Optimizing Biodiversity Conservation in Sundaland through Advanced Geospatial Techniques and Remote Sensing Technologies

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Abstract. Sundaland ecosystems are under threat from human activity and climate change such as logging, agricultural practices, overexploitation of wildlife and climatic change that have led to frequent forest fires and a decline in indigenous plant and animal species. This study investigates the risks to Sundaland's biodiversity as well as the management possibilities using GIS, RS, and AI. The goal was to find out how artificial intelligence (AI) can be applied to effectively manage biodiversity and expand on the body of knowledge already available about the useful roles that GIS and RS play in the area. In this systematic method, seven databases were used to gather data from 110 research publications, of which 101 were screened for scope and subject variable. 80% (81articles) of the examined studies collected data using GIS and RS. It is found that. AI in biodiversity management is poised to grow, offering new opportunities to address the intricate challenges facing our planet's diverse ecosystems. In conclusion, for efficient monitoring, well-informed policy creation, and decision-making to guarantee the long-term preservation of Sundaland's biodiversity, integration of GIS, RS, and AI is essential.

1 Introduction

Sundaland region biodiversity with other Southeast Asia's biodiversity has been threatened for decades and is predicted to decrease by 13% to 85% by the year 2100 [1-3]. As a result of widespread logging, agricultural development, and hunting pressure, ecosystem loss and degradation are the principal risks [4, 5]. Natural forests have deteriorated due to increased agricultural growth, with a 50% loss in lowland areas over the past two decades [6](Hussein, 2023) and in montane areas [7]. Protected areas (PAs) are places set aside to

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preserve biodiversity and stop logging, habitat preservation and wildlife population maintenance [8](Chen, et al., 2023). As a result, at the global level, PAs have higher species richness than those outside of them [9] But as numerous studies have demonstrated, PAs are frequently biased toward vested commercial advantages and do not usually prioritize places with high concentrations of biodiversity [10], leaving ecosystems vulnerable [9]. Sundaland is an ecological region spanning parts of Indonesia, Malaysia, and the Philippines. It is home to an incredibly diverse array of species and habitats, making it one of the most biodiverse regions in the world, Unfortunately, this biodiversity is increasingly threatened by human activities such as unsustainable logging, unsustainable agricultural practices, and overexploitation of wildlife [11].

Findings from Verma et al. (2020) [12] on protected regions in Malaysia and Indonesia's Sundaland found significant human pressure that reduced the areas to only one-third and half of the official protection, respectively. This shows that Malaysia and Indonesia have a long way to go before achieving Aichi Target 11, which calls for effective management of PAs [11]. Additionally, according to a study by Katona et al. (2023) [13] one-third of the area covered by global PAs is under strong human pressure; as a result, the network's level of protection is far lower than expected. These threats have serious impacts on the region's biodiversity and require the use of geographic information systems and remote sensing to monitor the entire region for better biodiversity conservation [12].

Geographic information system (GIS) is a powerful tool that can be used to identify and track threats to Sundaland's biodiversity [7]. GIS can help us identify areas where there is a high potential for conflict or environmental degradation, and it can also be used to develop sustainable solutions (Ahmad, 2023) [14]. GIS data can be used to monitor logging activities in an area, and this information can then be used to determine when the trees are being harvested in a way that does not damage the environment [15, 16].

Remote sensing (RS) is another important tool that can be used to study Sundaland's biodiversity [17]. Remote sensing technologies allow us to see things that are not directly visible, such as vegetation and water resources [18]. This information can then be used to monitor and protect Sundaland's resources from damage [19]. For example, remote sensing data can be used to identify areas where there is a high potential for forest fires, and this information can then be used to develop fire prevention strategies [7]. By using GIS and RS technologies, we can protect Sundaland's biodiversity and ensure that the region remains an important ecological resource [20]. Therefore, this systematic review paper review the use of geographical information system (GIS) and remote sensing (RS) technology in Sundaland biodiversity conservation to explore the vital role of the GIS and RS in biodiversity conservation. The goal was to find out how artificial intelligence (AI) can be applied to effectively manage biodiversity and expand on the body of knowledge already available about the useful roles that GIS and RS play in the area.

2 Sundaland has a hotspot

In Sundaland, there are over 25,000 different vascular plant species, 15,000 among which are exclusive. At least 117 indigenous plant genera, including 59 from Borneo, 17 from Sumatra, and 41 from the Malay Peninsula, are found in the hotspot. According to [21]. Furthermore, 39% of the vertebrates there are endemic, and 5% of the world's plant endemism is supported there [22]. Wallace's separate creation of the theory of evolution by natural selection was affected by the region's unusual biodiversity, which also had a substantial influence on the early growth of the field of biogeography [23].

3 Biodiversity threats of Sundaland hotspot by human activities

To reduce rates of species extinction and achieve the Aichi Biodiversity Target 11 of the United Nations Convention on Biodiversity, which aims to have 17% of land area protected, consideration must be given to the nature, distribution, and intensity of human impact on the environment [24]. To sustainably protect biodiversity, these statistics are crucial for directing policy and action [21]. to properly preserve Sundaland's biodiversity The creation of methods for gauging the distribution and magnitude of accumulated human pressures is crucial [12].

Rees, et al. (2018) [24] first evaluated the distribution and intensity of accumulated human pressures to map the terrestrial global "human footprint." The maps were successful at demystifying intricate cumulative land-use processes and making them understandable and communicable to scientists, communities, and policymakers [25, 26]. The official percentage of land covered by PAs in Malaysia and Indonesia is 19.12% and 12.17%, respectively [27, 26]. According to these figures, Malaysia has already achieved the Aichi Target 11 established by the Convention on Biological Diversity, while Indonesia is on course to do the same. To achieve this goal and stop the loss of biodiversity, 17% of the land must be preserved. The findings of Verma et al. (2020) [12] suggest that the actual protection after the removal of areas vulnerable to significant human pressure may only be one-third and half of the official protection, respectively. This shows that Malaysia and Indonesia have a long way to go before achieving Aichi Target 11, which calls for effective management of PAs. Additionally, according to a study by Hoffmann, (2022) [28] one-third of the area covered by global PAs is under strong human pressure; as a result, the network's level of protection is far lower than expected.

Verma et al. (2020) [12] researched 308 lowland forest specialist birds in Sundaland, a biodiversity hotspot in Southeast Asia, to gauge the extent and size of recent changes to the massive human footprint within protected areas. According to the most recent human footprint dataset, 70% of Sundaland has experienced considerable human change [28-30]. These stressed areas have increased by 55% since 1993. Averagely, areas with heavy human pressure contained 50% of the size of significant biodiversity hotspots, 78% of each protected area, and 38% of the range of lowland forest specialist birds [31-33]. The results show that the real level of protection offered by protected areas (PAs) is only between one-third and half of that on paper, after accounting for human footprint [34]. All protected areas were impacted by human demands, but those that were managed primarily for the preservation of biodiversity had the greatest increases [35, 36]. These findings show the disproportionately large human footprint in Sundaland and the likely escalation of the biodiversity crisis there.

The most crucial conservation values of the Sundaland biodiversity hotspot are in jeopardy as a result of heavy human pressure [37]. The majority of protected land is frequently subject to intense human demands [38]. This is much greater than the global average of about 30% due to the high concentration of human activity in Sundaland [18]. According to the investigation's findings, Sundaland is not covered in human footprints equally [39, 40]. For instance, the key areas where the human footprint rose were Sabah, Riau, and Central Kalimantan. Although the human footprint on Java as a whole did not change between 1993 and 2009, this indicates that people have had a significant impact on the ecosystem since that year and that no areas are remaining in their natural state [41, 42].

4 Climatic threat to Biodiversity loss in Sundaland hotspot

Sundaland is a biogeographical region located in Southeast Asia that encompasses the Malay Peninsula, the Sunda Islands of Borneo, Sumatra, Java, and the surrounding islands [43]. This region is known for its incredible biodiversity, with over 1,500 species of fish and over 3,000 species of plants. However, this unique and fragile ecosystem is being threatened by climate change and human activities, with potentially dire consequences for the future [44].

5 Effect of climatic change in the Sundaland hotspot

In Southeast Asia, there has been a dramatic decrease in both species diversity and suitable habitats, according to a study by Namkhan et al. (2022) [3]. The natural forests of Southeast, Asia have been impacted by rising temperatures and changing precipitation patterns, which have led to more frequent forest fires and a decline in indigenous plant and animal species [45]. Indo-Burma and Sundaland are areas of significant biodiversity hotspots in Southeast Asia. The findings showed that both hotspots are experiencing a loss in biodiversity[3, 12].

In the Sundaland hotspot, which contains much of the tropical lowland rainforest, there has been a decline in species habitats and high biodiversity areas, especially in central Malaysia, where high biodiversity areas have been replaced by medium and low biodiversity areas [3]. Despite this, 7-8 species showed improved habitats, notably in lowland locations like Borneo and Sumatra that are heavily impacted by humans, with a 55% rise in areas under severe human pressure since 1993 and 70% of the areas significantly impacted by humans [12].

6 Threats to terrestrial biodiversity loss in the Sundaland hotspot

The The primary causes of the loss of terrestrial biodiversity in the Sundaland biodiversity hotspot are deforestation and forest degradation. As of the year 2000, the hotspot's original habitat had shrunk from 1.6 million km2 to 125,000 km2 [12, 45]. Additionally, by 2010, it had lost roughly 773,000 km2 of tropical lowland forests, or roughly 70% of its total lowland forest area [46]. According to Peyre (2021) [48] Sundaland's tropical forests are seeing the highest rate of deforestation in the world. This deforestation is mostly the result of road construction, unsustainable logging practices, and rapid agricultural growth [49]. For example, between the 1980s and 2010s, Sumatra and Borneo saw over 40% of their respective forests destroyed by palm oil plantations. Additionally, Sumatra's deforestation pace has been accelerated by the speedy development of roadways [48, 50, 51].

In particular, new logging roads make it simpler for logging trucks and inhabitants to access the once-remote sections of the Sumatran woods, which may ultimately cause ecological damage and a fall in biodiversity [52-54]. The vulnerability to biodiversity in the Sundaland hotspot is exacerbated by additional anthropogenic impacts including illegal wildlife trading and hunting [55, 56]. Due to habitat destruction, unlawful hunting, and poaching for profit, just about 500 severely endangered Sumatran tigers, of whom only 33 remain in North Sumatra, are present in Indonesia [57-60].

7 Suggestions for protection strategies.

There are numerous obstacles to the successful administration of these protected areas, even though countries in Southeast Asia have created and implemented strategic plans to do so [61, 2, 62]. To ensure the sustainability of biodiversity and ecosystem services, corrective actions are therefore urgently required to address the shortcomings of these protected areas [2]. The following paragraphs discuss several preventive and remedial actions that can support monitoring and ensuring the effectiveness of terrestrial areas in Southeast Asia [63, 64].

7.1 Involvement of Indigenous hinterland community

According to studies, indigenous lands outperform protected areas in stopping deforestation and preserving biodiversity [65, 66]. Native communities should be encouraged by the government and NGOs like WWF to actively participate in the protected area decision-making process [67, 68]. 80% of the world's biodiversity is protected by indigenous peoples, who are also responsible for managing natural habitats [69, 70]. Indigenous traditions, opinions and knowledge are crucial for promoting the management of sustainable ecosystems and preserving local communities' way of life [71]. Enforcing conservation laws and carrying out good deeds is comparatively simpler [72, 73]. The inclusion might foster a sense of ownership that motivates the local groups to work together to safeguard their countries from exploitation and sustainably use the resources they have access to [74]. This corrective action is consistent with the Aichi Target 18 established by the CBD, which states that by 2020, indigenous and local communities should actively participate in biodiversity conservation and ecosystem management and local and traditional knowledge, innovations, and practices should be incorporated into these efforts [75, 76].

7.2 Reforestation and Afforestation

To restore biodiversity and ecosystem services over time, protected areas urgently require reforestation and afforestation. For instance, Vietnam's Five Million Hectare Reforestation Program enabled it to successfully increase its forest coverage from 32% in 1998 to 39.5% in 2010. (5MHRP) [78]. Additionally, the 5MHRP has enhanced local communities' standard of living and contributed to the creation of several employment possibilities [79]. The Southeast Asia Green Program, a regional conservation initiative founded by Southeast Asia, was presented in 2021 to plant at least 10 million native trees within ten years, to significantly increase reforestation and afforestation activities [61]. Through cooperative efforts across the Southeast Asian nations, this greening project adopts a whole-society approach to restore degraded lands and stop biodiversity loss for a sustainable future [79].

7.3 Funding

Additionally, conservationists may more effectively plan and design the growth of protected area networks in Southeast Asia with sustainable sources of finance [79]. Therefore, to sustainably support the efficient maintenance of these protected areas, conservationists should aggressively seek diverse and sustainable finance streams [61].

7.4 Use of GIS and RS in biodiversity conservation of Sundaland hotspot

Geographic Geographic Information Systems (GIS) and Remote Sensing (RS) have been promoted more and more as a way to effectively combat the challenges mentioned above and preserve the biodiversity of the Sundaland hotspot [79, 61]. Tan, et al. (2022) [61] reported that the area-weighted producer's accuracy for their composites from the years 2000, 2005, and 2010 was 77%, 85%, and 86%, respectively. Their goal was to identify and experiment with a technique of post-classification compositing of Satellite images to expedite multi-decadal monitoring of marshland forest cover in Sundaland [2]. These findings demonstrate that, despite the SLC-Off issue since 2003, the geographic coverage, classification accuracy, and levels of missing data in Landsat composites are comparable across 20 years [63]. Landsat continues to be useful for monitoring tropical forests, especially the fast-diminishing peat swamp forests of Sundaland [80, 62].

GIS is a computer-based system that enables scientists to collect, process, and map data on a large scale [2]. In the context of biodiversity conservation, GIS has been used to map the distribution of species and habitats, identify potential hotspots for conservation action, and develop management plans [63]. RS is an important tool in mapping ecosystems and monitoring changes over time. RS can provide valuable information on the distribution of plant species, animal populations, land use maps, and more [80].

Despite the benefits of using GIS and RS in the conservation of the Sundaland hotspot, there is still some debate over their effectiveness. Some scientists argue that GIS has limited ability to identify important spatial patterns within biodiversity data and that RS can be unreliable when used for long-term monitoring [64]. Nevertheless, despite these limitations, GIS and RS remain powerful tools for biodiversity conservation in the Sundaland hotspot. In particular, GIS has been used to identify priority areas for conservation action, and RS has been used to monitor the status of key species and habitats [80]. One important way to protect the region's plants, animals, and other organisms is through the implementation of protected areas [64]. Protected areas can help conserve species and habitats while also providing a place for people to live and work without fear of harmful effects on their environment [2]. Additionally, sustained research efforts are needed to better understand the biodiversity of Sundaland and its risks so that effective management measures can be developed.

8 Use of Artificial intelligent

The world of biodiversity is broad and complicated, and traditional monitoring techniques face many obstacles [7, 18]. With the advent of artificial intelligence (AI), remote sensing, and geographic information systems (GIS), there are now a plethora of innovative options for efficiently maintaining and keeping an eye on the diverse array of species on our globe [81, 17].

Artificial Intelligence (AI) has emerged as a powerful tool in the field of Geographic Information Systems (GIS) and Remote Sensing, revolutionizing biodiversity monitoring and management [19, 20]. GIS integrates spatial data, enabling the analysis and visualization of geographical information [14]. AI enhances GIS by providing advanced algorithms for data processing, classification, and predictive modelling [15]. According to a study by Qamar et al. (2023) [16] AI techniques, such as machine learning and deep learning, have been successfully applied to extract information from remotely sensed data, improving the accuracy and efficiency of land cover classification and change detection [82]. This synergy between AI and GIS facilitates the identification of critical habitats, migration patterns, and ecological changes, supporting informed decision-making in biodiversity conservation [83]. Remote sensing, which involves collecting data from a distance, plays a pivotal role in biodiversity monitoring, providing valuable insights into ecosystems and species distribution [19]. AI applications in remote sensing have been instrumental in automating the analysis of large-scale and high-resolution satellite imagery. For instance, Wang et al. (2020) demonstrated the effectiveness of convolutional neural networks (CNNs) in species identification based on satellite imagery, significantly reducing the time and effort required for manual classification [8]. The integration of AI and remote sensing enables real-time monitoring, early detection of threats, and timely intervention in biodiversity management [9]. This interdisciplinary approach not only enhances the accuracy of biodiversity assessments but also contributes to the development of adaptive conservation strategies in the face of environmental changes [10].

The realm of biodiversity monitoring and management faces formidable challenges due to the intricate nature of ecosystems [13]. However, the integration of artificial intelligence (AI) with geographical information systems (GIS) and remote sensing technology has introduced innovative approaches to address these challenges [84]. AI models, trained on

extensive datasets, are significantly contributing to biodiversity conservation efforts [85]. First, image recognition algorithms, as demonstrated by Joly et al. (2022) [86], enable automated species identification and population monitoring using diverse sources such as camera trap photos, drone footage, and satellite imagery. This advancement facilitates the tracking of migration patterns and habitat utilization with remarkable accuracy [87].
Secondly, AI plays a pivotal role in mapping and analyzing habitat changes through the analysis of satellite and aerial imagery [88, 89]. These technologies detect alterations in land cover, deforestation, and other environmental factors critical for understanding biodiversity loss drivers and guiding conservation strategies [90]. Thirdly, AI models, trained on historical data and environmental variables, can predict areas at risk of biodiversity loss due to climate change, invasive species, or human activities [100]. This predictive capability empowers proactive conservation measures [91].

Furthermore, AI contributes to optimizing conservation strategies and resource allocation by analyzing complex datasets [92, 93]. This approach ensures that conservation efforts are targeted effectively, maximizing their impact and promoting the long-term survival of species and ecosystems [94-96]. GIS and remote sensing provide the necessary spatial data and imagery to train and operate these AI models, facilitating the integration and visualization of critical information layers, such as species distribution, habitat maps, and environmental factors [16, 97].

Despite the undeniable potential of AI in biodiversity monitoring and management, several challenges and considerations must be addressed [98]. These include data availability and quality, model bias and explainability, and ethical concerns related to privacy and potential misuse [11, 99]. Overcoming these challenges is crucial to fully harness the power of AI, GIS, and remote sensing, allowing us to gain deeper insights into the intricate web of life and take more effective steps toward protecting the Earth's biodiversity [94, 95].

9 Methodology

In this research, a systematic literature review was conducted, utilizing nine databases for comprehensive data collection. These databases included Google Scholar, Emerald Insight, SSRN, Web of Science, BSC, JSTOR, ProQuest, Scopus, and others. A set of 20 keywords was strategically employed for data retrieval, this include the followings words Sundaland in Asia, Threats to biodiversity through technological means, Traditional ecological knowledge, Habitat degradation, Analysis of geographic data, Sustainable solutions for biodiversity utilizing technology (RS GIS & AI), Conservation initiatives employing technology, Challenges and threats posed by logging, Conservation strategies employing technology (RS GIS & AI), Adoption of technology in biodiversity conservation, Practices of unsustainable agriculture, Geographic Information System (GIS) in biodiversity, Ethical considerations, Financial constraints, Integration of data in technology (RS GIS & AI), Biodiversity management through RS GIS & AI, Engagement of local communities, Remote Sensing (RS) technology in biodiversity, Capacity-building, Protocols for data-sharing. The study's temporal scope spanned from 2017 to 2024, during which a total of 5582 papers were initially identified. This paper includes the scholarly article seminar article, thesis, dissertation etc. Following a judicious screening process based on the study's objectives, 110 papers were downloaded for further consideration. Employing purposive screening, a subset of 100 research papers was ultimately selected for a detailed review. Qualitative data analysis was performed using the computer-assisted data analysis tool, NVivo. The qualitative content of the findings was explored through the application of tree diagrams and word clouds. This systematic approach ensured a comprehensive and focused examination of relevant literature, employing a mix of established databases and advanced qualitative analysis tools to distil key insights from the vast body of available research.

Table 1. Data collection and the data management a total of 110 paper was finally downloaded and 100 sets were used for the study

	Key Search Words	Database								Year	Result of the search (Papers related)	No. Of papers screed	No. Of paper used in the study
		Google Scholar/others	SSRN	Web of Science	BSC	JSTOR	ProQuest	Scopus	Emerald insight				
1	Sundaland in Asia	25	15	11	25	54	21	28	20	2017-2024	199	5	5
2	Threats to biodiversity using technology	132	8	56	65	41	1	52	1	2017-2024	356	2	2
3	Traditional ecological knowledge	145	12	77	55	41	2	2	1	2017-2024	335	6	6
4	Habitat degradation	88	3	54	51	62	15	1	2	2017-2024	276	4	4
5	Geographic data analysis	25	13	71	44	22	2	5	2	2017-2024	184	5	5
6	Sustainable solutions for biodiversity using technology (RS, GIS & AI)	25	15	89	77	22	2	8	3	2017-2024	241	5	5
7	Conservation initiatives using technology	111	11	85	45	32	8	2	5	2017-2024	299	5	5
8	Logging challenges and thread	124	5	58	54	51	5	2	8	2017-2024	307	4	4
9	Conservation strategies using technology (RS &GIS)	55	6	58	55	55	5	21	15	2017-2024	270	2	2
10	Technology adoption in biodiversity conservation e.g AI	52	14	95	58	33	3	5	15	2017-2024	275	6	6
11	Unsustainable agricultural practices	124	24	54	54	51	8	23	19	2017-2024	357	2	2
12	Geographic Information System (GIS)using AI in biodiversity	33	12	56	24	21	2	21	21	2017-2024	190	6	6
13	Ethical considerations	121	22	54	88	14	20	1	21	2017-2024	341	5	5
14	Financial constraints	31	18	55	57	53	15	1	22	2017-2024	252	5	5
15	Data integration in technology (RS &GIS)	58	21	51	56	56	1	25	22	2017-2024	290	3	3
16	Biodiversity management using RS & GIS and AI	45	25	25	21	65	21	54	23	2017-2024	279	4	4
17	Local community engagement	415	33	59	41	12	1	21	24	2017-2024	606	7	7
18	Remote Sensing (RS) technology in biodiversity that incorporate AI	21	11	58	55	12	6	33	25	2017-2024	221	22	9
19	Capacity-building	72	28	55	21	3	14	2	32	2017-2024	227	8	8
20	Data-sharing protocols	24	41	56	55	44	3	1	55	2017-2024	279	8	8
												110	101

10 Findings

The The Sundaland region, spanning Indonesia, Malaysia, and the Philippines, faces a critical threat to its extraordinary biodiversity, with a projected decline of 13% to 85% by 2100 due to factors such as widespread logging, agricultural expansion, and wildlife exploitation. Despite being a biodiversity hotspot, Sundaland is challenged by the ineffectiveness of protected areas (PAs), as revealed by Verma et al. (2020) [12], with significant human pressure reducing these areas to only one-third and half of their designated protection in Malaysia and Indonesia, respectively. Katona et al. (2023) [13] further highlight that one-third of global PAs experience intense human pressure, undermining the overall protection level. To address these challenges, figure 1.1 shown a tree diagram of the word technology in this study it was executed using the NVivo tool. The integration of Geographic Information System (GIS) and remote sensing technology is crucial. GIS, identified as a potent tool, not only aids in identifying and monitoring threats but also provides a means to develop sustainable solutions for the conservation of Sundaland's unique biodiversity [7, 14, 15, 16].

The expected findings of the review paper on Sundaland biodiversity management using Geographical Information System (GIS) and Remote Sensing technology are anticipated to reveal the significant and escalating threats facing the biodiversity of the Sundaland region. As demonstrated in existing literature, including studies by Ma et al., (2023) Nilsson (2019) and Namkhan et al. (2022), [1-3], it is expected that the biodiversity in Sundaland, along with other Southeast Asian regions, will face a substantial decline ranging from 13% to 85% by the year 2100. The principal threats include widespread logging, unsustainable agricultural practices, and overexploitation of wildlife [4, 5]. The degradation of natural forests, both in lowland and montane areas, is likely to persist without effective intervention [6, 7] as shown in figure 1.2.

Protected areas (PAs), essential for biodiversity conservation, face challenges in effective management and protection, as indicated by the findings of Verma et al. (2020) [12] in Malaysia and Indonesia's Sundaland. It is anticipated that these PAs may fall significantly short of achieving Aichi Target 11, emphasizing the need for improved management strategies to mitigate human pressures on these vital conservation areas [11]. Furthermore, the findings aligned with the study conducted by Katona et al. (2023) [13], revealing that a considerable portion of global PAs is under intense human pressure, diminishing the overall effectiveness of the protected area network.

In light of these challenges, the review paper emphasized the crucial role of the Geographical Information System (GIS) and remote sensing technology in addressing and mitigating these threats to Sundaland's biodiversity. Building upon the insights of Kerry et al. (2022), Ahmad (2023), Akhtar et al. (2023), and Quamar et al. (2023), [7, 14-16] it was found that GIS emerged as a powerful tool for identifying and monitoring threats, as well as developing sustainable conservation solutions tailored to the unique ecological context of Sundaland.

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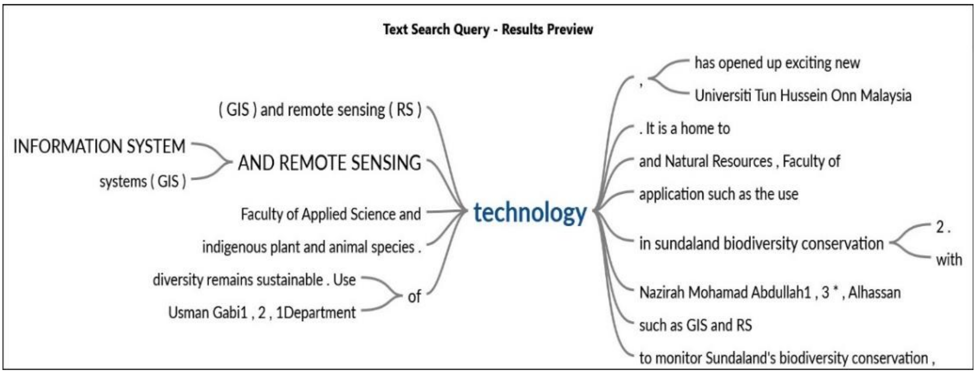

Fig. 1. The tree diagram of the word technology executed using NVivo.

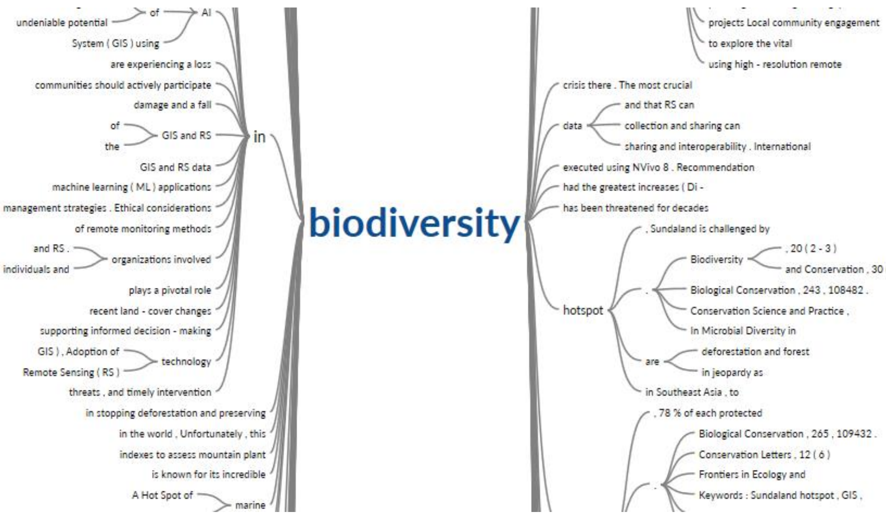

Fig. 2. Tree diagram of biodiversity executed using NVivo.

11 Recommendation

The successful integration of Geographic Information System (GIS) and Remote Sensing (RS) in biodiversity management in the Sundaland region necessitates a comprehensive set of recommendations derived from the identified challenges and considerations. Firstly, there is a critical need for increased investment in capacity-building programs to enhance the skills and knowledge of conservation practitioners in GIS and RS technologies. Institutions, both governmental and non-governmental, should collaborate to establish training initiatives, workshops, and educational resources to empower individuals and organizations involved in biodiversity conservation efforts. This will ensure that practitioners are well-equipped to harness the full potential of GIS and RS tools for effective management. Furthermore, addressing the financial constraints associated with GIS and RS applications is essential for widespread adoption. Initiatives aimed at reducing the cost of data acquisition, processing, and technology infrastructure should be explored. This may involve the establishment of partnerships with research institutions, international organizations, and private sector entities to facilitate the sharing of resources and expertise.

Data integration challenges can be mitigated through the development and implementation of standardized protocols for biodiversity data sharing and interoperability.

International collaboration and the establishment of data-sharing platforms can facilitate the seamless integration of ecological, climatic, and socioeconomic data, supporting more holistic biodiversity management strategies.

Ethical considerations in biodiversity data collection and sharing can be addressed by establishing clear guidelines and protocols for responsible data management. This involves ensuring the privacy and security of sensitive information while promoting transparency in the scientific community. Legal frameworks should be established or reinforced to govern the ethical use of GIS and RS data in biodiversity research and conservation.

To overcome challenges related to scale and scope, initiatives should be implemented to enhance the accessibility of GIS and RS technologies in smaller organizations and resource-limited settings. This may involve the development of user-friendly tools and platforms, as well as the provision of financial support and technical assistance for organizations working on large-scale biodiversity conservation projects.

Local community engagement and the incorporation of traditional ecological knowledge are crucial components of successful biodiversity management. Establishing participatory approaches that involve local communities in data collection, interpretation, and decision-making processes can enhance the effectiveness and sustainability of conservation initiatives. This approach fosters a sense of ownership and cooperation, aligning conservation goals with the needs and values of the local population.

Lastly, continuous monitoring of technological advancements is essential to stay abreast of the latest developments in GIS and RS. Organizations involved in biodiversity management should invest in ongoing training programs and updates to ensure that practitioners can leverage cutting-edge technologies for optimal outcomes.

12 Conclusion

In conclusion, the effective management of biodiversity in the Sundaland region through the utilization of Geographical Information System (GIS) and Remote Sensing (RS) technology demands a concerted effort to overcome challenges and harness the full potential of these tools. The identified threats to Sundaland's biodiversity, including widespread logging, unsustainable agricultural practices, and habitat degradation, underscore the urgency of implementing comprehensive strategies. Addressing capacity gaps, financial constraints, and ethical considerations is paramount to ensuring the successful integration of GIS and RS, with a focus on fostering collaboration, facilitating data sharing, and engaging local communities. Through conscientiously utilising AI's potential while upholding moral principles and inclusive methodologies, we may advance towards a future in which biodiversity thrives and the health of our planet is guaranteed. Embracing these recommendations, the Sundaland region can leverage GIS and RS technologies as indispensable allies in the conservation and sustainable management of its rich and threatened biodiversity.

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