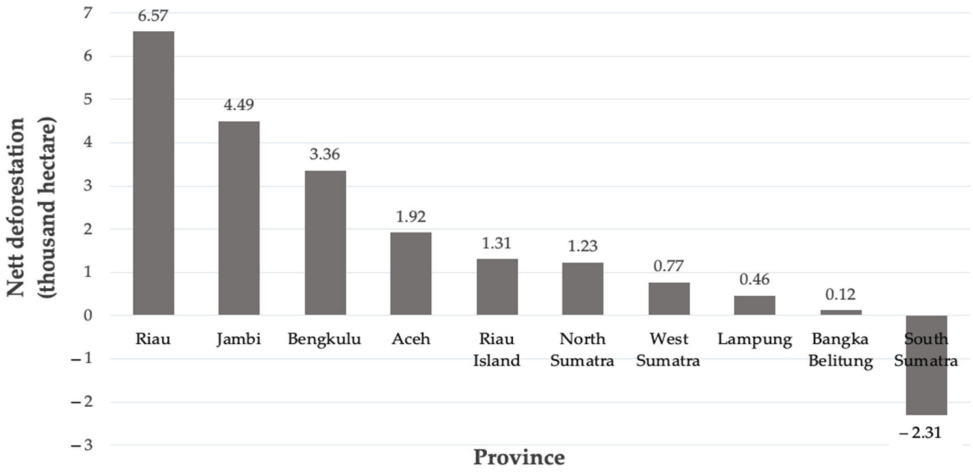


Figure 4. Nett deforestation in Sumatra in 2019–2020 [54]. Nett deforestation is the change/reduction of the land cover area by forested category in a certain period obtained from the calculation of gross deforestation area minus the area of reforestation. Gross deforestation 'without taking into account the reforestation that occurs'. Minus (−) means: that reforestation has a bigger value.

The development of infrastructure to improve the access to Sumatra Island also contributes to forest loss and forest disturbances. For instance, the development of 2700 km trans-Sumatra highway across Sumatra by the central government started in 2019 not only increases habitat fragmentation on the island, but also the access to remote areas for poaching and illegal logging activities that may bring negative effects to forests and wildlife [15,16,37,56]. In Riau, the establishment of 2400 km of new roads in Riau Province is mostly adjacent (about 100–1000 m) to Tesso Nilo National Park (TNNP). This enables easier access to the forest [57].

The impact of deforestation and habitat fragmentation is generally higher for elephants than for other wildlife because elephants require a wide home range and a huge amount of food [12,35,58]. The fragmentation of elephant habitat into smaller blocks forces elephants to have closer contact with people and frequently generate HEC [59–61]. In the long term,

habitat fragmentation will lead to a genetic decline due to inbreeding depression that threatens the species' sustainability [61,62].

2.3. Conflict Evidences and Driving Factors of HEC across Sumatra Island

Several scholars reported that the most common form of HEC is crop-raiding [63,64]. HEC becomes more intense when communities plant crops preferred by elephants, such as rubber trees, cacao trees, coconut trees, banana, corn, ground beans, cassava, and rice [65–67]. The economic losses caused by HEC in Sumatra Island is varied, depending on the scale of the damage, location, and the types of crops and property damaged by elephants. The economic loss caused by HEC on oil palm plantations and forest plantations in Riau was US$105 million/year [68]. While in Lampung, the direct economic losses due to 2000–2002 crop-raiding incidents in WKNP were US$12,000 (±US$6000/year) [11].

HEC also puts negative effects on both humans and elephants. The 2012–2017 HEC events in Aceh killed 8 people and 11 were injured [69]. During this period, about 45 elephants died due to HEC [69]. In Lampung, the 2000–2002 HEC damaged 24 houses, killed three people, injured three people, and killed two elephants [11,18]. In general, crop-raiding incidents have altered people's perceptions of Sumatran elephants. Most people around elephant habitats have considered elephants as pests, aggressive and dangerous wildlife [70]. For instance, most people around Way Kambas National Park have no willingness to coexist with elephants [27]. Negative perception towards elephants is mainly driven by community economic conditions where most of the communities living around the elephant habitat live in poverty [70]. The summary of HEC in each province in Sumatra is provided in Table 3.

Table 3. HEC across Sumatra Island.

Province/Region	Current Distributions of Elephants	Frequency of HEC	Drivers
Aceh	27 pockets in 13 regencies [71].	262 events (2012–2017); 102 events (2020) [69,72]	Habitat conversion into mining and agriculture [29]
North Sumatra	1 pocket (Langkat Regency) [13]	34 (2010–early 2022) [73]	Habitat conversion into agriculture [65]
Riau	7 elephant populations, where TNNP acts as the most important population [16,74]	46 events (2018–2019) [75]	Deforestation and habitat fragmentation [76]
Jambi	Bukit Tigapuluh Landscape, covering Tebo Regency, Sarolangun Regency, KSNP (Kerinci Regency), and Bungo Regency [77]	538 events (2017–2018) [78]	Habitat conversion into community settlements, agricultural, industrial plantations, and mining [78,79]
South Sumatra	Eight spots: Benakat Semangus (259,801 ha), Meranti Sungai Kapas (48,906 ha), Lalan (262,823 ha), Jambul Nanti Patah (282,727 ha), Mesuji (64,712 ha), Saka Gunung Raya (75,883 ha), Suban Jeriji (138,542 ha), and Sugihan Simpang Heran (631,953 ha) [80]	37 events (2013–2019) [81]	Deforestation and habitat fragmentation [80]
Bengkulu	Four groups: Air Teramang–Air Dikit, Air Teramang–Air Berau, Air Ipuh–Air Teramang, and Seblat [82]	17 events in oil palm plantations adjacent to Seblat ECC (2007–2008); 62 events in several villages and oil palm plantations around KSNP (2007–2012) [39,83]	Deforestation and habitat fragmentation [46].
Lampung	Bukit Barisan Selatan (BBSNP), and WKNP [11,23,46]	717 events in BBSNP and WKNP (2000–2002); 437 events in WKNP (2015); 150 events annually in WKNP (2016–2020) [11]	Deforestation and habitat fragmentation [18,64,84]

3. Overview of HEC Mitigation in Sumatra Island

3.1. Regulation and Policies Relating to Conflict Mitigation

Indonesian regulations related to forestry and wildlife conservation consist of: (a) the Conservation of Biological Natural Resources and Ecosystem Law No 5/1990 [85]; (b) Forestry Law No. 41/1999 [86]; (c) Government Regulation No. 7/1999 [87] concerning the preservation of wild plants and animal diversity; (d) Government Regulation No. 28/2011 [88] concerning management of sanctuary reserve and nature conservation areas; and (e) Job Creation Law No. 11/2020 [89]. Special policies regarding the mitigation of human and wildlife conflicts are stated in the Forestry Minister Regulation No. P.48/Menhut-II/2008 [90]. However, the legal force of ministerial-level regulation is not strong enough to overcome the human and wildlife conflicts that require a cross-sectoral collaboration [24].

The Indonesian government started releasing policies to mitigate the human and wildlife conflicts in the early 2000s through the Ministry of Forestry. One issued policy is the translocation of elephants from their original habitat into conservation centers, such as ETC in Riau. In 2004, the Indonesian Government adopted the Elephant Flying Squad program from India and developed it as a national program [91]. This program aims to drive elephants away from the contact areas to the core zone by using tame elephants and a routine patrol. The squad consists of rangers with noise and light-making devices and trained elephants (usually four elephants) to drive the wild elephants back into the forest whenever they are trying to enter villages [92].

Elephants receive legal protection in forest areas which are regulated under Forestry Minister Regulation No. P.50/Menhut-II/2008. This regulation can determine the state forest areas for wildlife habitats by synchronizing the national forest map with the provincial spatial planning map. The synchronization of the provincial and national spatial map is regulated in Government Regulation No. 26/2008 [93] amended to No. 13/2017. Besides that, the government also issued the technical guidelines of the Director-general of Natural Resources Conservation and Ecosystem, original name Director-general of KSDAE, No. P.8/2016 [94] relating designation of wildlife corridors as essential ecosystem areas (EEA). The designation of EEA aims to develop and conserve the elephants' corridors to connect the fragmented habitats.

To reduce habitat loss, the government has issued President Regulation No. 9/2016 [95] concerning the acceleration of the implementation of one map policy. One map policy aims to synchronize all maps to overcome the overlapping of land use maps that often causes conflicts in the field. This one map will be used as the basic map for all institutions, including the development of industrial plantations, agriculture, and physical buildings that commonly disturb the natural habitats of wildlife. In 2018, the Indonesian President also instructed the moratorium on the new permit for industrial forest plantations and oil palm plantations by releasing President's Instruction No. 8/2018 [96]. This instruction aims to evaluate the existing permit for forest plantations and oil palm plantation on natural forests and peat forests and their impact on wildlife's habitat and elephant corridors. As an output, the government through the Ministry of Environmental and Forestry, has released the indicative map of primary natural forest and peatland with business license termination, business approval, and land-use change business approval contained in Ministerial Regulation No. SK.666/MENLHK-PKTL/IPSDH/PLA.1/2/2021 [97] on 15 February 2021.

To reduce forest land conversion caused by regional expansion since the decentralization policy in 1999 [98–100], the central government released Government Regulation No. 10/2010 [101] amended to be No. 60/2012 concerning the procedures for changing forest status and functions. The autonomous regions that need to renew their regional spatial planning should coordinate with the central government and synchronize the regional planning with national planning. However, the need for economic development was stronger than the environmental focus, resulting in 22 provinces that renewed their regional spatial planning by 2015 causing forest conversion in many regions (provinces and districts) including in Sumatra [102].

3.2. The Current HEC Mitigation in Sumatra Island

Since the 1980s, the Indonesian Government has addressed three programs to mitigate HEC, i.e., population management (*Tata Liman*), elephant empowerment (*Bina Liman*), and the utilization of trained elephants from the ETC (*Guna Liman*) [13]. The *Tata Liman* is a program addressed to translocating elephants from fragmented forests to a more suitable habitat [103]. The *Bina Liman* program comprises habitat improvement, fencing, community education, and elephant training [104]. The *Guna Liman* utilizes domesticated elephants in the forestry, agriculture, and tourism sectors [97]. Between 1986 and 1995, 520 elephants were captured and translocated to six ETCs on Sumatra Island [105].

However, these programs are unsustainable because the demand for tame elephants for utilization and conservation activities is limited [103]. Some of the captured elephants are either too young or too old to be used for patrol programs. On the other hand, the number of elephants captured from the conflict areas and trained in ETC increased significantly which increased the operational cost of maintaining the tame elephants. As shown by the Directorate General of KSDAE [13], from 2006 to 2007, the budget for ETC increased significantly from Rp. 2.1 billion to 7.8 billion/ha. The government collaborated with 14 forestry companies in Sumatra to utilize the domesticated elephants in their operational systems or pay an elephant conservation fee (Rp. 10 million/elephant/year), but this strategy also did not work effectively due to the low commitment of the parties [103].

Realizing these programs were still not optimal to resolve HEC due to the high operational cost and low commitment of the companies, the government revised these programs by developing new captive elephant management and avoiding elephant capturing from the wild [13]. In the new management, the government collaborates with numerous conservation organizations (local and international) that have potential resources (human resources, budget, and networking) to improve the previous management systems. As shown by the Directorate General of KSDAE [13], these collaborative works have addressed numerous programs, including (1) the utilization of captive elephants to drive wild elephants back to their habitats; (2) elephant registration using a microchip; (3) ecological studies to investigate elephant feed and the relationship between feed nutrition contents and feeding behaviour; (4) the utilization of elephants for conservation activities (patrol, habitat protection, survey, and monitoring); (5) conservation education; and (6) ecotourism to improve ETC management and mitigate HEC.

Besides these programs, the government and conservation organizations also developed several other programs to mitigate HEC, and the most prevalent one is the community-based crop-guarding [106]. This program is classified as an active deterrent method and early detection of elephant contact with humans [107]. In this program, the local communities protect their crops from elephant disturbances using supplementary tools, such as loud noises, sirens, firecrackers, spotlight, cracking whips, fireworks, kerosene lamps, and watchtowers [64,106,107]. This program is quite effective in mitigating HEC [107]. Hedges and Gunaryadi [63] and Gunaryadi et al. [106] found that community-based crop-guarding using conventional tools thwarted crop-raiding up to 81.2% in 2005–2006 and 91.2% in WKNP in 2007.

Other strategies for HEC mitigation are the passive deterrent methods such as, using trenches, barbed wire fences, beehive fences, chili fences, chili-dung fires, electric fences, and rolling drums [107]. These strategies have different characteristics and requirements (Table 4). Until now, tin-can fences, trenches, rolling drums, tripwire fences, and community-based guarding are still implemented in mitigating HEC on Sumatra Island [107]. Electric fences are also used to minimize HEC; however, establishment and maintenance costs are quite expensive [106,108]. Another program addressed to mitigate HEC is the cultivation of non-preferred crops such as lemongrass and orange. This program has been implemented around Gunung Leuser National Park (GLNP) and Bukit Tigapuluh landscape (Tebo, Jambi). This program can minimize crop damage, and it is beneficial to communities. However, the methods are less effective because they cannot be applied across wide areas and are costly [109,110].

Table 4. Methods of crop raiding prevention in HEC mitigation used in Sumatra.

No	Mitigation Methods	Advantage	Disadvantage	Effectiveness to Mitigate HEC	References
1.	Community-based crop-guarding	• Low costs • No maintenance costs • Low risks to elephant • Can be implemented in a wide area	Low commitment and dedication of the local people	High	Gunaryadi et al. [106]; Sugiyo et al. [107]; Fernando et al. [109]
2.	Trenches	• Low risks to elephant • Can be implemented in a wide area	• High establishment costs • High maintenance costs	High	Department of Forestry [90]; Sugiyo et al. [107]
3.	Barbed wire fences	• Low cost • Low risk to elephants • Easy to implement • Can be implemented in a medium area	• Not durable • The implementation problem is medium	Low	Febryano et al. [105]; Sugiyo et al. [107]
4.	Beehive fences	• Low cost • Low risk to elephants • Beneficial to communities	• High maintenance • Not durable • Difficult to implement • Implemented in a small area	Low	Department of Forestry [90]; Sugiyo et al. [107]
5.	Chili and tobacco crop protection methods (applied in fences)	• Low risk to elephant • Establishment cost is medium • Easy to implement • Beneficial to communities • Can be implemented in a medium area	• High maintenance costs	Low	Department of Forestry [90; Gunaryadi et al. [106]; Sugiyo et al. [107]
6.	Tin-can fences	• Low cost • Low maintenance costs • Can be implemented in a medium area • Low risks to elephant	• Not durable (prone to get broken)	Low	Sugiyo et al. [107]
7.	Tripwire-triggered fences	• Low establishment cost • Can be implemented in a medium area • Low risks to elephants	• High maintenance costs • Not durable	Medium	Sugiyo et al. [107]
8.	Rolling drum	• Low cost • Durable • Maintenance cost is medium	• Implemented only in a small area	Medium	Sugiyo et al. [107]

3.3. The Basic Needs for Elephants and Humans and the Potency of Coexistence

The basic needs of elephants are feed, water, shade trees, and salt [111–113]. Elephants generally consume 290–400 different species and different parts of plants [8,112,114]. In their home ranges, elephants consume 50–59 species. When feed availability is decreasing, elephants will search for food within and outside their home ranges [18,113,115]. Elephants like oil palm, bananas, corn, and pumpkins that are raided in the fields [63,69,78,110]. The

daily movement of the Sumatran elephant is between 5.93–10.78 km, and the home range is around 97.4 km^2 [33,111,115] with the roaming distance for a group between 7–15 km/day (Average 0.01–1.5 km/h) [111,115].

The interaction of elephants and humans for space dates back to the Paleolithic period [28,116]. Humans utilized elephants for food, religious rituals, and pets. Archaeologists found evidence of elephant exploitation in the dismembered bones and signs of damage done by poachers [117,118]. In this case, humans interact with wildlife to fulfill their food needs, to gain self-esteem, and to reduce stress [119]. However, nowadays, natural resource utilization is not only for basic needs but also for economic purposes that cause over-exploitation and reduce food resources for elephants [113,120]. Other activities that have direct impacts on elephants are poaching and illegal ivory trade [42,43,121].

The successful coexistence between humans and elephants can be achieved if humans adapt their behavior to elephant behavior [122]. Negative perceptions toward elephants need to be altered by considering the benefits of elephants to human life [20,123]. For instance, elephants are helpful in plant spreading and elephants' feces can be used as a natural fertilizer. The level of community welfare adjacent to the elephants' habitats might influence human perceptions towards elephants and promote opportunities for harmonious coexistence. Human perceptions towards elephants relate to income level and dependency on forest resources. The income level of the local people around the elephant habitat is generally low, and they generally live in poverty [124]. As an example in OKI District, South Sumatra Province, the family income was Rp. 1,060,833–1,814,583/month (around US$75–128), which is below the regional wages [124]. Local people usually work in the agriculture sector and cultivate the forestland adjacent to residential areas. This denotes the higher dependency of local people on forest resources [125].

To meet a decent life, people particularly who work in the agricultural sector need adequate land to grow crops. Based on the Indonesian statistical agency, the minimum required land for a decent family life is 1.0 ha. This minimum amount of land per household may vary depending on regions, the number of families, farmland conditions, and commodities grown on the land [126]. In a village near the forest, the minimum land area that farmers must own to meet their welfare was 2.51 ha, which is 0.65 ha for rice, 1.12 ha for corn, and 0.74 ha for soybeans [127]. However, many farmers around the conservation forests manage land less than one hectare which is a potential cause for land grabbing or illegal forest land occupation [124]. Therefore, farmland intensification and livelihood diversification are needed to minimize HEC, such as agroforestry and ecotourism development [128].

4. Recommendation on the Successful Human-Elephant Coexistence

The government and related parties on Sumatra Island have developed strategies to minimize HECs. However, they are still not optimal considerably, as shown by the increasing HEC cases in several parts of Sumatra and the detrimental impacts on both sides [28,129–131]. Based on this review of the available HEC mitigation strategies and an understanding of the needs of both humans and elephants, we recommend the following recommendations to improve the successful human-elephant coexistence. They are: (1) strengthening policies and institutions; (2) increasing conservation programs on the habitats and movement corridors of elephants; (3) community empowerment; and (4) implementing compensation schemes for conflict victims.

4.1. Strengthening Policies and Institutions That Relate to HEC Mitigation

To save wildlife and overcome HEC, the Indonesian government has issued several regulations in Section 3.1. The most specific regulations to overcome human and wildlife conflicts are the Forestry Minister Regulation Number P.57/2008 [132] on the Strategic Directions for National Species Conservation 2008–2018 and the Minister of Forestry Regulation No. P.48/2008 on human and wildlife conflicts management [24,25]. However, those regulations are not strong enough in terms of their legal force, and they are not specific enough to mitigate HEC.

In the future, policies in mitigating human-wildlife conflicts in Indonesia must accommodate various interests in forest management, such as animal conservation, social, economic, cultural, political, and provincial/district spatial issues. Regulations need to accommodate social, cultural, and economic aspects for the benefit of the local community [25]. The legal power of regulations at the ministerial level is insufficient to address several HEC issues that involve other institutions from different ministries. Therefore, a regulation with higher levels, such as government regulation, needs to be released. Government regulations can instruct various institutions across provincial and district governments, such as the National Disaster Management Agency, the Indonesian national army, the Indonesian police, the Ministry of Agriculture, and the Ministry of Health in overcoming HEC [24].

Furthermore, the synergy of goals and missions of institutions in mitigating HEC also needs to be improved through coordination and collaboration. Collaborative management can accommodate the interests of various parties that can improve the effectiveness of conflict mitigation and overcome financial problems. Some relevant stakeholders that are commonly connected to HEC consist of regional governments, logging companies, industrial forest companies, plantation corporates, NGOs, and local communities. Institutions must be built legally, operationally, and approved by the Ministry of Environment and Forestry to represent the Central Government [25].

4.2. Increasing Habitat Conservation

4.2.1. Habitat and Corridor Restorations

Conservation practices to mitigate conflicts include restoring degraded habitats and constructing elephant corridors. Elephant habitat restoration programs are essential to increase the availability of resources to reduce the likelihood of elephants entering agricultural areas. Habitat restoration includes habitat enrichment by planting trees and understorey plants that are favorable to elephants, high nutrient contents, fast-growing, endemic plants, and/or non-invasive plants. The recommended species of trees are *Artocarpus integer, Garcinia celebica, Palaquium obovatum Macaranga gigantea,* and *Macaranga lowii* [133]; while the recommended understorey plants are *Pennisetum purpureum*, *Ottochloa nodosa Melastoma malabathricum*, *Stenochlaena palustris*, *Cyperus kyllingia, Setaria megaphylla, Nephrolepis biserrata*, *Andropogon intermedius*, and *Andropogon halepensis* [51,133]. Habitat restoration should also consider elephant home range and access to water sources [51,134].

Restoration of elephant corridors is important to connect fragmented habitats to fulfill the basic need of elephants such as feed, migration, and finding water. Corridor restoration can be implemented by constructing natural corridors (based on land, water, and vegetation improvement) and artificial corridors (paths created by humans) such as bio-bridges [135]. Enriching corridors with vegetation is a practical, cheap, and valuable solution. It is because these targeted areas are small, and the corridors can be utilized by communities if locals understand the natural behavior of elephants, such as the food selection and migration period [135,136].

A corridor should be developed by following elephant migratory/movement tracks. One of the recommended shapes is the stepping-stone model. Each stepping-stone is planted with an annual feed species by combining tree species, legumes, and understorey that elephants like to consume (grass and shrubs). The trees or perennial plants that are not preferred by elephants, such as oranges can be used as corridor barriers with 30–40% of their proportion. The disliked trees will grow, and at the same time, the trees will reduce the likelihood of the elephants entering the human areas and thus can reduce disturbance. Fruit can also be utilized by farmers [110]. Stepping-stone corridors are built based on the distance of animals to the outside of the forest area to prevent disturbances to settlements and agricultural areas. For example, in the forest plantation in Ogan Komering Ilir Regency, elephants enter gardens and community settlements 2–3 km from the industrial forest boundary [51]. Stepping stones can be made along 4–5 km of forest or 1–2 km before the edges of a community settlement. Stepping stones must be free from obstacles (temporal

or permanent), such as roads, electric fences, crop cultivations, and buildings [135]. On the farmland close to elephant habitats or corridors, farmers are recommended to grow plants that are disliked by elephants, such as some medicinal plants (ginger, chili, lemongrass, garlic, and onion) and beehive fences (bee feed) that are safe and also economically beneficial for the communities [137,138].

4.2.2. Encouraging the Establishment of EEA Outside Conservation Forests

The largest area of Sumatran elephants' habitat is outside the conservation forest. The Indonesian government has made a policy that ecosystems outside conservation areas that are ecologically, socially, economically, and culturally important for biodiversity conservation can be designated as EEA [139]. EEA can also be developed to improve the connectivity between fragmented habitats and animals' home ranges in the same landscape [140,141]. The mammals that have a wide home range, such as elephants, tigers (*Panthera tigris*) [142], Sumatran rhinos (*Dicerorhinus sumatrensis)* [143], and orangutans (*Pongo abelii)* [144], use more than one ecosystem as their habitat [145]. Therefore, they need wider areas to avoid human disturbance to their natural habitats. One of the EEA concepts has been successfully applied to mitigate conflicts in Tebo Regency, Jambi [78].

Management of ecosystems in the landscape needs to be done through an integrated approach that heeds ecological, socio-cultural, and economic aspects [141,145]. The integration of community activities within EEA is organized with limited access to fulfill daily needs that are regulated in a zoning system. Strict prohibition of public access to elephant habitats only results in antipathy of the public towards the region and the existence of elephants [59,146]. Therefore, granting access to utilization zones is a form of coexistence as it facilitates sustainable management that benefits communities and improves habitat conservation [147,148].

The EEA for elephants must be designed as a unitary area that can include a protection forest and several management units with different businesses (oil palm plantations, industrial forest, concession forest, and indigenous forest). Therefore, it needs the support and participation of many stakeholders, such as local government, corporates, and local people. The support and participation can be in the form of providing land for EEA, budgeting, and synergizing the unit management in the EEA. To realize the coordination among the stakeholders, collaborative management of EEA either through a forum or a consortium is recommended [145].

4.3. Community Empowerment

Community empowerment is an essential strategy in wildlife management that must be implemented to reduce human-wildlife conflicts. The improvement of human and elephant coexistence can be realized through the development of socio-cultural communities adjacent to forests [149,150]. Several alternatives of community empowerment recommended on Sumatra Island are ecotourism-based elephant management, the development of value-added community-based enterprise, providing legal access to forests through Social Forestry (SF) program, and implementing compensation schemes for conflict victims.

4.3.1. Ecotourism-Based Elephant Management

The Directorate General of KSDAE [151] highlights that ecotourism is expected to be the best solution for overcoming ETC financial issues. Ecotourism is an ecological protection model that provides economic and social benefits to communities around forests [152,153]. Wildlife has enormous potential as a tourism icon [25,36,154,155]. The authenticity and physical interactions with wild animals, including elephants, are enticing for tourists and increase ecotourism potential [155,156]. Elephant-based ecotourism is a farmer empowerment strategy in the form of community-based resource management (CBRM) [108,157]. The development of elephant ecotourism can be carried out on wild or tame elephants. Semi-natural tame elephant ecotourism has been implemented through the development

of ETCs in several parks in Indonesia, such as in GLNP, WKNP, and KSNP [20,158] that involve the communities to reduce conflicts [159].

Some scholars have evaluated the impacts of the implementation of ecotourism-based elephant management in Indonesia. Mahfud [154] evaluated Seblat ETC in Bengkulu Province based on habitat conditions, authenticity, and aesthetic values, which are valued as high quality. Seblat ETC has provided a safer and more feasible habitat for captured elephants from conflict areas [39]. In GLNP, which covers Aceh and North Sumatra, the development of ecotourism has become a new source of income for the community, so timber extraction and encroachment activities in the national park have decreased [25]. The direct financial contribution of ecotourism can help to improve conservation activities, such as treating injured animals, forest protection, and removing invasive species [135].

From socioeconomic aspects, communities around the ETC highly support elephant ecotourism because it creates job opportunities and generates income for local people. Elephant ecotourism needs mahouts, tour guides, security guards, and other employment forms that can empower local people, as practiced in Aek Nauli Elephant Conservation Camp (ANECC) in North Sumatra [160]. Ecotourism also generates economic income from services and facilities such as lodgings, food, and souvenir vendors. Elephant ecotourism is also well received by visitors. A study in Seblat ETC reported that 64% of the visitors were very satisfied with the tame elephant attractions and willing to pay (WTP) Rp. 32,329 (about US$2.2) for one visit to the area [154].

For wild elephants, wildlife ecotourism programs (e.g., safari tourism widely implemented in Africa) are still limited in Indonesia. The development of wild elephant ecotourism is potential in Indonesia because national parks and EEA including their corridors, such as Bukit Tigapuluh National Park (BTNP) and KSNP have been designated for elephants' habitats. The designation of the essential elephant habitats can increase the chances for humans to observe elephants in their natural life, including when a herd of elephants is migrating. Therefore, the managers should improve the facilities to allow the public to observe and access those areas. The local people around the essential areas need to be involved in managing the ecotourism, developing supporting facilities, and providing supplementary feed for elephants. Ecotourism development can be supported by collaboration with companies around the area, especially in financial support through a Corporate Social Responsibility (CSR) scheme, or funding by the government [20,25]. However, elephant-based ecotourism management needs to pay attention to elephant welfare. The recreation areas that utilize tamed animals to attract visitors including Sumatran elephants have the potential for animal exploitation by forcing elephants to entertain visitors [160]. Therefore, ecotourism practices that use elephants must ensure to do not negatively impact their welfare. Five domains of animal welfare including nutrition, physical environment, health, behavioral interaction, and mental state should be considered and fulfilled in the development of elephant-based ecotourism [161].

4.3.2. The Development of Value-Added Community-Based Enterprise

The biggest challenge to creating the coexistence between humans and elephants is to change the farmers' behavior from the dependency on the direct products of forest (provisioning) into industrial communities [135,157]. To overcome this issue, training should be given to local people to improve their knowledge and skills to run the new model of resource management, that is value addition to land and products. For instance, the enhancement of community enterprises to provide foods and souvenirs is a valuable addition to products that has been successfully implemented in elephant ecotourism [155]. Agroforestry, silvopasture, silvofishery, and beekeeping are examples of the increasing value of forest land that can be promoted to improve land productivity to reduce the expansion of forest clearing [162].

4.3.3. Providing Legal Access to Forest through Social Forestry (SF) Program

The involvement of local people in forest management is the best approach to improving forest protection and reducing HEC [162]. Provision of legal access to forests has been implemented in several programs in Indonesia, and SF is the most applied program that covers the broader aspects and types of forests, including the forests adjacent to elephant habitats. Government regulation No. 6/2007 [163] and Environmental and Forestry Ministerial Regulation No. 9/2021 [164] have regulated the implementation of the SF program. Agroforestry and ecotourism are two SF management models of conflicting areas [165] that are also potential to be implemented in the forests with HEC. In general, community members (families) can manage 2 ha of forest per family in the agroforestry model [125]. For the ecotourism model, community members usually manage the designated CF forest collectively. If the communities managed areas properly, the forest can provide a feasible income to communities and can reduce the pressure on elephants' habitat. In the HEC areas, local people can cultivate the land with species that are not preferred by elephants, such as citrus and citronella.

4.3.4. Implementing Compensation Schemes for Conflict Victims

Compensation can reduce the financial impact on farmers that has the potential to improve the opportunities for harmonious coexistence [166,167]. Compensation must be accompanied by an agreement and guarantee that the community will not repel and kill animals if their plants are eaten or damaged by wild animals [168,169]. The compensation recipients are farmers that are directly involved in conflict with elephants who can be identified by the Conflict Management Team [170]. The compensation value is adjusted to the losses suffered by each farmer or 'victim' of the conflict. One approach that can be taken is to calculate the number of damaged plants multiplied by the average yield of harvest sales from the landowner.

In India, the allocation of compensation costs in conflict mitigation can be up to US$5,332,762, which is used to replace damage to crops and other property, replace livestock, human injury, and death contribution to the victims [169]. Compensation given must be in non-cash, such as (1) seeds and plant fertilizers, (2) machines to manage land, and (3) marketing assistance for crops so that they are not controlled by agents [162]. The budget allocation for compensation can be part of the Government budget (Central and Regional) and Corporate Social Responsibility (CSR) and grant assistance from abroad through NGOs.

5. Conclusions

HEC is a severe threat to elephant conservation and human lives and livelihood. HEC is mainly driven by habitat conversion into monoculture plantations, community settlements, and infrastructures. Deforestation has caused the loss of 80–90% of elephant habitat. This condition has forced elephants to have closer contact with people, leading to increased conflicts. Continuous HEC has resulted in the declination of more than 50% of the elephant population in the last 20 years. HEC commonly occurs in the remaining elephant enclave in each province. Regulations for mitigating human-wildlife conflicts need to be upgraded from the ministerial level to the government level to serve as instructions for various government institutions and organizations. Numerous programs addressed to mitigate HEC are still ineffective as some of them require high operational costs and may only be effective in a small area. Though it is challenging to develop, successful coexistence between humans and elephants is essential to protect Sumatran elephants from extinction. We recommend numerous strategies for developing successful coexistence between humans and elephants including strengthening policies and institutions, habitat restoration, corridor development, encouraging the establishment of EEA in every province, empowering the community through an economy generated from elephant-friendly ecotourism, providing legal access to forestlands for farmers, and improving community resilience through the

compensation scheme. The program should be made in a collaborative and integrated manner with relevant stakeholders.

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