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Tropical forest conservation efforts as climate change mitigation in Indonesia: A Review

Bahana Aditya Adnan[1], Dadi[1]
[1]Department of Biology Education, Universitas Galuh, Indonesia

Abstract
Climate change affects forests both directly and indirectly through disturbances. Disturbances are a natural and integral part of forest ecosystems, and climate change can alter these natural interactions. When disturbances exceed their natural range of variation, the change in forest structure and function may be extreme. Each disturbance affects forests differently. Reducing Emissions from Deforestation and Forest Degradation (REDD+) is a global initiative aimed at curbing carbon emissions from forest cover change. Indonesia, one of the most biodiverse places on the planet with the third largest extent of tropical forest, has been extensively involved in REDD+. Despite commitments from the government of Indonesia and the international community, the deforestation rate has not stabilized or decreased in the years since REDD+'s introduction in 2007. Although there is an extensive body of literature on REDD+, the need for grounded observations from the field could clarify existing challenges and inform future pursuits. Challenges identified for each criterion include a lack of sufficient funding opportunities, inability to enforce boundaries due to corruption, and lack of a solid plan for involving communities. Carbon sequestration and biodiversity preservation results were mixed because of a lack of monitoring and problems with encroachment. We argue that changes must be made to Indonesian policy to help enable the enforcement of project boundaries, monitoring technologies should be utilized, and stakeholders, particularly at the national level, need to address some of the challenges discussed to achieve effective REDD+ outcomes in the future.

Keywords: Climate change; conservation; deforestation; Indonesia; mitigation

Corresponding author:
Bahana Aditya Adnan
Department of Biology Education
Universitas Galuh
Jl. R. E. Martadinata No.150, Ciamis, West Java
bahanaaditya@unigal.ac.id

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INTRODUCTION

Climate change is predicted to affect future forest conditions by altering forest processes and biodiversity. Predicted climate changes are thought to result from increasing concentrations of atmospheric CO_2 and to be gradually warming the planet. About a quarter of the increase in atmospheric CO_2 comes from deforestation, and thus forest distribution has an impact on global climate (Milad et al., 2011). In recent years, the responses of species to climate change have received increasing attention at local, regional, and global scales. Biodiversity is often influenced by climatic variations including changes in temperature, precipitation, evaporation, radiant flux, carbon emissions, and the increasingly frequent extreme climatic events (Wang & Myint, 2016).

As climate continues to change at an increasing rate, species and ecosystems can be expected to respond accordingly, though their response depends on multiple factors from species, community, and ecosystem levels (Jones et al., 2016). These will affect distribution and range shifts, interspecific relations, and abundance. While economic forces may compensate for some monetary repercussions of climate change impacts on forests, changes in productivity, carbon sequestration, forest water resources, and the way people relate to the forests such as recreation may be less resilient to change (Börner et al., 2016). However, all of these impacts are moderated by interactions between climate, disturbances, and forests. Therefore, it is important to understand how particular disturbances influence forests and are affected by climate change (He et al., 2019).

Forests play a major role in both climate change mitigation and adaptation, and several programs, policies and projects reflect this (Locatelli et al., 2011). The UN Framework Convention on

Climate Change (UNFCCC) discussions on Reducing Emissions from Deforestation and Degradation (REDD) in developing countries result from a recognition of the substantial greenhouse gas emissions resulting from deforestation, especially in the tropics (Gusti et al., 2019). Currently, implementation of the REDD mechanism is seen as one of the important practices for reaching the climate change mitigation target cost-effectively (Houghton et al., 2015). Forests capture carbon from the atmosphere and store it, whereas deforestation accounts for 6%–17% of global anthropogenic CO_2 emissions (Baccini et al., 2012). In addition, forest ecosystems provide a wide range of ecosystem services that can help people cope with and adapt to both current climate hazards and future climate change (Pramova et al., 2012). For example, mangroves protect coastal areas against storms and waves, forest products provide local communities with a safety net when climate variations affect agriculture, and forests regulate water flows (Thuy et al., 2014).

More recently, the importance of Indonesia's forests to the global climate has attracted international attention. Indonesia's forests are among the most carbon-dense in the world (Baccini et al., 2012). When cleared and burned, trees release their stored carbon into the atmosphere, contributing to climate change. On peatlands, which are prevalent throughout lowland Indonesia, soils can contain several times more carbon than the trees themselves. When cleared and drained by canals, peat soils dry out and become susceptible to fires that can emit carbon for decades (Hooijer et al., 2010). In addition to global environmental services, Indonesia's forests provide a host of other locally valued services, including clean water (Carlson et al., 2014), shade, non-timber products, and protection from waves (Bayas et al., 2011).

This review aims to provide a deeper understanding of efforts in forest conservation for climate change mitigation, especially in Indonesia. This study builds on several data collection and analysis efforts and a literature review on synergies between mitigation and adaptation. The first is the analysis of the major climate change mitigation. The authors searched for the keywords: climate change, deforestation, forest conservation, and REDD+ in Indonesia. The inclusion criteria were all research articles concerning the relationship between deforestation and climate change with REDD+ in Indonesia. The sources for this paper consist of scientific publications, research reports, conference proceedings, and other relevant materials.

STATUS OF FOREST AREA IN INDONESIA

Indonesia is the world's largest archipelagic country where 120.5 million hectares or 63% of its total land area are designated as State Forest Area. Most of Indonesia's remaining land area is made up of non-forest areas or public lands, known as Other Use Areas (APL). In addition, 5.3 million hectares of its water territories are designated as marine conservation areas managed under the Ministry of Environment and Forestry (MoEF) authority. As of December 2021, the total of these areas stood at 125.8 million hectares.

On the land designated as Forest Area and APL, land cover may take several different forms, including natural forests (consisting of primary forests and secondary forests), plantation forests, plantation/estate crops, agriculture, shrubs, settlements, and others. There are 23 land cover categories in Indonesia and these are used for forest and forest resource monitoring. Based on a reassessment of land cover conducted in 2020 using image interpretations derived from the Landsat Data Continuity Mission (LDCM) for 2020 coverage, 79.9% of Indonesia's conservation forest areas; 81.7% of its protection forest areas; and 81.2% of its limited production forest areas are covered by forests. In permanent production forest areas, the forest cover is 63.6%, while in convertible production forest the figure is 50.2%. Another type of a forest is a planted forest, which is land covered with trees planted that fulfill the definition of a forest. This is known as an Industrial Plantation Forest or reforested and rehabilitated areas, within and outside the Forest Area. The remaining land cover types found in the Forest Area are estate crops, agriculture, shrub, settlements, and so on which are classified as non-forested areas or areas without forest cover (MoEF, 2022).

Indonesia's forest area is managed in accordance with three functions. Production forests cover a total area of 68.8 million hectares. Conservation forests cover a total area of 22.1 million hectares (with an additional 5.3 million hectares of marine conservation areas). Protection forests have watershed functions and cover the remaining 29.6 million hectares. Blessed with a tropical climate, Indonesia's 17,000+ islands are located between two continents, Asia and Australia, and between two oceans, the Pacific and the Indian Oceans. Because of its geographical location, Indonesia has an extremely high level of biodiversity, and endemicity, and has a higher level of biodiversity than any other country in the world, together with Brazil and Colombia (Kusmana, 2011; MoEF, 2020).

Indonesian state forests, in addition to their global salience for carbon sequestration as well as biodiversity, play many important roles for local people living in and around the forest, including a wide spectrum of goods and services (Adnan, et al., 2023). Protection Forests play a major strategic role in protecting environmental life-support systems by regulating water supplies; preventing floods; controlling erosion; preventing seawater intrusion; maintaining soil fertility; providing adequate food and energy supplies for human life; and serving as a storehouse of germplasm (living genetic resources such as seeds or tissues that are maintained for the purpose of animal and plant breeding, preservation, and others research uses). In recognition of this vital role, the management of these forests by dedicated Protection Forest Management Units is being undertaken at the ground level. Indonesia continues managing its protection forests to ensure their protection functions, but also their benefits to communities (Kaskoyo et al., 2017).

DEFORESTATION AND FOREST DEGRADATION IN INDONESIA

Deforestation threatens human life and other living species. The biggest contribution to climate change that is happening right now is deforestation (Alisjahbana & Busch, 2017). Land cover in forest areas, particularly forest cover, is dynamic and subject to rapid change. The deforestation rate has been changing, either increasing or decreasing, due to human anthropogenic causes reflected in land use resulting in the loss of or an increase in forest cover (Tsujino et al., 2016). Several contributing factors include the conversion of forest areas for other development purposes such as (1) plantations and transmigration; (2) unsustainable forest management; (3) illegal logging; (4) changes in forest use purposes; (5) legal conversion into other use areas; (6) mining activities; (7) illegal land occupation; (8) forest fires; and (9) natural disasters. Less effectiveness and failures to optimize reforestation and land rehabilitation have also contributed to an increase in the extent of severely degraded land (Cisneros et al., 2021).

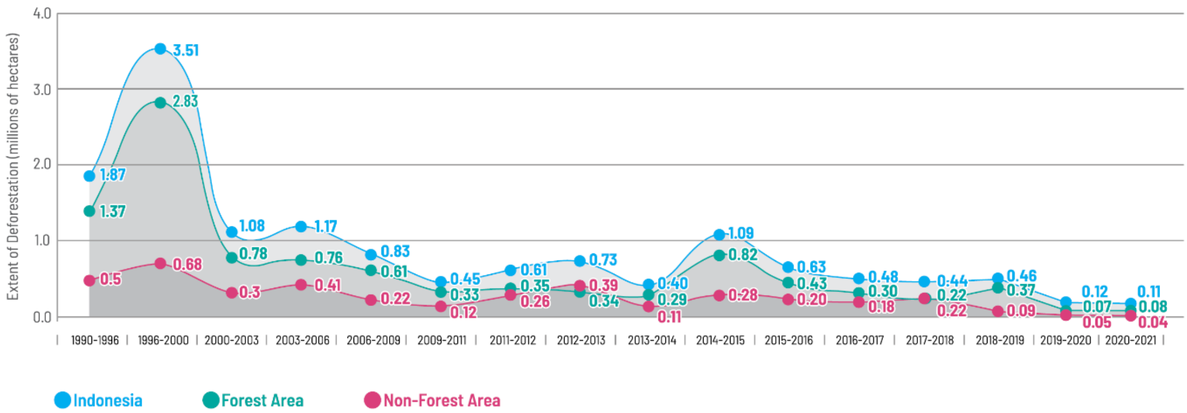

Figure 1. Deforestation trends in Indonesia (Source: MoEF, 2022).

The exploitation of forest areas is the main factor causing critical land. Critical land does not function well as a production medium for growing cultivated and other crops. The land is defined as critical land referring to the conditions of land cover, erosion, nutrient cycles, microclimate regulators, and carbon retention. Forestry land exploitation activities will contribute to the reduction of Indonesia's forest cover (Margono et al., 2014). The occurrence of land conversion from vegetated land to non-vegetative land will result in a decrease in carbon stocks in land use. Departing from this, it is suspected that the extent of forest fires as the cause of high greenhouse gas emissions is directly proportional to the rate of deforestation (Maryani, 2020).

Deforestation events were recorded in Google Earth Pro for visual interpretation. Austin et al. (2019) imported selected deforestation events into Google Earth Pro for visual interpretation. Two interpreters classified the sampled deforestation events into 12 driver categories based on the land cover observed following a tree cover loss event (Table 1). The interpreters used features in the landscape within and adjacent to the event to determine the subsequent land cover. To identify drivers of deforestation the interpreters viewed all available high spatial resolution imagery and annual cloud-minimized Landsat composites in the four years following the event.

Table 1. The drivers of direct deforestation in Indonesia.

Category	Land cover description
Oil palm plantation	Large network of rectangular plantation blocks, connected by a well-defined road grid. In hilly areas the layout of the plantation may follow topographic features. The presence of oil palm is confirmed by noting individual palm crowns.
Timber plantation	Large network of plantation blocks connected by a well-defined road grid. The shape of the blocks is varied, and may be rectangular or conform to watershed boundaries. The presence of timber species is confirmed by noting canopy structure.
Other large-scale plantations	Like oil palm or timber plantations, but the plantation species cannot be discerned via high-resolution imagery, or trees are too young to reliably determine plantation species. This category is used as long as the distinctive road network is clearly visible, even if trees have not yet been planted and the land cover within plantation blocks is bare ground, grassland or shrublands.
Grassland/shrubland	Large homogeneous areas with few or sparse shrubs or trees, and which are generally persistent. Distinguished by the absence of signs of agriculture such as clearly defined field boundaries.
Small-scale agriculture	Matrix of clearly defined fields, which may be covered by bare ground or crops, or temporary fallow lands with varying degrees of vegetative growth.
Small-scale mixed plantation	Similar to small-scale agriculture land but at least 75% of the deforestation event is covered by planted rows of trees.
Small-scale oil palm plantation	Similar to small-scale mixed plantations, but the tree cropping systems should be dominated by palm, determined by noting individual palm crowns.
Mining	Modified bare ground including evidence of mining activity, such as pits, terraces and ponds.
Fish pond	Semi-rectangular ponds with well-defined borders and observable reflective water surface.
Logging road	Branching roads surrounded entirely by forest, far from villages, clearings, or signs of agriculture. These roads are commonly ephemeral due to forest regrowth.
Secondary forest	Forested areas with closed or nearly closed canopies. These are generally very small forest loss events followed by rapid recovery of canopy structure, and may be due to selective logging. While such tree cover loss events would likely be considered a form of forest degradation, rather than deforestation, we included in our assessment of deforestation drivers in the interest of comprehensiveness.
Other	Includes urban expansion, such as roads, housing developments and golf courses, and non-anthropogenic disturbances, such as shoreline erosion, volcanic activity and landslides.

(Source: Austin et al., 2019)

Oil palm is identified as a chief driver of deforestation. Oil palm plantations are located in primary forest, secondary forest, and production forest resulting in deforestation soil erosion and habitat fragmentation, loss and biodiversity (Afriyanti et al., 2016). The expansion of oil palm plantations in forest areas also has an impact on changing the ecological landscape that threatens many dangers (Dadi, 2021). Between 1990 and 2010, the total area of oil palm plantations increased from 1.1 million to 7.8 million hectares. The rapid development of oil palm plantations has been facilitated by the state's policies and further enhanced by the decentralization policy that enabled local governments to issue plantation permits (Tacconi et al., 2019; Austin et al., 2017). Driven by increasing global market demand, its establishment tends to be uncontrolled. For instance, hundreds of permits covering nearly four million hectares of forestland in Central Kalimantan alone have been granted to investors without a formal land release from the central forest authority (Setiawan et al., 2016; Susanti & Maryudi, 2016).

Large areas of forest have been impacted by industrial activities, Gaveau et al. (2014) estimating that 266.257 km^2 of the 1973 forest cover on Borneo has been logged, of which 179.917 km^2 remained standing in 2010. Oil palm and timber plantations covered 75.480 km^2 on Borneo in 2010, equivalent to 10% of the island's land area. From 2000 to 2017, the area of industrial plantations on Borneo is estimated to have increased by 170% (6.2 Mha), of which 88% can be attributed to palm oil expansion, with 3.06 Mha of forest converted to plantation (Gaveau et al., 2019). Two thirds of the Borneo Forest area lost to plantations between 1973 and 2015 had been selectively logged prior to conversion (Gaveau et al., 2014; Sloan, 2014). This has occurred despite recent research that has called the oft-justification of poverty alleviation for oil palm development into question, particularly in remote areas with high forest cover, where oil palm development is associated with reductions in wellbeing indicators (Santika et al., 2019). Road and rail infrastructure developments pose an additional serious threat, with recent estimates suggesting that if all imminently planned projects proceed, landscape connectivity in Kalimantan will decline from 89% to 55%, and will impact 42 protected areas (Alamgir et al., 2019).

Indonesia's forests continue to experience land loss due to agricultural conversion, forest fires, timber harvesting, and the use of firewood. Deforestation has a very big effect on climate change related to the carbon in the air and on peat soil if you lose the trees it will release the stored carbon into the air (Jati et al., 2018). Nature-based solutions could contribute substantially to climate change mitigation. These solutions include the protection, restoration, and improved management of forests, wetlands, grasslands, and agricultural lands to increase carbon dioxide sequestration, reduce emissions, and enhance climate resilience. Protecting and ensuring the health of natural ecosystems are also important for conserving biodiversity, providing clean air and water, safeguarding food security, and sustaining livelihoods (Koh et al., 2021).

Efforts can be made to reduce increasing deforestation so that the rate of deforestation does not increase, various efforts can be made, namely by carrying out selective logging where this selective logging system will be able to maintain the sustainability of the forest ecosystem and function as life support, in the logging system. also choose to replant so that these activities do not cause losses (Butler & Laurance, 2008). Then it can be done with reforestation or greening efforts, namely replanting in forest areas while reforesting non-forest areas, because forests that are experiencing denudation are unable to carry out their functions properly. Reducing deforestation in Indonesia is being held in focus group discussions (FGD) concerning efforts to reduce deforestation and reduce forest degradation with various policies for the 2020-2024 medium-term development plan (RPJMN). Various simple activities if carried out properly and in cooperation or cohesiveness will have a good effect on nature, especially in reducing emissions (Wahyuni & Suranto, 2021).

The form of concern about deforestation that has arisen is giving birth to REDD+ (Reducing Emissions from Deforestation and Forest Degradation, Role of Conservation, Sustainable Management of Forest and Enhancement of Forest Carbon Stocks) which is an approach to forest land conservation using a financial scheme in conserving forests which is a business that can provide benefits or income compared to logging forests through payments (Koh et al., 2021). The implementation of REDD+ is considered a necessity and an element in the process of mitigating climate change in Indonesia, considering that at COP 21 in Paris (Paris Agreement), the Indonesian state has entered into a joint agreement with a nationally determined contribution that will reduce emissions of the greenhouse gas effect by making their own efforts to around 29% and reducing 41% of greenhouse emissions with international assistance in the coming 2030. Form a complex resolution mechanism and accelerate conflict resolution that can create tenuarial certainty, and increase transparency and participation between government agencies at the district and provincial levels in REED+ implementation (Rodríguez-de-Francisco et al., 2021).

REDD+ IMPLEMENTATION FOR FOREST CONSERVATION IN INDONESIA

Reducing Emissions from Deforestation and Forest Degradation (REDD) are measures designed to use financial incentives to reduce emissions of greenhouse gases from deforestation and forest degradation. REDD+ is a global mechanism that provides a unique opportunity for developing countries like Indonesia, which have large areas of forest and are facing deforestation threats (Sunderlin et al., 2014; Pujiono et al., 2019). REDD+ does not only cover greenhouse gas reduction but also includes the role of conservation, sustainable forest management, and enhancement of forest carbon stocks. This scheme will help reduce poverty and achieve sustainable economic growth (Brockhaus et al., 2012). Under REDD+, which recognizes forest carbon stock enhancements (sequestration) from improved conservation and sustainable management of forests, developing countries that reduce forest-based emissions below an established 'business as usual' projection will be rewarded through payments from donor funds or market sale of emissions reduction credits (Bayrak & Marafa, 2016).

The process of implementing REDD+ focuses on the involvement of stakeholders. The voices of the community, indigenous peoples, and traditional communities must be taken into account to ensure that the rights of those living in and around the forest are guaranteed (Luttrell et al., 2014; Hartoyo et al., 2019). The design of a valid REDD+ strategy must include guidelines and safeguards that ensure that the benefits of REDD+ will reach the people who maintain and protect forests and biodiversity. The UN-REDD program works very closely with various countries to involve stakeholders and forest maintainers at all stages of program design and implementation so that they are the ones who benefit from protecting forests (Enrici & Hubacek, 2018).

In forest-rich Indonesia, forest-related mitigation is very high on the agenda. The national REDD+ strategy mentions a general need to sustain ecosystem services. For example, it indicates that the expansion of investments in REDD+ should not only support carbon emission reductions but also maintain environmental services such as biodiversity and regulation of hydrological systems. However, the benefits of adaptation are considered primarily for activities that have major mitigation impacts, such as the prevention of wildfires (Murray et al., 2015). Forest Watch Indonesia found in the field that there is a need for an understanding of forest and land use in the context of REED+ utilization in the regions in the context of fulfilling community rights to information, participation, and accountability through management of technical improvements that encourage the implementation of aspects of transparency and participation in policy-making.

Community engagement was chosen as another essential criterion to consider for assessing effectiveness of REDD+ projects because it has been widely discussed in REDD+ literature, and frequently mentioned by stakeholders (Lawlor et al., 2013). Community engagement is widely discussed as important for REDD+ effectiveness and presents challenges in Indonesia and elsewhere. Governing capacity was chosen because of its presence as an important topic in the literature and the prevalence with which it came up in our research (Resosudarmo et al., 2014). Encroachment when there is a lack of ability to enforce boundaries has been an ongoing issue in Indonesian forest management. Although establishing protected forest areas can lead to reductions in deforestation and degradation, encroachment still occurs in many areas (Gaveau et al., 2016). This is a problem that also affects REDD+ projects, as reported by stakeholders from this research and so is an important criterion to include. The other aspect of governing capacity, monitoring, is also recognized as important for assessing the effectiveness of REDD+ projects though working out the details of how exactly monitoring will be carried out has been a matter of debate among many interested in REDD+. Carbon sequestration, through a reduction in deforestation and forest degradation, was the initial goal for REDD+ and is a crucial outcome for REDD+ projects, necessary for demonstrating overall project effectiveness (Beaudoin et al., 2016).

Indonesia has committed to reducing emissions from deforestation. However, it has not yet been successful in reducing illegal logging and illegal deforestation (Hoare, 2015; Tacconi et al., 2019). Conserving a forest has been widely acknowledged to mitigate climate change by avoiding carbon emissions that are released after conversion. Concerns about deforestation from the resulting impacts have given birth to REDD+ by trying to calculate the value of carbon stored in forest land and making offers to developing countries to be involved in reducing emissions in the framework of investing in low-carbon pathways. Protection of existing carbon stored, through the inclusion of forests within conservation areas, and links to policies and community livelihood that prioritize sustainable management of forest conservation areas are important processes to mitigate climate change (Liu et al., 2020). When community-based forest management (CBFM) has been placed for carbon-based forest conservation strategy, land tenure reform, supportive governance, and local involvement should be established to ensure that the benefits of conservation are not only for global climate but also for human welfare.

CONCLUSION

Influences other than climate change, such as habitat destruction, intensified and altered land use, fragmentation and deposition might also be important driving forces for ecosystem change and should be minimized to increase the resilience of forest ecosystems. Deforestation is a type of forest land loss that poses a harm to living things. As a result, land degradation will occur in areas where land productivity has declined. Burning land will also result in an increase in carbon emissions, which will have an impact on greenhouse gas emissions in the atmosphere. As a result, the sun's heat is trapped in the earth, resulting in global warming. If this continues, it will result in climate change. The reviewed papers attach differing importance to the individual driving forces and still, there are great uncertainties about the interrelations between them. Here, further research should be conducted, allowing for the identification of vulnerable areas and adjusted conservation strategies. Whether the emphasis is placed on economic, ecological, or social objectives in forests will in large part depend on societal decisions and values. In light of partially antagonistic ways to adapt forest ecosystems to climate change, implementation of conservation measures will require awareness raising and a high level of information on the part of all stakeholders

Limitations and Future Direction

Despite such complications, conservationists must learn to deal effectively and forcefully with the corporate drivers of tropical deforestation. Such drivers will certainly increase in the future because global industrial activity is expected to expand by 300–600% by 2050, with much of this growth in developing countries (Butler & Laurance, 2008). For their part, an increasing number of corporations are realizing that environmental sustainability is simply good business. Aside from the influence of environmental groups, the impacts of the industry will also be mediated by government policies and international agreements, such as the UN Framework Convention on Climate Change and the Convention on Biological Diversity. Whereas international carbon trading could eventually slow rapid forest destruction in certain countries. Because such policies can change rapidly and have far-reaching implications, conservationists ignore them at their peril.

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Declarations

The authors state there is no conflict of interest.

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