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CRITERIA AND INDICATORS FOR ASSESSMENT OF FOREST DEGRADATION IN DRY-TROPICAL FORESTS OF INDIA

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ABSTRACT

Forest degradation is a critical issue around the globe particularly in developing countries like India which has diverse phytogeography and forest types. It is a complex issue, existing parameters are difficult to apply across different forest types and classes, due to lack of specific guidelines therefore needs to be addressed in broader terms and scale. Therefore, the present paper proposes a new methodology based on Sustainable Forest Management (SFM) criteria and indicators leveraging remote sensing data for assessing the forest degradation. Emphasis is put on the upscale and explicability aspects of the methodology rather than stand level and local dentitions of forest degradation so that the methodology can be broadly applicable to all Tropical Dry Deciduous Forests of India. Hence to provide a scientific framework for assessing forest degradation and helps in the implementation of specific rehabilitation practices in degraded forests.

Keywords:Forest degradation, criteria, indicators, sustainability

INTRODUCTION

Forest degradation is a complex and critical issue around the globe particularly in developing countries like India which has diverse phytogeography and forest types (Davidar *et al.*, 2010). Forest degradation reduces the capacity of forests to produce goods and services due to anthropogenic and environmental changes (FAO, 2011). The existing parameters of forest degradation assessment are difficult to apply across different forest types and classes, due to lack of specific guidelines therefore needs to be addressed in broader terms and scale (FAO, 2011). This process needs be observed on a long-term scale and does not cover short-term changes associated with forest management operations. This process involves a decreasing trend in Net Primary Productivity (NPP), changes to the composition & structure of the forest, regeneration pattern. These changes also influence underlying bio-physical interactions affecting forest functioning and diminishing the ecosystem services. Furthermore, degradation process reduces the recovery capacity of the forests in terms of structure, functions and process alters forest's capacity to recover from this exploitation over the time. In the Global Forest Resource Assessment 2015, the extent of primary forest accounts only for 30% percent of the total forest area of 4.06 billion hectares (FAO, 2015) and 2 billion ha of forests need restoration at global level (A.Stanturfa, 2014). Therefore, forest degradation is a serious environmental, social and economic problem and harmful both to the ecosystems and society as a whole. Considering its manifold negative effects, it has been defined as a priority action in many international conventions and global policies that address biodiversity, forest management and climate change mitigation.

India is a mega diverse country with many forest types ranging from subtropical forest to tropical dry deciduous forests (MoEFCC, 2018). With the two decades of community forest initiatives, India has been able to increase forest cover of the country, but quality of forest cover is still a major concern (FSI, 2019). In India, priority policy actions have been identifying and addressing drivers of degradation as a significant part of the country's forests under various drivers of degradation (MoEFCC, 2014) . However, the statistics on forest degradation are very poor in the country and in the absence of time series data(Reddy *et al,* 2001); it is difficult to calculate the accurate losses due to forest degradation. Moreover, the losses from foes degradation in respect of changes in stand composition, biodiversity, carbon sequestration potential and organic soil carbon are very important for the overall ecological stability and environmental conservation. The state of the forests needs to be assessed so that appropriate steps can be initiated to arrest and reverse the process of degradation. It will also enable to take prioritization of management objectives and resources to prevent further degradation and to restore and rehabilitate degraded forests (Simula, 2009). More specifically, information generated from the measurement of forest degradation can be used for better forest management

Forest degradation is linked with anthropogenic activities to a large extent, once these linkages are clearly understood it can be addressed. The main reasons for the forest degradation are fuel wood extraction, unsustainable NTFP harvesting, grazing, forest fires etc (Sahu *et al.*, 2016). In addition, it is a continous process which negatively affects the capacity to supply forest products and services. Forests may be assumed as degraded in terms of loss of any of the goods and services that they provide and this process becomes evident gradually.However, thesere is no standard methodology to classify and assess the forest degradation and it is more difficult to discern and quantify (UNFCCC, 2010). Further, forest degradation has more than 60 definitions of the concepts of forest degradation with emphasis ranging from loss of carbon stock, mitigation of climate change, soil degradation (FAO, 2011).

In order to understand these linkages, an attempt is made here to assess forest degradation using the Sustainable Forest Management(SFM) Criteria & Indicators.SFM Indicators. This would help us not only in understanding the causes of degradation but also helps us in formulating policies to check degradation in future.

The GFRA, 2020 has used the forest cover as a proxy indicator for the forest degradation. It has overlooked the key indicators like area, stock density, affected by fires species extinction, soil erosion, forest/canopy cover production/value of timber and non-wood forest products (NWFPs) etc. The methodology has specifically adopted SFM indicators like canopy cover, basal area, diversity indices along with the qualitative indicators like ecosystem goods and services to the local communities. The focus should be around the identification of the various components in various indicators and threshold values to rationalize definitions related to forest degradation elements .

The inherent level of uncertainty surrounding the degradation definition and process will also lead to a high degree of variability in the capacity of forests. However, Sustainable Forest Management (SFM) criteria & Indicators along with a broad set of remote sensing indicators provide a certain degree of standardizated parameters that may be easily monitored (Catherine M. Tucker, 2013) and compared with reference forest levels. In addition, it is also important to estimate reference levels for the key indicators of differentforest attributes related to stocks of biomass, soil organic carbon, forest fragmentation, land biophysical parameters, fire frequency and extent, soil erosion etc. Though, this approach is robust to cover large swath of forest areas to understand forest degradation but fails capture some species compositions with succession. Therefore, it is a careful trade off to determine the forest degradation. This paper provides framework considering the Tropical deciduous forests in India, which account for approximately 46% of the forest land in the country (Singh and Singh 1998).

MATERIALS AND METHODS

Forest degradation process adversely impact functional characteristics of the forest. It occurs as a result of anthropogenic activities driven by macroeconomic factors (Stanturf, Palik, & Dumroese, 2014). This process takes place over a long period and becomes evident gradually (Putz & Sasaki, 2009). Further, forest degradation has more than 60 definitions of the concepts of forest degradation with emphasis ranging from loss of carbon stock, mitigation of climate change, soil degradation (FAO, 2011).

The study would follow quantitative research design for developing methodology for assessment of forest degradation (FAO, 2011). The rationale for choosing this research design was that it had to provide robust key indicators that could provide the basis for the forest degradation assessment at the landscape level. In other words, the methodology will specifically adopt SFM indicators like Biomass, Forest Carbon Pools, diversity indices along with the remote sensing proxy indicators related to ecosystem goods and services and unusual disturbances to develop comprehensive forest degradation assessment methodology.

Elements of Sustainable Forest Management (SFM): There are various ways to rationalize existing definitions of forest degradation to improve their transparency and identify possibilities for their improvement in view of comparability, coherence and consistency (Asner, Hughes, Vitousek, Knapp, & T. Kennedy-Bowdoin, 2008). The possible theoretical approaches followed for the assessing the forest degradation: In a broad sense, SFM elements which provide a wide range of criteria & indicators for assessing forest degradation.Further, addresses imprecise, multiple and often subjective interpretations of the forest degradation and providing a common framework for measuring forest degradation.

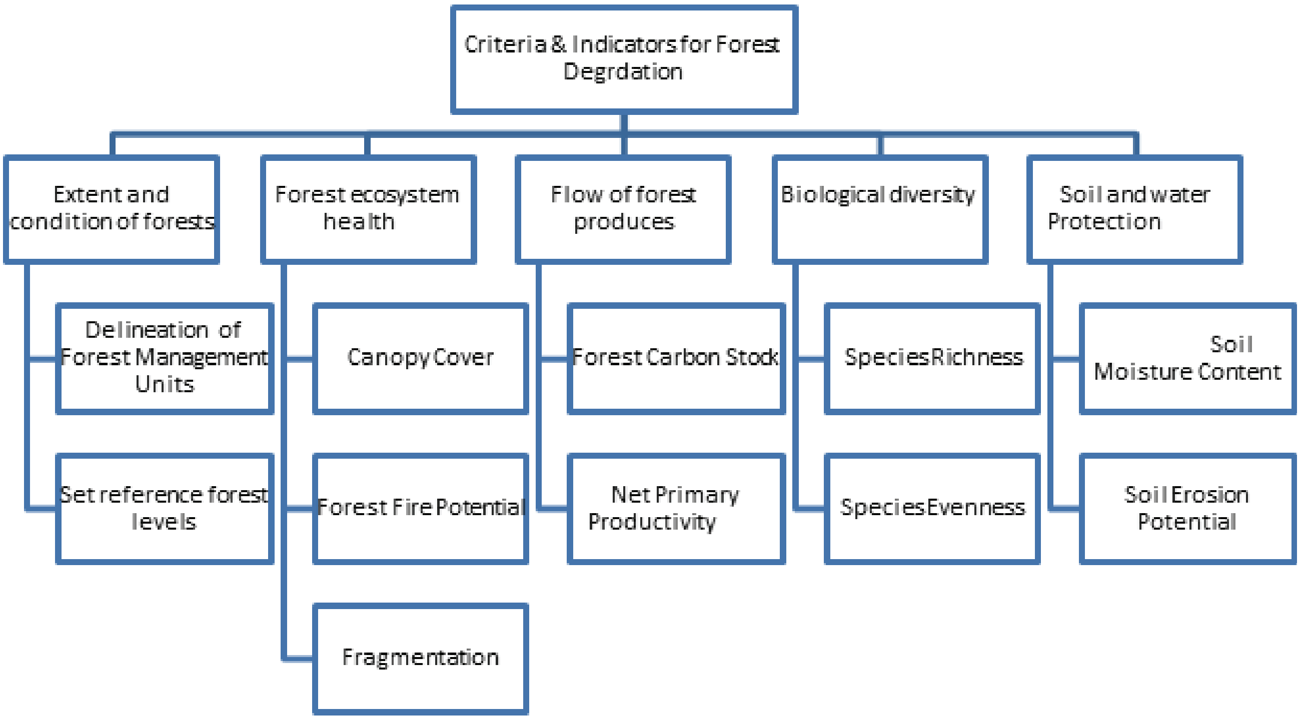
The present paper draws five thematic elements of Sustainable Forest Management(SFM) Criteria & Indicators (C&I) to assess forest degradation. These C& I elements provide a framework for identification of forest characteristics and services which can be used in formulating the relevant components of forest degradation. These various C&I set represents important forest policy instruments which were developed mainly for monitoring and reporting on the SFM goals (Kotwal, 2004).

The elements selected for assessment using above methods include 1: Extent and condition of forests; 2: Forest ecosystem health 3) Flow of forest produce 4) Biological diversity and 5: Soil and water Protection.

For the selected key SFM criteria, the indicators selected based on the availability of data across time and space, literature research and consultation with domain experts and can be monitored through remote sensing techniques, so that the methodology can be scalable and applicable to other areas as well. A set of 12 indicators have been identified for the purpose. Details of the list of identified indicators, their SFM Criteria are given in Table 1.

Table 1: Criteria Adopted form SFM

SFM Criteria		Indicators estimated through Remote Sensing Tools
Extent and condition of forests	1.	Delineation of Forest Management Units for assessing Remote sensing tools (Graticulation Tool)
	2.	Set reference forest levels using canopy cover (>80%)
Forest ecosystem health	1.	Canopy Cover
	2.	Forest Fire Potential
	3.	Fragmentation
Flow of forest produces	1.	Forest Carbon Stock
	2.	Net Primary Productivity
Biological diversity	1.	Species Richness
	2.	Species Evenness
Soil and water Protection	1.	Soil Moisture Content
	2.	Soil Erosion Potential



Composite measures: The composite indices wereelaborated for SFM Criteria by weighting indicator's components of forest degradation. This kind of approach was used for assessment purposes to reduce the indicators to be reported. Further, the composite indices reduce subjective judgments and provide specific indicators to improve rating of the forests and sometimes measurement outcomes becomes easy to interpret (Siry *et al.*, 2005).

RESULTS AND DISCUSSION

Criteria and Indicators for Defining forest Degradation in India: The study approach draws on the five thematic elements of Sustainable Forest Management (SFM) for developing a conceptual, methodological framework for assessment of forest degradation following (FAO, 2011). The SFM elements provide a framework for identification of forest characteristics and services which can be used in formulating the relevant components of forest degradation as is also used by ITTO (2016).

Criterion 1

Extent and condition of forests: This criterion lays the foundation for SFM within a well-planned distribution of production and protection forests. It considers the extent and percentage of land under natural and planted forests and the wider context of land-use planning, the need for the conservation of biodiversity and soil and water protection through the maintenance of a range of forest types, and the integrity and condition of forest resources

Scale of the Forest Management Units (FMU): This criteria provide an important indicator of spatial scale for assessing the forest degradation. Generally, it needs to be assessed at the landscape level to understand the various benefits like watershed, soil protections etc. rather than just Biomass or carbon stock. Therefore, choosing the Forest Management Unit (FMU) is crucial (FAO, 2011) to study degradation patterns at standardnd level or at a landscape level.

In India, generally forest compartments are the standard unit for preparing the management prescriptions (MoEF&CC, 2014). However, over the years, changes in the land use, these compartments are irrelevant for the assessing forest degradation. So, graticulation of the forest areas at the 100 ha (1 Sq.km.) area would be optimum for the forest degradation (FAO, 2011) to study degradation patterns at the landscape level rather than a site specific approach. Further, it would be convenient assessed through a mix of field inventory and remote sensing techniques.

Set reference forest levels: Forest degradation reduces the capacity of the forests due to unsustainable extraction of timber, Non-Timber Forest Products (NWFP), to the extent that its structure, underlying processes and dynamics to recover completely from this exploitation in the short or medium term is compromised. In this context, a reference level is useful to determine the state of the forest, whether it is a non-degraded forest or a degraded forest based on the structural variables or indicators of the sustainable forest management practices, Further, it will also help in avoiding the subjective judgements and also useful to assess wider forest areas. Overall, the reference level will establish the reduced output of products and services from a degraded forest in a given area with a limited degree of biological diversity and provides a scale to measure the possible degradation of a forest. To establish a benchmark for reference states, observations above 80% of forest canopy can be used as reference values for the determination of "stable" forest cover and have reached maturity or "equilibrium state (Martin Enrique Romero-Sanchez, 2017).

Criterion 2

Forest ecosystem health and resilience: The extensive, unusual disturbances reduce the capacity of a forest landscape to provide ecosystem services and reduce resistance to biotic & abiotic stresses. These biotic & abiotic agents are continuously influence Forest ecosystems by at all spatial scales, intensities of impact, and combinations of agents. As long as these do not exceed the threshold or natural variation of an ecosystem over time, they may cause long-term forest degradation. However, over exposure to these agents exert severe negative effects on the original ecosystem changes and impair ecosystem services (Ellison, *et al.*, 2005).

Tropical dry deciidous forests effected by a variety of anthropogenic activities such as illegal harvesting, human-induced fire, animal grazing etc. In addition, various natural phenomena also affects the forest ecosystem health and resilient . Therefore, Canopy Cover, Forest Fire Potential and Fragmentation

Canopy Cover: Canopy Cover is key important factor to determine forest's capacity to recover in the short or medium term. With the optimum tree cover, the degraded forests are able to recover and generate output of products and services for a given area. Normalized Difference Vegetation Index (NDVI) is a standardized remote sensing techncique used to measure canopy cover in the forest inventories (Forest Survey of India, 2013). In addition, Soil Adjusted Vegetation Indicators can be explored for more accurate canopy cover and to reduce errors due to soil moisture and hill shadow effects.

Forest Fire Potential: Tropical dry deciduous forest are vulnerable to forest fire. Therefore, forest fire potential of the area need to be assessed . This can be assess using a ratio of burned area mapping algorithm to map frequent fire prone areas and to develop forest fire potential index. This will be helpful to assess forest health.

Forest fragmentation: Natural forests have become increasingly fragmented in Tropical Dry Deciciodus Forest and pose a substantial threat to biodiversity. Fragmentation of forests is a clear indicator to assess forest degradation and mainly driven by fuelwood collection and selective felling. This fragmentation alters ecosystem processes leading to reduced forest outputs. In addition , anthropogenic pressures further reduces dense forest patches size over time and creating excessive edges. At the landscape scale, the patch level land use statistics will be help in determining the forest fgramentation. The detailed study of this parameter will help in understanding the pressure on the forest resources and influence on the large animals and rare species. In addition, it is also important to have management regimes to address this issues.

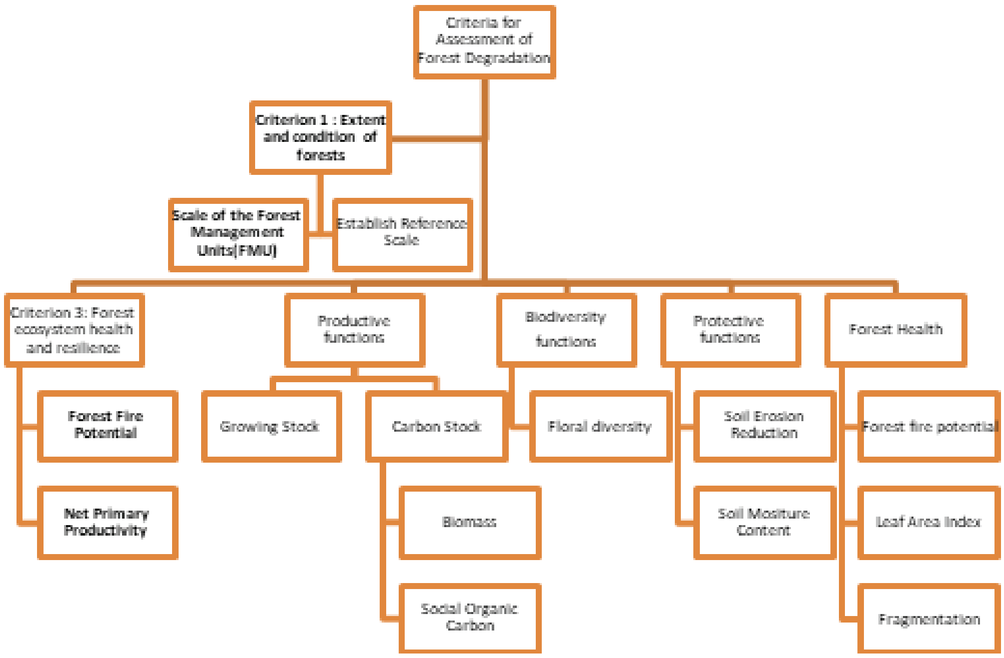
Criterion 3

Forest production: The long term sustainability of the production of forest goods and services is a key objective of forest management and the harvesting of forest ecosystem goods is not considered degradation unless it leads to significant reductions in future availability/ extinction. Hence, degradation can be assessed through changes in the productive functions in growing stock, fuel wood, NTFP resources production and carbon sequestration (A. A. Wani., 2012).

Forest Carbon Stock: As per the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories. 2006 there are five carbon pools namely Above Ground Biomass (AGB), Below Ground Biomass (BGB), Deadwood, Soil Organic Carbon (SOC) and Litter. (Forest Survey of India, 2013). Out of this, AGB and SOC variables are important to assess forest degradation. The remaining indicators could be taken as a fraction of the AGB.

AGB: Above Ground Biomass can be using sample plots and can be extra ploted to the entire region

Soil Organic Carbon : Forest degradation also leads to soil degradation which in turn reduces soil organic carbon. In addition,



Growing Stock: This is an important indicator for assessing forest degradation and it also complements several indicators which are effective forest management and planning. Growing stock is the total standing volume of all trees in a forest area and it can be measured as or total volume (m³); FAO 2005). It is often estimated through a combination of remote sensing & field measurements (Bahamóndez *et al.* 2009). It can be compared with the reference areas to determine adequacy of stocking density undegraded (Phat *et al.* 2004). Further, the volume of wood and biomass resources provides proxy indicators for tree cover and NTFP production resources. It can be accessed through a combination of forest inventory and remote sensing techniques (FSI, 2019)

Net Primary Productivity: Gross primary productivity (GPP) is an important component of terrestrial carbon flux. Thi s indicator based on the reflectance from leaf chlorophyll content, which is directly correlated with photosynthesis . The satellite data can be used to assess the NPP . It can be used as a proxy from the vegetation Indices

Criterion 4

Forest biological diversity: Biodiversity functions provide important ecosystem goods and services. It supports pollination services,decomposition, seed dispersal, resilience and disease reduction. The biodiversity functions should be assessed at two scales: (i) landscapes (multiple stands) and (ii) stands (individual groups of trees distinguishable from other surrounding groups). Both these scales are important and require a different, but sometimes overlapping, set of indicators. Therefore, field inventory and remote sensing data should be used for the purposes of reporting on degradation.

Criterion 5

Soil and water protection: Protective functions are intrinsic properties of the forest ecosystems to maintain soils, soil structure, moisture levels and contribute to forest resilience. Soils also play key roles in forest bio-geochemical cycles; reduced soil stability, erosion causes degradation through siltation of watersheds, reduced fertility and increased rates of rainfall run-off. The two indicators selected for protective functions are: soil erosion and Soil Moisture Content

Soil Erosion Index: The presence of soil erosion is a prime indicator of forest degradation. Soil erosion has a major impact on a range of forest produce & services and leading to land degradation. In most States, forest are located on the shallow-soiled, rocky, steep, windblown and otherwise low-fertility lands. Therefore, they are inherently fragile and need ongoing protection against erosion and other forms of degradation. This need may be increased by projected changes in weather patterns due to increasing atmospheric concentrations of greenhouse gases. (Razaf *et al.*, 2010). The area affected because of soil erosion can be calculated using the based on remote sensing Soil Erosion Index

Soil Moisture Content: Anthropogenic factors lead to change the soil properties, like soil moisture content of the forest area. The relation between soil moisture and plant community has been an important aspect for natural regenaration of the area and microbial decomposition. so this Indicator is important to understand to asses the forest degradation. For this indicator , a combination field inventory and remote sensing tools can be used.

CONCLUSIONS

This study provided a comprehensive methodology by combining SFM C & I and remote sensing techniques to estimate forest degradation in dominant forest type of India. Currently, there is no standard method for estimating forest degradation and only depend on canopy cover data to assess forest status. Using this methodology, degradation status of given forest area can be assessed and further it will also help to plan specific activities to improve the status of the forest. The study suggested remotening data to assess forest degradation making this methodology scalble and replicable across different forest types. This methodology also suggested efficient categorization of local Field Management Units (FMU) to address this issue comprehensive and mainstreaming ecosystem services in the forest management.

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