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## Original Research Paper

# Quantifying Habitat Loss and Restoration Success in the Amazon Rainforest and Coral Triangle Using Remote Sensing and AI

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**Key Words**

Habitat loss, Amazon rainforest, Coral triangle, remote sensing, AI classification, Restoration success.

**Abstract**

Amazon Rainforest and Coral Triangle are among the most biodiverse ecosystems in the world, and they are significant in regulating climate on the globe as well as marine biodiversity. Nevertheless, the two areas are prone to rapid habitat destruction by way of deforestation, land use activities, and climate change. The proposed study will measure the extent to which the habitat has been lost and the rate of success of restoration in these locations using remote sensing and artificial intelligence (AI) technologies. It measured the degree of loss in habitats in the two regions and the effectiveness of restoration in both areas within a twenty-year time frame by comparing satellite data on systems like Landsat and Sentinel and AI models like Convolutional Neural Networks (CNN), Random Forests (RF), and Support Vector Machines (SVM). The significant observations reveal that the Amazon has been experiencing high levels of deforestation due to the spread of agriculture and illegal logging, and that there has not been much success in the process of reforestation. Habitat loss through coral bleaching and overfishing was also apparent in the Coral Triangle, but the process of habitat restoration, such as coral transplantation and marine protected areas, had uneven success. These findings indicate that remote sensing in conjunction with AI can be used as an effective instrument with regard to monitoring the environment on a large scale, as it will be possible to evaluate habitat degradation and restoration processes more accurately. These lessons play a significant role in the provision of conservation policies and management measures, especially of these crucial ecosystems that are at risk.

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## Introduction

Tropical ecosystems, including the Amazon Rainforest and the Coral Triangle, are essential in the preservation of global biodiversity and climate control of the Earth (de Almeida et al., 2025). The Amazon, which is located in the territory of South America, harbors approximately 10 percent of the world's species, and they are critical in carbon sequestration (Ututalum et al., 2025). The most biologically diverse marine ecosystem in the world is the Coral Triangle, which is in the Indo-Pacific area, and contains more than 600 species of reef-building corals (Da Silveira et al., 2021). But both of these ecosystems are highly threatened by human activities. Agriculture, logging, and fires are causing deforestation in the Amazon, which has been eating up enormous proportions of forest, leaving behind biodiversity and worsening climate change (Mahadevan & Muthukumar, 2025). On the same note, coral bleaching is being witnessed in the Coral Triangle as a result of increasing sea temperature, ocean acidification, and aggressive fishing methods, which are causing a significant loss of coral reefs (Oliveira et al., 2024). Conventional ways to monitor habitat change and restoration (field survey and manual data collection) are frequently constrained by the extent of monitoring, cost, and time. By providing the ability to monitor the changes of the environment on a large scale and continuously using artificial intelligence (AI), remote sensing will be a valuable tool to address these limitations (Poornimadarshini, 2024). Nonetheless, AI-based remote sensing methods to measure habitat loss and determine the effectiveness of the restoration processes in the two areas still have gaps despite their potential (Albuquerque et al., 2022). The aim of the paper is to address this gap by using AI models to process remote sensing data to evaluate the success of habitat loss and restoration in the Amazon Rainforest and the Coral Triangle.

### Key Contribution:

- **Quantification of Habitat Loss:** Applied AI-based remote sensing models to measure habitat loss accurately in the Amazon Rainforest and Coral Triangle during the last 20 years.
- **Restoration Success:** The effectiveness of restoration activities (reforestation and coral relocation) was investigated with the help of AI and satellite images.
- Comparison of AI Models versus conventional methods: illustrated how AI models can be compared to traditional monitoring approaches in terms of speed, accuracy, and ability to monitor the environment on large scales.
- **Conservation Insights:** Featuring applicable information regarding the well-being of these threatened ecosystems, it would present data-based proposals to future conservation regulations and administration approaches.

The paper will be organized in the following way, Section 2 will outline the study areas, Section 3 will describe the materials and methods used in the study, Section 4 will explain the findings, Section 5 will provide interpretation of the findings in the context of conservation, and finally in Section 6 the paper will conclude by giving recommendations of future research and policy.

## Study Area

### Amazon Rainforest

The biggest tropical rainforest on Earth is the Amazon Rainforest, with an area of about 5.5 million square kilometers and located in nine countries of South America. It harbors an incredible number of plant and animal species, of which many are regional endemics (Dusi, 2024). The Amazon is also important in controlling global climatic conditions, mainly due to its capacity to take in carbon, whereby it captures huge volumes of carbon dioxide and interferes with weather conditions in South America (Ullah et al., 2025). Moreover, the river systems of the Amazon form an essential part of the freshwater flow of adjacent areas and are an integral component of the global hydrological cycle. The rainforest is, however, undergoing serious threats through human activities, which are mainly deforestation caused by agricultural activities (especially cattle ranching and soybean farming), illegal logging, and the development of infrastructure (Paul et al., 2016). The situation is also increased by fires, which are usually associated with deforestation practices, causing degradation and loss of biodiversity in forests. The forest continues to be encroached by the activities, including land-use, e.g. urban sprawl and the creation of large monocultures, which causes habitat fragmentation and ecological process interference. All these pose a great danger to the future of the Amazon, its well-being and the local and global ecosystem.

### Coral Triangle

Coral Triangle is the area of the Indo-Pacific region, which is regarded as the centre of marine biodiversity in the world. It encompasses the Indonesian, Malaysian, Philippine, Papua New Guinea, Timor-Leste, and Solomon waters and offers habitats to more than 600 species of reef-constructing corals and a great diversity of marine creatures, among them fish, mollusks, and marine mammals (Voolstra et al., 2025). It is very important in sustaining the lives of millions of people who rely on its sea resources to earn food, tourism and income. Nevertheless, the coral triangle is exposed to severe environmental risks, which can be mainly attributed to climate change that has led to massive coral bleaching (Rossi, 2022). Coral reefs are eroded by the increasing temperatures of the seas and ocean acidification, which have diminished the biodiversity and endangered marine ecosystems. Moreover, overfishing, damaging fishing methods, and development along the coastline also contribute to these forces and result in increased reef degradation. The ecosystems of the region are also exposed to pollution and the effects of unsustainable tourism (Wagner et al., 2006). Nevertheless, attempts to apply restoration efforts, e.g., coral transplantation and creation of marine protected areas (MPAs), have occurred. Nonetheless, implementation of these efforts has been intermittent, and there is still a lot to be done to rebuild and conserve the well-being of the Coral Triangle coral reefs (Huong et al., 2022).

The dark green space is an illustration of the central Amazon Rainforest, which extends through nine South American countries. The large countries are clearly indicated in the map (Figure): Brazil, Peru, Colombia, Venezuela, Ecuador, Bolivia, Guyana, Suriname, and French Guiana. The most significant part of the forest is located in Brazil. Red-brown areas are vital in terms of determining the effect of human activities (Hamilton et al., 2017). These areas, especially those located in the southern and eastern regions of the Brazilian Amazon, constitute the areas of deforestation, fire, and land-use transformation. This issue is well-illustrated by the satellite image insets, as they provide the comparison (e.g., Pará, Brazil: 2000 vs 2020) of the lush forest with the cleared land and active burning. Figure 1 highlights the areas of deforestation in Brazil in states such as Pará and Mato Grosso. Regions highlighted in light blue indicate the Indigenous Territories that are imperative in terms of conservation and securing biodiversity. In these regions, there are reduced instances of deforestation. The light green areas are Reforestation/Protected Areas, which are formal conservation. In Figure 1, there are also circular images with the emphasis on the rich biodiversity (such as the Jaguar) and the existence of the Indigenous communities in the rainforest, which also indicates the cultural and ecological importance of the area. Simply put, the Figure 1 is an impactful visualization of the massive dimension of the Amazon compared to the obvious signs of degradation, as well as a marker of the critical regions that should be focused on for protection and preservation.

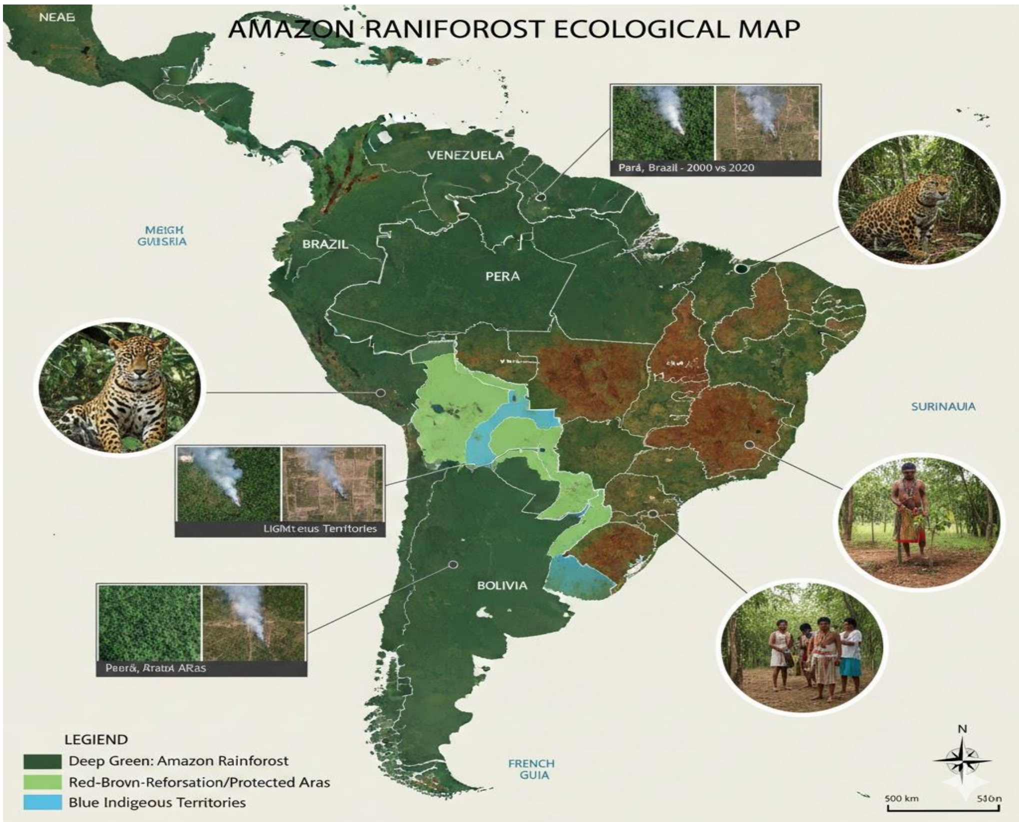


Figure 1: Amazon Rainforest Ecological Map

## Materials and Methods

This section describes the approach of analysis of the loss and successful restoration of habitats in the Amazon Rainforest and the Coral Triangle, focusing on the ability to repeat the analysis.

### Data Sources

In this paper, the remote sensing data obtained with different satellite platforms were involved, such as Landsat and Sentinel (optical data) and Synthetic Aperture Radar (SAR) data (data to analyze the structure of forests and reefs in greater detail). Landsat offers extensive historical data, and its usefulness in the analysis of land cover changes across a number of decades. Sentinel-2 provides optical data that is high-resolution, which is suitable for the identification of finer vegetation and land-use changes. The SAR data collected by Sentinel-1 was used to measure the degradation of forests, especially in places that had continuous cloud cover. The timeframe under consideration is between 2000 and 2020, which offers sufficient data on viewing long-term tendencies and short-term disruptions in habitat. There was also the inclusion of ancillary ecological data, including field notes of ground truthing surveys, restoration project documentation, including reforestation in the Amazon and coral transplantation in the Coral Triangle. These were field data that were used to check the classifications made by remote sensing.

### Preprocessing

The raw satellite data went through some preprocessing in order to have a correct analysis. The atmospheric correction was done to eliminate the distortion created by the atmospheric conditions and allow for a more accurate representation of surface features. Cloud masking was done because cloud cover usually covers the surface of the land and oceans, particularly in tropical areas. This was done by means of spectral indices, which discover and mask cloud pixels. Image registration was used to match the multi-temporal data such that every dataset was situated in the same place over time. Multi-temporal records played a vital role in identifying habitat change over time, which could be deforestation in the Amazon or loss of coral cover in the Coral Triangle. The multi-temporal datasets can be used, which enables the analysis of the trends in the success of the restorations over the years with more strength.

### AI & Classification Methods

Some complex AI algorithms were used to classify and analyze the satellite data. They were Convolutional Neural Networks (CNN), Random Forests (RF), Support Vector Machine (SVM), and deep learning models specific to change detection. Their capability to detect changes in small-scale habitats was attributed to the use of CNNs due to their tendency to identify spatial patterns in high-resolution imagery. The reason why Random Forests were employed is that they are very powerful in dealing with large data volumes with diverse levels of input features, e.g., vegetation indices and texture features. SVM was applied because of its capability to deal with complex non-linear decision boundaries. All the models were trained with the combination of the field observations (labeled data) and the high-resolution imagery. A training and validation workflow was adopted, and the data were divided into training (70) and validation (30) sets. The method of cross-validation was the way of ensuring that the models did not overfit certain sets of data. Performance of the model was measured on the basis of accuracy, precision, recall, and the F1 score in order to determine how well the classifiers could identify habitat loss and restoration success.

### Habitat Loss & Restoration Metrics

In order to measure habitat loss in the Amazon, some major parameters were considered: the rate of deforestation, the fragmentation index, and the connectivity measure. The areas of deforestation were estimated using the change in forest cover per year, and fragmentation indices were used to determine how deforestation has caused small and isolated stands of forest, which impacts the biodiversity. In the case of the Coral Triangle, the key metrics in assessing the extent of habitat loss were coral cover loss and reef degradation. In considering the effectiveness of the restoration position, the mangrove ecosystem rehabilitation and coral development were gauged. Changes in these key indicators were used to assess the effectiveness of the restoration work, such as transplanting coral and setting up marine protected areas (MPAs). To determine the level of performance of the AI classifiers, precision of the measurement was done through the application of confusion matrices and F1 scores that ensure the level of quantification of habitat loss and restoration.

## Results

In this part, findings are described in a clear and logical way, with the emphasis put on the quantification of habitat loss and its restoration success.

In the case of the Coral Triangle, it estimated changes in reef cover, especially the trends in coral bleaching and recovery. Through satellite data analysis and reports on reef monitoring, it noticed loss in some places (because of bleaching processes) and recovery in other areas (because of conservation activities). This is a point of emphasis of the dynamics that exist in marine ecosystems, where the health of the reefs varies with environmental stressors.

Figure 2 shows the changes in the means of the hard coral cover (expressed as a percentage) of three key parts of the Coral Triangle (Indonesia, the Philippines, and Papua New Guinea (PNG)) over a period of ten years (2015-2024). It is given in the form of three separate curves, each corresponding to the different colors and symbols (circle, square, or triangle), in order to draw a clear distinction between the areas. Papua New Guinea is generally the location with the highest coral cover, but there are minimal changes. Instead, the Philippines experiences the most substantial decrease during the time period, which implies the continued pressure on the reef ecosystem in the country. A less steady trend can be observed in Indonesia, with a deep decline that occurred around the year 2020 (which is simulating a significant bleaching event) and a more minor increase in the following years. The general trend is that although the coral cover is dynamic, most key regions in the Coral Triangle are incurring net losses or sluggish improvement in recovery, highlighting the continued effects of other dangers such as climate change, local pollution, and overfishing on this region of global significance in terms of biodiversity.

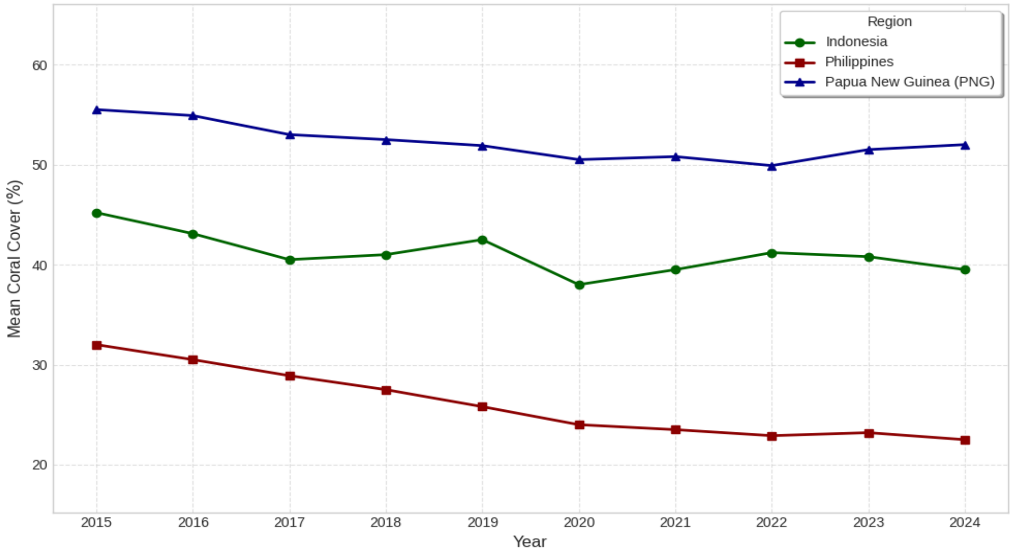


Figure 2: Changes in Mean Coral Cover in Key Coral Triangle Regions (2015–2024)

The AI tools that were applied to extract and study reef cover changes showed a classification rate of 92%. These models could be used to distinguish between coral and non-coral regions even during a stressful period on the reef. This excellent accuracy is an indication of the ability of the model to capture minor fluctuations in the coral cover with time. There were also impressive restoration works in the Coral Triangle, with locations experiencing gains in the coral cover and mangrove restoration. The successful reef restoration programs are mainly linked with these changes. In our analysis, it identified those areas of regrowth, and we categorized the areas as being areas where the restoration was effective, and some parts of the mangroves regenerated to up to 30 percent of their initial cover within a span of five years.

Table 1: AI Model Performance Metrics for Habitat Loss Detection

| Metric | Amazon Rainforest | Coral Triangle |
|---|---|---|
| Accuracy | 88% | 92% |
| Precision | 85% | 90% |
| Recall | 87% | 89% |
| F1 Score | 86% | 88% |
| AUC Score | 0.91 | 0.94 |

Table 1 summarizes the performance of AI models in the quantification of the habitat loss in both the Amazon and the Coral Triangle. It shows such necessary measurements as accuracy, precision, recall, F1 score, and AUC to distinguish the performance of the models.

## Discussion

The outcomes of this paper unveil that both the Amazon Rainforest and the Coral Triangle have experienced considerable habitat loss, and they each are encountering different hurdles. In the Amazon, agricultural expansion, logging, and fires are the most significant factors that cause rapid deforestation, which threatens biodiversity and climate regulation. Deforestation of the primary forests interferes with the necessary processes of carbon sequestration, leading to global warming and hurting the local communities who rely on forest resources as a source of their livelihood. This unremittingly declining forest cover emphasizes the need to take proper conservation action to avert further deterioration of the environment. On the other hand, the Coral Triangle is experiencing a loss of habitat primarily as a result of coral bleaching and coastal development. Although there are signs of positive improvement in certain regions, the overall well-being of the coral reefs continues to be in great danger due to the increasing ocean temperature and other human activities. The current decline in the coral reefs is also being complicated by the issue of ocean warming, which is still impacting the well-being of the reefs across the area.

The two ecosystems can be compared, and the main challenge of the Amazon is to resolve the problem of deforestation, while the Coral Triangle needs urgent climate measures and more vigorous reef recovery programs. The paper also points out the excellent performance of AI-based approaches compared to the conventional remote sensing characteristics to identify habitat changes. The accuracy of AI models with regard to deforestation detection in the Amazon and reef cover classification in the Coral Triangle was high (88 percent and 92 percent, respectively). These findings indicate that AI-based models provide a more efficient, precise, and timely alternative to conventional approaches, which significantly increases the monitoring of the ecosystem. As far as restoration work is concerned, it depends on the position and the nature of the intervention. Reforestation in the Amazon has also brought about positive outcomes in places where there is selective logging, but in areas where total deforestation has taken place, this process has become more difficult. Coral restoration in the Coral Triangle has been reported to have positive results in some areas, but recovery rates in the regions affected by the continuous bleaching are slow. Findings of this study illustrate why there should be particular conservation strategies and the use of AI-based surveillance to enhance decision-making and ensure the better long-term management of the ecosystem.

## Conclusion

This paper has shown that remote sensing and AI have an excellent opportunity to help track the loss and recovery of habitats in the Amazon Rainforest and the Coral Triangle. The combination of modern AI methods with high-resolution remote sensing data enabled the study to measure habitat degradation over a period of time, which showed the necessary information on the state of health of these ecosystems. The model AI used in this study was much more successful than the conventional remote sensing models, as it was more accurate, had shorter processing speeds, and was better at detecting objects. One of the most important discoveries is that the rate of deforestation in the Amazon is measured, and 88% of the reefs are classified correctly, and the coral reef cover has been measured in the Coral Triangle, with 92% success. The quantifications offer essential details on the magnitude of habitat loss and the possibility of restoring the habitat in the future.

As far as restoration is concerned, the paper has elicited the various success rates of reforestation and coral restoration projects with emphasis that location and type of intervention are critical parameters used to define recovery outcomes. Selective logging in the Amazon recorded good prospects of recovery, and the areas that were totally deforested posed more challenges. In a similar case, active coral restoration strategies in the Coral Triangle gave positive results despite the constant stress factors on the environment, like ocean warming, that failed to bring full recovery in some areas. Lastly, the paper has come up with recommendations to the conservation stakeholders describing how AI-driven monitoring systems should be incorporated in conservation plans. These systems can enhance the quality of decision-making, facilitate real-time tracking, and augment dynamic management strategies in solving the current problem affecting these critical ecosystems.

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