



Environmental impacts: Deforestation

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Abstract

At its root, deforestation is far more than simply "cutting/chopping down trees". The impact on the environment of deforestation is much greater than that which would be described by the action of cutting down trees alone. The main reason for this is that, when deforestation removes complex forest systems to use them for more simplified forms of land use (such as agricultural production, mining, road building, plantations, etc., and urban expansion), the process is removing diversity and complexity from those environments. This can affect the storage of carbon in the ecosystem, how water moves throughout the landscape (hydrological cycle), soil stability, local temperatures and the ability of the landscape to support the diversity of plants and animals.

The article identifies the harmful impacts of deforestation on the environment in a number of interconnected ways. The first pathway involves an increase in greenhouse gases along with a reduced ability of forests to act as carbon sinks. The second pathway includes disruption of rainfall patterns, groundwater recharge and river sediment dynamics resulting in increased flooding, higher risk of drought and decreasing water quality. The third pathway (disruption to habitats/species) ultimately leads to local extinction events; usually due to a slow decline in the population size of one or more species rather than an abrupt collapse. The final pathway includes the potential for more conflict between humans and wildlife and the potential for spill over risks at the edge of forests. Next the article looks at India's legal framework and governance structure relative to deforestation, which includes India's diversion regime as outlined in the Forest (Conservation) Act and the jurisdiction of the Supreme Court regarding the working definition of "forest". The article will also consider rights and livelihoods under the Forest Rights Act, and would also outline the preventive principles necessary to prevent future deforestation.

Keywords: Deforestation, land use change, biodiversity loss, carbon sinks, forest governance, India

Introduction

The three major types of deforestation develop sequentially over time. First, an area is opened up by the construction of a roadway segment, followed by the establishment of a temporary base camp, then abandonment of the camp, the occurrence of informal resource removal (e.g., timber removal), designation of the area as "degraded", and finally, conversion of the land use to agriculture or some other form of land use.

The Food and Agriculture Organization has estimated that from 2015 to 2020 there was annual deforestation of about 10 million ha. While there is clearly a "gross" amount of forest area lost each year, there are also increases in forest area due to afforestation and natural expansion^[1].

While the implications of climate change may be relatively difficult to grasp for some individuals, with respect to greenhouse gas emissions, the Intergovernmental Panel on Climate Change (IPCC) has reported that the net CO₂ emissions from land use, land use change, and forestry in 2019 totalled approximately 6.6 +/- 4.6 GtCO₂; while the total emissions from fossil fuel burning and industrial processes totalled 38 +/- 3.0 GtCO₂ for the same period^[2].

In addition to the problems inherent in defining and measuring deforestation, deforestation in India is complicated further by a distinction between "forest cover" and "recorded forest area". Forest cover is defined and measured via remote sensing technology based on thresholds of canopy density. Recorded forest area, however, refers to the area of land designated as forest by statute and included in official records. A press release for the India State of Forest Report 2023 states that the total amount of forest and tree cover in India currently totals

8,27,357 square km, equating to approximately 25.17% of India's geographic area^[3]. This data is often used to determine if India is moving toward an increase in forest (greening), or an increase in deforestation. However, this is far too simple an approach. First, forest and tree cover include trees that have been planted in designated recorded forest areas via various practices such as agroforestry, orchard development, shelterbelts, and roadside plantings. While each of these practices adds value and contributes positively to an area, none of them necessarily mean that the old natural forests were converted to new forest ecosystems of high complexity. Second, forest cover maps are limited to determining what can be viewed visually from the air. Therefore, a forest can also look like a complete forest canopy even though many of its layers are gone. That is because many of those layers have already been taken away due to heavy burning and grazing. When the forest loses its layers, it supports less biodiversity and regulates water less effectively. So even if we are increasing forest area, it does not mean that the forest is still working ecologically.

What counts as deforestation and why it happens?

1. The mechanics: clearing, conversion, and fragmentation

Beginning with clearing: a mode of deforestation which is seen (and therefore measured) most directly: trees are cleared; stumps remain; land is open; and there is potential for immediate carbon emissions from decomposition or burning of biomass; and rapid changes to runoff processes. Clearing may be formally recognized (i.e., permitted cutting), or informally recognized (e.g., gradual removal at a level below detection thresholds). Frequently in landscapes,

the transformation occurs first as a "use" instead of "conversion", and then progresses to a form of conversion once the landscape has passed a critical point.

Conversion represents a mode of deforestation that is both structural and ecological: it represents the replacement of forests with farms, mines, plantations, or other forms of built infrastructure. The loss is not just trees, but also ecological diversity. For example, although a plantation may appear green when viewed from an airplane, it may exhibit different behaviours regarding water use, soil health, and biodiversity than did the forest it replaced; and it may be more susceptible to various stresses (pests, fire, etc.), and more likely to experience drought. When conversion is portrayed as "replacing", the primary environmental concern is the function(s) that will be lost, not how much green remains. Many deforestation conflicts arise as a result of disagreements about what social functions society is willing to sacrifice.

Fragmentation is a less obvious driver of deforestation, however it is frequently underestimated. Forests may continue to exist on maps while they are broken up into smaller areas by roads, power lines, and urban sprawl. From an ecological perspective, fragmentation results in changes in edge conditions due to hotter microclimates, increased invasive species pressures, easier access for illicit extraction, and reduced reproductive success for species living in the centre of the fragmented area. Like conversion, fragmentation can represent deforestation without a clear and distinct boundary; however the negative impacts can be significant. Species can persist for long periods of time, while failing to reproduce, and thus appear stable, until they do not.

The three modes of deforestation described here typically work together. Building a new road is not simply the construction of a single narrow strip of conversion. Access to land is a precondition for land users to be able to utilize the land; however, the way that land users utilize their access to land influences their incentives for utilizing that land. By turning roads into corridors for new economic activities, these roads create larger footprints for additional development. Thus, focusing an analysis strictly on the number of acres that have been removed from the forest cover may overlook the mechanisms that will ultimately lead to the next round of deforestation.

2. The drivers: why forests are converted

To determine the causes of deforestation linked to converting forests for agriculture, it is necessary to consider why individual farmers choose to clear land and not just the number of farmers who do so. The way that each individual farmer acts is shaped by both the institution and locality they find themselves in and by the specific conditions they face at that time.

In addition to understanding "how much" pressure there is to convert land (pressure), it is also necessary to understand the types of pressures driving this behaviour: "push" versus "pull".

Push pressures include debt, insecure tenure, and low levels of productivity; all of which can lead to short-term clearing. Pull pressures include high demand for commodities, government subsidies, and/or investments in new roads/infrastructure that increase land values after they have been cleared. The pull pressures, including commodity demand, are typically driven by finance and procurement.

Once a clearing has occurred, and a farmer has received financing and contracts related to that clearing; the clearing expands rapidly into even more large-scale conversion. This is because the financial system rewards consistent production; not necessarily sustainable production. Furthermore, supply chains also play an important role here. When consumers do not view land conversion as an external cost of producing their products; deforestation functions similarly to a subsidy for producers. On the other hand, if consumers expect transparency and punish producers who have converted land for their product; this creates potential shifts in the market, although these shifts will vary greatly depending on the specific sector of agriculture being discussed.

Agricultural expansion is a primary driver of forest loss in many areas of the world. Agricultural expansion does not have to occur in the form of large scale corporate plantations. Rather, agricultural expansion can occur through a large number of individual clearings by multiple individuals that add up to significant amounts of forest loss over time. There are times when individuals continue to clear land because they feel they have no alternative. For example, when crop yields decline, and an individual's ability to hold onto their land is uncertain; the decision to continue to clear land may be a survival strategy; not a profit strategy.

The idea that "intensive agricultural practices will save forests" is an overly simplistic policy assumption that ignores the possibility of rebound effects in the long run.

Timber and fuel wood extraction pressures are somewhat mixed. While timber extraction can be carried out lawfully and still degrade forests when governance is poor or when rotation cycles are not realistic, illegal timber extraction can thrive in environments where the timing of enforcement is predictable (i.e., when the timing of enforcement is so predictable that producers know exactly when to anticipate enforcement and can therefore pay off enforcement officials).

Both mining and linear infrastructure projects can create intense concentrations of land conversion. The primary area of impact is the physical footprint created by these projects; however, the secondary impacts of these projects can include increased rates of in-migration, settlement growth, and the development of new local markets that drive additional extraction activity. Once an area is modified by either a mining project or linear infrastructure; the term "degradation" is often used to justify further modification of the area, resulting in a self-reinforcing process. Enforcement of regulations related to approval processes, compliance checks, and post-conversion rehabilitation plans are often vastly different from what occurs in practice, particularly in the absence of effective monitoring mechanisms and when violations are met with little consequence.

Forest fires can function as both a cause and a tool of forest conversion. For example, some forest loss is not intentional but rather the result of continued burning that prevents forest regeneration. Fires can also be intentionally used as a low-cost method of clearing land. Climate-related stresses can extend and intensify fire seasons, creating a feedback loop in which burned-out forests burn more easily and repeated burning causes the forests to transition to scrub.

Governance gaps allow the conversion of forests to occur. Governance gaps refer to:

(1) undefined property boundaries; (2) ineffective mechanisms for resolving disputes; (3) inadequate land title documentation, all of which increase the likelihood of an opportunistic clearing of the land.

Environmental impacts: what deforestation does to climate, water, soil, and biodiversity?

Trees in forests act as both sinks and reservoirs of carbon relevant to climate change. However, the way forest sinks and reservoirs act in relation to climate is in two interconnected ways: stored carbon and on-going sequestration. When trees are harvested (cut down) or changed from being a forest to another land use (cleared or converted), stored carbon is released into the atmosphere. In addition to stored carbon release, when trees are degraded or change from a high-complexity forest to a low-complexity forest (through replacement), the ability of the forest to act as a future sink is lost. There is also a political aspect: Once clearing or converting forests is seen as a normal process, it will be very difficult to stop further degradation or conversion of these areas, regardless of whether the economic and social effects of climate change are recognized globally. What often begins as "temporary" clearing of forests eventually becomes a permanent land use.

Local climates are also affected by clearing/deforestation. Forests cool the surrounding environment through evapotranspiration and shading. With removal of trees, surface temperatures increase, humidity changes, and individuals feel an increased amount of heat stress. Many have stated that they perceive this phenomenon as "the area has gotten hotter".

Deforestation affects how water is treated from a variety of scales (e.g., watersheds and catchments). The loss of trees increases runoff and reduces the rate of water entering the soil as infiltration; both changes lead to increased peak flow when there is heavy rainfall and decreased base flows when there is little rainfall. This is an apparent paradox: large monsoon flooding with less water for use in the summer months.

The communities that live in newly cleared hillside areas will notice "flashy water" (fast-flowing water) during large precipitation events and "missing water" during dry seasons. They may be correct in their observations.

Practical consequences of deforestation exist beyond theoretical hydrological modelling. Larger sediment loadings will result in increased cost of treatment for communities located downstream from areas cleared of their forest cover. Smaller irrigation canals will fill sooner. Gradual declines in reservoir storage will require more difficult choices regarding use of drinking water, agricultural water and electric power generation. Costs are often borne by users that received no benefits from the conversion of the forest to another land use, which explains much of the politicization of water issues associated with forest landscapes.

On the slope scale, forested watersheds provide the mechanical means of binding soil particles together and maintaining the litter layer on top of the soil surface that slows water flow through the system. When these are removed from the landscape, the surface of the soil can seal, increasing runoff and accelerating erosion. Sediments from the eroded material will clog the river, reduce the capacity of the reservoir; and suffocate the habitat of aquatic species.

In mountainous regions, the removal of the tree cover plus the poorly planned construction of roads can lead to landslides and debris flows. These events are not just natural disasters, but rather a product of poor land management practices. Small changes in the stability of the slope can make a large difference in the amount of damage caused by an intense rainfall event.

In addition to quantity, there are impacts on the quality of water. Trees act as filters for the water passing over the soil surface. When the trees are removed, there are fewer barriers to pollution from agricultural activities and mining that enter the stream. Although replanting can occur, the time required to restore the filtering function can be long (years), and may never be fully restored if the replacement vegetation has been ecologically simplified. A grassed slope is not able to provide the same degree of protection for water quality as a mature forest floor.

Topsoil which has taken many years to develop can disappear after a number of monsoon rains if there is no longer any vegetation on the land and the ground has been disturbed.

When topsoil disappears, the impact will also appear further downstream. With less fertile soils, agriculture will have to use increasing amounts of inputs (such as fertilizers) and there will be increased instability of infrastructure such as roads, riverbanks, etc., and increased risk of failure of hillside developments and settlements.

When ecosystems are disrupted through loss of seed banks and loss of microorganisms in the soil, regeneration is difficult or impossible. An implication for policymakers is that restoration of degraded lands is not simply "tree planting". When soils are lost, tree planting may be expensive and have a low rate of survival and therefore poor ecological returns. Therefore, the stabilization of slopes, the management of grazing, and protection against repeated fires can sometimes be important, as well as planting saplings. There are also occasions where the first restoration task is to stop the disturbance cycle long enough for natural regeneration to occur.

Habitat loss from deforestation is perhaps the greatest single threat to habitats and ecosystems. Loss of habitats results in less wildlife; however, it also has additional negative impacts on the ecosystem's functioning, including pollination, seed dispersal, pest control; and nutrient cycling. The greater the loss of function, the less resilient the forest becomes to natural (drought, etc.) and unnatural (invasive species, diseases) stresses.

This emphasis on maintaining the integrity of habitats is evident globally in biodiversity policy, specifically in the Kunming Montreal Global Biodiversity Framework, which was developed through the Convention on Biological Diversity ^[4]. The reason this is relevant to arguments focused solely on total tree cover is that an area may be able to maintain or even increase its total tree cover while experiencing the loss of ecosystem integrity. For example, when a native forest is converted into a simpler system (e.g., a plantation), the area will still have trees but will no longer support many of the ecological processes that exist within intact native ecosystems.

Some of the most significant declines in ecosystem integrity are not easily detected by looking at green pixels, i.e., changes in canopy cover; they occur over time and are often undetectable until they are severe enough to result in a measurable decline in the health of the ecosystem.

While both shrinking forests and fragmented forests increase the distance between wildlife and human populations, they do so differently. Prior to their decline, animals roamed continuously throughout large expanses of habitat; now they are often forced into agricultural fields and into communities. The consequences include increased crop raids on farms and livestock losses for farmers due to predators, as well as injuries to humans who come into contact with wildlife. These events lead to political instability and make it increasingly difficult to conserve wildlife because many of those affected have little tolerance for wildlife when they experience economic hardship due to lost crops and/or livestock loss. In this way, the costs associated with damage from wild animals may create a self-sustaining cycle: increased conflict, reduced tolerance, and increasing retaliation against wildlife; ultimately, conservation efforts appear to be an expense instead of a shared good.

India's forest governance and legal tools to address land use changes

The diversion of forest land in India is regulated by the Forest (Conservation) Act, 1980^[5]. There is a relatively simple operational rule for the regulation of forest land diversion: no diversion of forest land shall take place for non-forestry uses unless approval has been obtained from the Central Government. Approval at this point represents a checkpoint in the environmental process where alternative measures and mitigation strategies may be examined and evaluated.

However, the strength of the system will ultimately be determined by the level of compliance and monitoring. If a condition of approval is contained only within a file, then it will not protect forests. Thus, amendment debates concerning the scope of the Act are important: a reduction in scope will likely result in fewer conversions being subject to approval^[6].

Legal meaning governs the map of what constitutes "forests". In *T.N. Godavarman Thirumulpad v. Union of India*, the Supreme Court took a broad view of "forests" and extended the definition to include all "forests", in the dictionary sense and any area recorded as forest in official records, regardless of who owns them^[7].

The legal system is designed to impede deforestation at the time of decision making, when conversion to non-forest use is generally irrevocable. However, the effectiveness of that impeding force is directly related to the quality of process and the degree of follow through. For many projects affecting forest lands in India, two separate approvals are typically obtained contemporaneously, i.e., one for diversion of forest lands under the Forest Clearance System and another for environmental clearance under the framework established by the Environment (Protection) Act. The Environmental Impact Assessment (EIA) Notification of 2006 serves as the foundation for the environmental clearance process, establishing a four-step process consisting of scoping, public consultation (as required), appraisal, and binding conditions^[8].

Similarly, there is an established procedure governing the forest clearance process. The Forest (Conservation) Rules, 2022 outline the procedure for applications, scrutiny levels, committee functions and provide for tools such as accredited compensatory afforestation^[9].

Judicial review has periodically pushed the system toward the concept of decision integrity. In *Lafarge Umiam Mining Pvt. Ltd. v. Union of India*, the Supreme Court articulated environmental decision-making as a structured process involving reasoning and proportionality, recognizing environmental protection as a constitutional value and not merely a peripheral technical consideration^[10].

An additional layer of complexity has been introduced by the Forest (Conservation) Amendment Act, 2023, which is now part of the renamed Van (Sanrakshan Evam Samvardhan) Adhiniyam, 1980, amending the coverage rules and creating specific exemptions for particular types of lands and projects. The Memorandum explaining the implementation of the new law indicates that the amended legislation was notified and came into effect on 1 December 2023, and provides details of the new coverage and exemption regime^[11].

India's Compensatory Afforestation Fund Act, 2016 created national and state funds and established general parameters for the utilization of monies collected pursuant to the Act, including compensatory afforestation and net present value (NPV) sums^[12]. While the legislative design is required to ensure proper management of monies collected, successful execution of that plan is critical, as evidenced by repeated audits showing that compensatory afforestation administration can deviate from intended ecological objectives to focus on expenditures rather than ecological performance. Examples of such deviations include lack of planning for adequate monitoring, and poor utilization of monies collected, both of which compromise the ability of compensatory afforestation to achieve ecological objectives^[13]. These failures are not merely accounting errors, but lead to the establishment of low survival plantings, plantings in inappropriate locations, and creation of "green cover" that fail to restore the ecological services lost at the diversion location.

As noted above, incentives will shape behaviour leading to deforestation; therefore, the design of incentives must be included in the design of controls. Two external pressures that will increasingly influence the deforestation control effort are emerging. First, results-based forest finance under REDD+ (within the context of UNFCCC decisions and guidelines) aims to create a framework for measuring and reporting forest-related greenhouse gas emissions reductions, while incorporating safeguards^[14]. The promise of paying people to protect their forest ecosystems by preserving them depends on having a credible system to measure how much forest remains intact, and the creation of protective measures that safeguard property rights and the preservation of biodiversity as opposed to just measuring carbon.

Secondly, trade-linked due diligence requirements are rising in larger markets. For example, the European Union's Regulation (EU) 2023/1115 requires due diligence obligations for the marketing of various commodities and products in the EU, including that they be "deforestation-free" as well as that the companies demonstrate traceability and complete risk assessments to support such claims^[15]. These regulations could push companies to improve the quality of their suppliers' operations; however, there is a possibility these regulations could add to the burden of smaller producers without some form of support structure.

Conclusion

Deforestation is usually viewed as an enforcement issue. While it is true that enforcement is important to address this issue, there is an underlying structural problem in how institutions have been designed: deforestation is profitable where the benefits from converting land into another use are private and the benefits of keeping the land forested are public. For a policy to be effective, it must narrow the gap between those two types of benefits by increasing the number of decision checkpoints along the way to convert land, creating an ability to measure compliance with regulations, and changing the incentives so that keeping land in its forested state is not considered "idle" land.

In India, the diversion of forest land and the environmental clearance process have real leverage points, but only if files reflect what is happening on the ground and if monitoring of conditions occurs instead of relying on routine. Compensatory afforestation funds may also assist, but the audits explain why simply providing funding is insufficient to restore forests: the design of ecological systems and accountability to ensure that those systems are working properly determines the outcome. The emerging trade and climate financing opportunities present both challenges and opportunities. If used effectively, these opportunities could promote lower deforestation pathways. If not used effectively, these opportunities could create paperwork compliance and additional inequities.

The goal should be to establish an achievable endpoint for deforestation, and that does not include the complete removal of all forest use. That said, the aim is to have predictability and decision making with respect to the use of forest lands in such a manner that it does not damage high value forests, reduce fragmentation of remaining forests, and view the process of restoration as actually restoring damaged ecosystems, and not simply symbolic tree planting. While the environmental impacts of deforestation are serious, the availability of policy options to mitigate, or remove those impacts, are less clear.

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