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APPROACHES TO CLASSIFYING AND RESTORING DEGRADED TROPICAL FORESTS FOR THE CLIMATE CHANGE MITIGATION MECHANISMS

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ABSTRACT

Various approaches to restoration are needed to counter the full range of degradation in tropical forests. We propose approaches for restoration of forests that range from being slightly and severely degraded forests. Our methods start with ceasing the cause of degradation and setting forests regeneration in degraded areas to accelerate tree plantation and growth, and finally include the stage of degradation at which re-planting is necessary. We argue that when the appropriate techniques are employed, forest restoration is cost-effective relative to conventional planting, providing abundant social and ecological co-benefits, and results in the sequestration of substantial amount of carbon. For success of restoration effects, MNREGA and plantation programme of Bihar government must be useful in coming future.

Key words: Assisted natural regeneration, Biodiversity, Forest restoration, Reduced-impact logging, Silviculture.

INTRODUCTION

Tropical forests plays major role in biological diversity and contribute substantially to the global economy, to local human welfare and to the global carbon budget. Unfortunately, the capacity of tropical forests to provide these services is reduced each year by deforestation (FAO, 2010) and degradation due to uncontrolled logging (Asner et *al.*, 2009) and fires (Nepstad et al. 1999).The limited data available on carbon emissions due to forest degradation 1.5–2.2 pgcyr^{-1} (Asner et *al.*, 2010). Furthermore, deforestation and forest degradation also affect 89% of the threatened birds, 83% of threatened mammals, and 91% of threatened plants (MR Abdar, 2013).

There is growth of carbon credits through deforestation and degradation of forests with enhancement of carbon sinks. Much less attention has been paid to halting and reversing forest degradation through restoration, interventions that in addition to increased forest carbon stocks have many collateral benefits including the improved capacity of forest lands to provide other ecosystem services, support biodiversity and contribute to social welfare. Restoration strategies with cost-effective manners should be a key element of carbon sink in increased carbon dioxide and therefore such strategies need to be clarified. Here we focus on the causes of degradation, purpose a classification scheme that reflects the severity of degradation, and point to restore methods of forests that are appropriate for the tropical forest ecosystem.

MATERIALS AND METHODS

We adopted UNFCCC's definition of forest, deforestation and forest degradation for the purpose of elucidating forest degradation of their limitations (Putz & Rediford, 2010). Although, this definition lack reference to species composition, we define forest to be an area of >0.05 hac with tree crown cover >20% with a tree as a plant with the capacity to grow >3 meter tall. It follows that "forest degradation" is the loss of trees and their carbon stocks down to the point that an area no longer qualifies as being forested. We further define "restoration" as management activities that help degraded forest recover their lost carbon stocks, biodiversity and capacities to provide other goods and environmental services.

RESULTS AND DISCUSSION

Restoration strategies and approaches:

Tropical forests are degraded in ways that reduce tree cover area and carbon stocks by indiscriminate logging (Asner et *al*., 2010), fires (Page et *al.*, 2002), shifting cultivation (Lawrence 2005), and harvesting trees for charcoal production (Ahrends et *al.*, 2010). To counter the effects of degradation, regardless to cause and degrees, tree planting is often prescribed (Chazdon, 2008). Without denying the value of tree planting where seed sources have been approaches to forest restoration that are often most cost- effective and that engender fewer ecological concerns (Letcher & Chazdon, 2009). By categorizing forests on the basis of degradation degrees (Fig.1), we can select approaches with more assured success in terms of low financial costs, better biodiversity conservation, and broad social and environmental benefits.

To facilitate communication about restoration strategies for forests modified from their primary, old growth, or mature condition (Fig. 1), we define the following arbitrary set of states. Forests in state A are slightly degraded but retain some trees above the minimum diameter at breast height (DBH) for legal harvesting. Forests in state B are moderately degraded due to having lost their legally harvestable trees but retain many that are just smaller than the minimum cutting diameter. Forests in state C are highly degraded as they contain only trees much smaller than the minimum cutting diameter. Finally, forests in state D are critically degraded as they have few residual trees of any size.

To provide rough estimates of the carbon stocks lost from forests degraded from point A to Point D, data from tropical areas suggest restorable losses of carbon stocks of 26.3 to 173.0 mg Cha-1 with an average of 112.4 Mg C (Fig.2). Depending on the degree of degradation, ecological norms of the residual species, needs and preferences of critical forest, availability of funds, any of three general approaches to restoration can be followed.

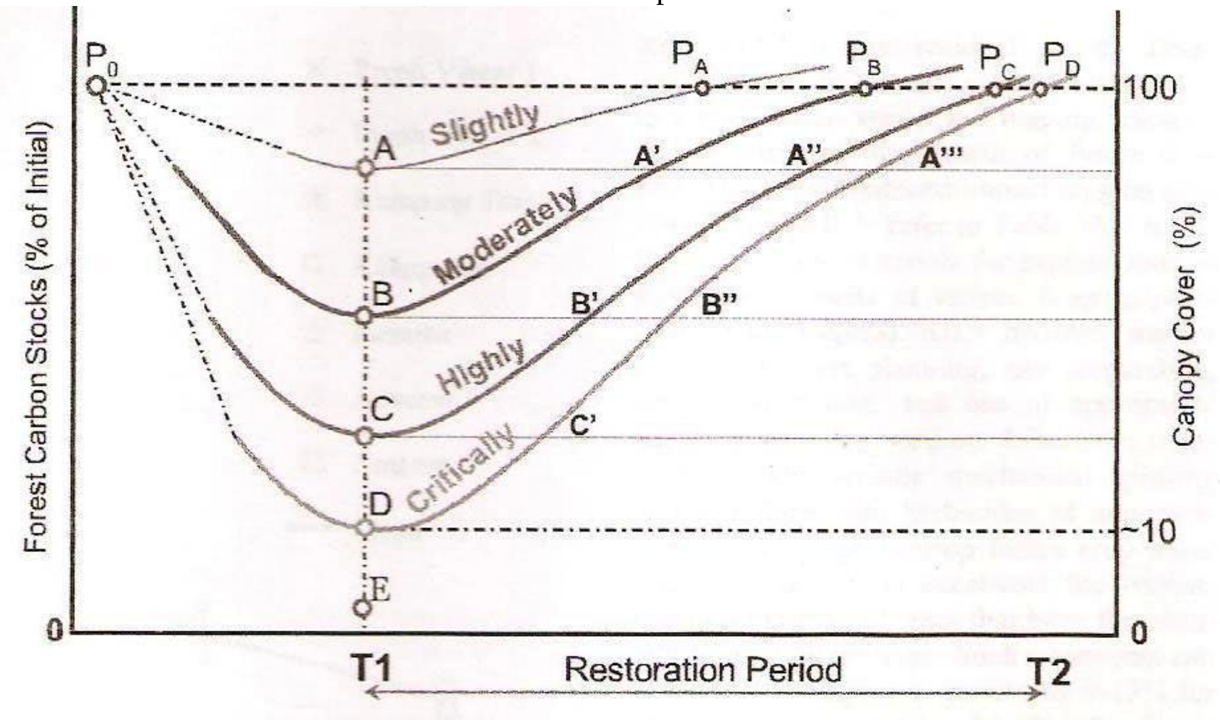
Restoring slightly degraded forest (SDF, P_0 to A to P_A):

SDF refers to areas where timber harvesting was restricted to the legally permitted fraction of trees and only occurred in accordance with government specified minimum cutting cycles or at longer intervals. The degradation is due to regulated harvests being more intensive and frequent than the forest can biologically sustain, at least in the absence of silvicultural treatments, as well as due to harvesting by untrained workers operating without the aid of adequate harvest plans. The consequent reductions in carbon stocks and high-value tree species are represented by the transition from points P_O to A.

To restore SDF, we propose reductions in logging intensities, avoidance of timber harvesting from step slopes, lengthening of cutting cycles, coupled with the use of reduced-impact logging techniques and liberation treatments of future crop trees in the residual stand. These changes in management practices that serve to reduce wood waste and logging damage, and to increase the growth of future crop trees are termed reduced- impact logging plus silviculture (RIL). RIL^+ involves worker training, harvest planning, site preparation, directional felling, and use of appropriate equipment for log yarding. Liberation treatments

Fig.1. Schematic diagram of different stages of forest degradation and time courses for restoration.

(Po): pre-harvest level of primary or old growth forest; (A): Only authorized tree harvesteing; (B) all trees larger than DBH; (C): all marketable trees are harvested; (D) : no longer forest according to UNFCC;(E): deforested;(C to E) : Eligible for reforestation or afforestation under the clean development mechanism (CDM); (A to D) : degradation; (D to E) : deforestation; (T1-T2): restoration period.



might include mechanical girdling and/or killing with herbicides of non-commercial trees that overtop future crop trees, plus vine cutting to accelerate the recruitment and growth of trees that have the capacity to grow to be large. Such treatments can accelerate average tree growth by 9-27% for all tree species, and by 50-60% for future crop trees (Villegas et *al.*, 2009). Reduced felling intensities benefits regeneration and growth of the residual stand with long-term ecological sustainability of forest management operations.

Restoring moderately degraded forest (MDF, P_0 to B to P_B):

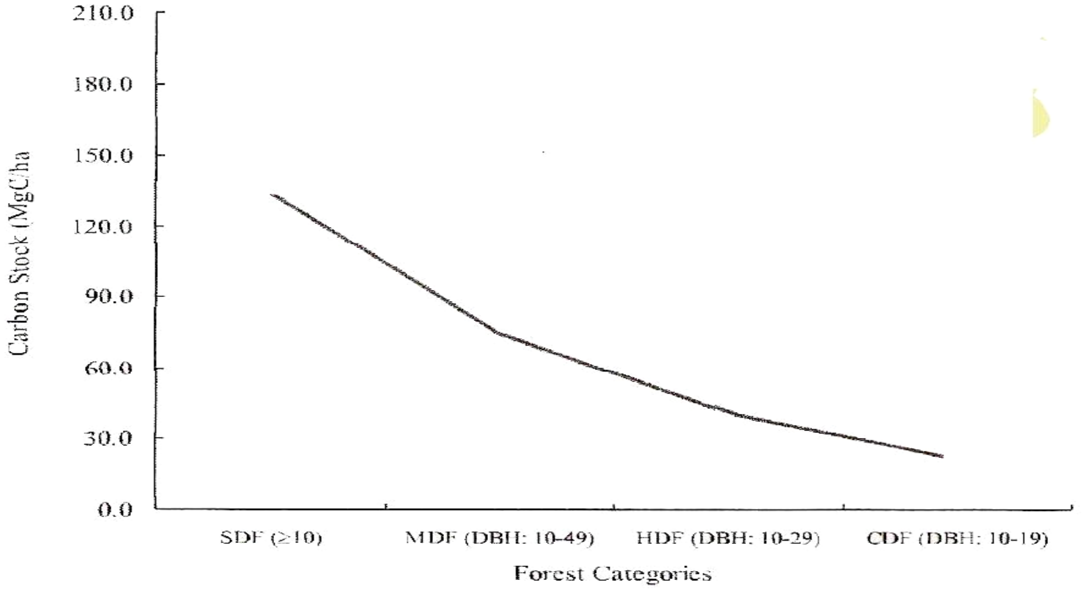
In MDF, more commercially high value trees are harvested than authorized, and excessive logging practices are employed. Unfortunately, failure to enforce forest management regulations in the tropics (Gustafsson et *al*,. 2007) results in substantial but avoidable losses in forest carbon stocks (Fig. 1). MDF still contains some intermediate size trees, some of which are reproductively mature, and some large trees with defective stems, but carbon stocks are reduced by half of that in SDF (Table 1).

MDF requires human intervention to protect the intermediate size trees and accelerate their growth. Forests in this category could be restored by active liberation and other silvicultural treatments to enhance the growth of future crop trees (B to A’), or more passively by preventing pre-mature re-entry logging and the continued use of poor logging practices (A’ to P_B).

Restoring highly degraded forest (HDF, P_0 to C to P_C):

In HDF even trees smaller than the legal size limit (Table 1) and reproductively mature trees of low financial value were harvested in response to strong demand for timber and fuelwood coupled with weak governance. Due to

Figure.2 : Above ground carbon stocks in SDF, MDF, HD and CDF degraded forests.



substantial canopy opening caused by excessive and repeated tree harvesting, such forests are very susceptible to further degradation by fire or grazing coupled with invasion by fire-favoring graminoids. HDF is assumed to still contain some small residual forest trees, but carbon stocks are further reduced from those in MDF (Table 1).

Restoration of HDF requires the cessation of the cause of degradation (B' to A') followed by intensive liberation treatments to stimulate growth of trees to large sizes. In forests allocated for timber production, one goal is to bring the degraded forest back to a point where some trees exists larger than the legal limit of harvesting (C to B'); if natural regeneration and seed trees of heavily exploited species are too scarce, enrichment planting with native species might be justified.

Restoring critically degraded forest (CDF, P_0 to D to P_D):

CDF have been stripped of most trees by over-harvesting of timber and fuelwood collection, often burned, overgrazed and dominated by lianas, shrubs, giant herbs, graminoids, or other non-arboreal species, both native and exotic. At point D, the risk of future degradation and transformation to non-forest land is generally very high (Du Tort et *al.*, 2004). CDF still contains some small trees, but carbon stocks are reduced to <20% of SDF values (Table 1).

Initial restoration of such areas begins with stopping the cause of degradation and allowing natural recovery processes to proceed, but such processes often need to be accelerated by various forms of more active restoration. The restoration strategies recommended for shift from point D to C' generally involve replanting (Chazdon 2008), which is costly and therefore unlikely to be widely implemented. Based on various studies across the tropics (Ganz & Durst, 2003), "assisted natural regeneration" is likely to be more cost-effective than replanting, thus making large scale implementation more feasible. This approach might include fire management, grazing restrictions, suppressing the growth of invasive and fire-favoring graminoids, protecting naturally regenerated native tree species, weeding, fertilizing, and interpolating of native or exotic nitrogen fixing trees, whenever necessary. Depending on geographical locations and forest conditions, agro-successional restoration approach has proven effective. Agro-successional approach involves the use of "taungya" system in which native tree species are interplanted with annual crops, and farmers move to another area after dominance of larger

Table 1: Average above-ground carbon stocks in tropical forests and carbon percentages

Carbon Stocks	Category			
	SDF (DBH≥10cm)	MDF (DBH:10-49 cm)	HDF (DBH:10-29 cm)	CDF (DBH:10-19 cm)
Above-ground carbon stocks ($MgCha^{-1}$)				
Min	75.3	49.0	33.1	17.1
Max	199.4	117.2	56.6	26.3
Mean	134.0	75.2	41.0	21.6
Percentage of above-ground carbon stocks (%)				
Min	100.0	65.1	44.0	22.7
Max	100.0	58.8	28.4	13.2
Mean	100.0	56.1	30.6	16.1

trees. Eventually, thinning may be needed to accelerate the growth of desired individuals, thus speeding the transition from point C' to B". The residues from pruning and thinning might be used for forage or fuelwood by nearby communities. With increasing forest stature, stopping the cause of degradation continues to be important as the recovery proceeds from B' to A". Eventually, during the final restoration phase (A" to PD), RIL$^+$ treatments become appropriate.

Function of climate change mitigation mechanisms:

A major constraint on the success of restoration interventions is the continued availability of funding, but some of the option we describe are not expensive to implement. For example, the switch from excessively destructive to reduced impact- logging reportedly ranges from having slight negative (Tay et *al.*, 2002) to large positive effects on profits from timber harvesting (Holwes et *al.*, 2002). The liberation treatment may also be useful depending on its location, season and implements. The costs of restoration using assisted natural regeneration techniques are far less than enrichment planting and other conventional plantation development techniques because the costs of propagating, raising, and planting seedlings are avoided (Ganz & Durst, 2003). Furthermore, forests resulting from assisted natural regeneration are more biologically diverse and provide more benefits to local people than plantations. As restoration proceeds, more long-term benefits from ecosystem services and employment are expected, especially where effects are financially supported by either the voluntary carbon market or funds from a future REDD$^+$ agreement.

Effective and efficient monitoring and verification care essential to any global program that includes halting degradation and restoration among possible climate mitigation mechanisms. The framework we propose fits well with the latest techniques in satellite monitoring that allow direct estimation of canopy loss, recovery and closure at a range of logging intensities (Asner et *al.*, 2006; Anand and Thakur, 2013). Moreover, the next generation of biomass-sensitive satellite will soon be launched with more planning which further supports the proposed strategy. Due to technological advancements and the availability of free data, the costs for monitoring carbon stocks and emissions are already low (Asner et *al.*, 2010).

CONCLUSIONS

Restoring degraded tropical forests has a huge potential for mitigating global climate change by enhancing carbon stocks. Among the approaches discussed, the first is to stop the cause of degradation and allow forests to regenerate itself. The second approach is to accelerate free regeneration and growth through application of any silvicultural treatments. The third general approach is to plant seeds or seedlings in natural or artificial gaps, a process often referred to as enrichment planting. To promote widespread implementation of these strategies under REDD+ initiatives, appropriate incentives, policies, institutional arrangements, and local participation are required. Since restoration takes time, long term political commitments by participating countries will be required REDD+ funded forest restoration will contribute to sustainable development and help secure the ecosystem services.

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