CONTRIBUTION OF TREES OUTSIDE FORESTS IN MITIGATING CLIMATE CHANGE – A REVIEW

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ABSTRACT: Forest Survey of India (FSI) is assessing the forest and tree cover of India since 1987 using geo-spatial technology and publishes State of Forest Report every 2 years. It gives estimate about Forest and Tree Cover in the country. Forest and tree cover consists of contribution of both Forest area and non-forest area which is known as Trees Outside Forest (TOF). It has assessed total carbon in forests for the first time in the India's State of Forest Report, 2011(ISFR,2011). Crisis due to climate change is threatening human kind day by day. Forests play an important role in mitigating the effects of climate change by absorbing the CO_2 from the atmosphere. Afforestation and reforestation are one of the cheapest ways of mitigating effects of climate change.

In the current paper contribution of TOF in total carbon stored in green cover in one of the states i.e., Tamil Nadu has been examined over the last decade in view of forestry target under Intended Nationally Determined Contribution (INDC) which envisages creation of additional carbon sink of 2.5 -3 billion tonnes of carbon dioxide equivalent through additional forest and tree cover by 2030. There is a little scope to increase forest area in the state due to high population density, urbanisation and competing other land-uses. It can be done only through afforestation on non-forest land, social forestry and agro-forestry. An example of how cyclones cause damage to green cover has been shown for Greater Chennai Corporation.

1.INTRODUCTION:

Industrial activities have caused increase in carbon dioxide emissions which is the cause of increased temperature on our planet. In the past also, there has also been increase in average temperature but the rate of change was very slow. In view of the rapid industrialisation in the 20th and 21st century, the rate of change of temperature and in turn climate change has become rapid and now threatening the very existence of the mankind. The life on the planet earth will be totally changed in a negative way resulting in water shortage, food shortage, inhospitable weather, submergence of coastal areas due to rising sea level etc. It will also cause frequent extreme weather events with increased intensity like cyclone, heavy rainfall, heat waves etc resulting in loss of lives and property. Hotter climate will increase the probability of forest fire. Life will be difficult for the poorer nations because their inelasticity in adaptation. As a result of climate change, species will shift to new location or their survival will become difficult. Corals which absorb a good quantity of CO_2 are being threatened because of increase in temperature and CO_2 (BBC). Average temperature of the earth has increased by 1.2^0C. If the average temperature increase goes beyond 1.5^0C, irreversible changes to the natural environment may happen (Paris Agreement, 2015). With the current pace of emission of greenhouse gases and deforestation and no remedial measures it is predicted that it may result in rise of 3^0C or more by the end of the century which will be catastrophic on the earth. A campaign is being run to go for net zero emission by 2050 by all the countries but there are differences between developing and developed countries (BBC).

2.GEOGRAPHIC PROFILE OF STUDY AREA-TAMIL NADU:

Tamil Nadu is situated on the south eastern side of the Indian Peninsula which is having the Bay of Bengal in the east, the Indian Ocean in the south, the States of Kerala and Karnataka in the west and Andhra Pradesh in the north. It is the southernmost state located between 8^0 5' and 13^0 35' N latitude and 76^0 15' and 80^0 20'E longitude. It has an area of 1,30,058 square km and is the eleventh largest State in India. There are 38 districts in the state. Physio-graphically, the State can be divided into four major regions viz Coastal Plains, Eastern Ghats, Central Plateau and Western Ghats. The main rivers of the State are Cauvery, Bhavani, Palar, Vaigai etc. which joins the Bay of Bengal in the east. It has a Humid Tropical Climate. Tamil Nadu is having a coast line of 1076 km India which is the 3rd largest. The temperature ranges between 19^0 to 37^0 C (TNBB). The north-western, western and southern parts of the State have hilly terrain and rich vegetation. The eastern coastal parts of the State are fertile for cultivation, whereas the northern

parts of the State are having both hills and plains. It is water deficient and relies heavily on monsoon rains and monsoon failures typically result in acute water shortage and drought conditions. It receives rains through both the North East and the South West monsoons, with relative contributions of 48 and 36 per cent respectively with a normal annual rainfall of about 937 mm which is less than the national annual rainfall of 1,200 mm. Land use of the state is give:

Table1: Land Use in the state of Tamil Nadu, India

Land use Type	Area (in Million Ha)	% With reference to total Geographical area
Forest	2.157	16.55
Net Cropped Area	4.738	36.35
Area under Miscellaneous Tree crops	.221	1.70
Permanent Pastures	.108	0.83
Current fallows	.920	7.06
Other fallows	1.906	14.62
Culturable Waste land	.322	2.48
Non-agricultural land	2.203	16.90
Barren and Unculturable land	.458	3.51
Total Geographical Area	13.033	100

(Policy Note 2021-22, Tamil Nadu Agriculture Department)

As per 2011 census the population of Tamil Nadu is 72.14 million which is around 6 per cent of India's population. Tamil Nadu is the sixth most densely populated State in India as per 2011 Census, with a population density of 555 persons per square.km. Part of the Western Ghat with evergreen forests, lies in the state which is a global hot spot in terms of bio-diversity. Hilly region is having a unique mosaic of grassland and shola forests. Coastal areas are having mangrove and corals. The Nilgiris Biosphere Reserve represents a unique and threatened ecosystem in the tropics inside the Western Ghats Mountain system and is one of the biodiversity hotspots. Tamil Nadu is famous for its Teak and Sandalwood forests. Plantations of Sandalwood, conservation and management of mangroves and wetlands are a priority area of the Tamil Nadu Forest Department. Recorded Forest Area (RFA) in the State is 23,188 square km (17.83% of GA of TN) (Policy Note TNFD 2021-22). The Forest Cover in the State is 26,364 square km of which 3,605 square km is very dense forest (Canopy Density >70%),11,030 square km is moderately dense forest (Canopy Density between 40 -70 %) and 11,729 square km is open forest (Canopy Density between 10-40%). Tree cover in the state is 4,830 square km. The total Forest and Tree cover in the state is 31,194 square km (23.98% of Geographical Area) which is around 9 % less than the desired level of 33% as per National and State Forest Policy (ISFR 2019).

As per the Champion and Seth Classification, the forests in TN can be classified into 9 forest type groups which are further divided into 39 forest types. The major forest type groups are given as below:

1. Tropical Wet Evergreen Forests (2.87%)
2. Tropical Semi-evergreen Forests (2.90%)
3. Tropical Moist Deciduous Forests (6.30%)
4. Littoral and Swamp Forests (0.40 %)
5. Tropical Dry Deciduous Forests (41.47%)
6. Tropical Thorn Forests (14.14 %)
7. Tropical Dry Evergreen Forests (1.41%)
8. Sub-tropical Broad Leaved Hill Forests (0.69%)
9. Montane Wet Temperate Forests (1.42%)
10. Plantations/TOF (28.4%)

There are 5 National Parks, 30 Wildlife Sanctuaries and 2 Conservation Reserves in the state over 4.97% of its geographical area (Policy Note, TNFD 2021-21).

3. FORESTRY IN INDIAN SCENARIO:

3.1. Forest Acts:

The Indian Forest Act of 1865 was enacted to establish British claim over forests in India to fuel their industrialisation needs. It has almost snatched the traditional rights of communities on forests. It conferred the British government to declare any land covered with trees as a government forest and make rules to manage it. The Indian Forest Act of 1878 classified forests into reserved forests (government controlled), protected forests (partially controlled by government) and village forests (controlled by adjoining villages). The Madras Forest Act,1882 conferred (Later renamed as Tamil Nadu Forest Act) the State government with a power to constitute reserved forests, district forest and village forests. Under the act, the process of declaring any government land as reserved forest has been defined and it will be done by appointment of a Forest Settlement Officer who shall have the power to enter, by himself or any officer authorised by him for the purpose, upon any land, and to survey, demarcate and make a map of the same and also have the powers of a Civil Court in the trial of suits related to matters of this Act. The Indian Forest Act, 1927 was enacted to consolidate the law related to forest, the transit of forest products and the duty liable on timber and other forest produce. The Wildlife (Protection) Act, 1972, provided for the protection of the wild animals, birds and plants and their habitat. The Act was substantially amended in 2002 to check organized poaching. The Forest (Conservation) Act, 1980 was enacted for providing a higher level of protection to the forests and to regulate diversion of forest lands for non-forestry purposes. Prior approval of the Central Government is essential for De-reservation of forest lands and / or diversion of forest lands for non-forestry purposes (Wikipedia1).

3.2. Common Property Land Resources and Degradation:

The Common Property Land Resources (CPLRs) are the most important source of rural poor in the rural pockets of India. “CPLRs include all resources like village pastures and grazing grounds, village forest and woodlots, protected and unclassed government forests, waste land, common threshing grounds, watershed drainage, ponds and tanks, rivers, rivulets, water reservoirs, canals and irrigation channels.” The rural population in general and the poor in particular depend largely on common property land resources for their sustenance. In the last few decades, the availability of such immense resources was degraded in both qualitatively and quantitatively in India. It has resulted in increased dependence of villagers on reserved forests for grazing, fuelwood, green fodder, small timber which takes heavy toll of reserved forests (Jodha)

4. SIGNIFICANCE OF FORESTRY IN CLIMATE CHANGE:

Forests plays an important role in the carbon cycle. Forests’ role in climate change is double-fold. It can both be part of solution or cause of the problem in case of greenhouse gas emissions. Land sector which contributes around quarter of global emissions is the second largest source of greenhouse gas emissions after the energy sector. About half of the emission from land sector comes from deforestation and forest degradation. Forests are also one of the most important and cost-effective solutions for addressing the negative effects of climate change. Approximately 2.6 billion tonnes of carbon dioxide, one-third of the CO_2 released from burning fossil fuels, is absorbed by forests every year. Estimates show that nearly two billion hectares of degraded land across the world – an area the size of South America – offer opportunities for restoration. Increasing and maintaining forests is therefore an essential and cost-effective solution to climate change.

To achieve the goals by 2030 as per the Paris agreement, it is essential to stop the loss and degradation of forest ecosystems and promote their restoration which will take care of around one-third of the total climate change mitigation. Globally, 1.6 billion people (nearly 25% of the world’s population) rely on forests for their livelihoods, many of whom are the world’s poorest. Forests provide US$ 75–100 billion per year in goods and services such as clean water and healthy soils. Around 80 % of the land’s biodiversity lies in the forests (IUCN).

5. ASSESSMENT OF TREES OUSIDE FORESTS OVER THE YEARS:

Forest Survey of India (FSI) is assessing the forest and tree cover of India since 1987 using geo-spatial technology and publishes State of Forest Report every 2 years. In Forest cover includes all patches of tree formations which are of size 1 ha or more, it does not discriminate whether the tree patch is within the recorded forest area or outsides. Therefore, forest cover map of the country also includes Trees outside Forests (TOF) which occur in tree patch size of 1 ha or more. Apart from this there is significantly large extent of TOF resource which occurs in the patch size less than 1 ha or in the scattered form. This segment of TOF resource is assessed by FSI through sampling techniques following stratified random sampling design and is assessed as tree cover in terms of extent, growing stock etc.

The inventory of TOF started by FSI in 1991 was confined to the States or group of districts. Separate methodology was followed for inventory of rural and urban TOF.The methodology adopted during 1991 to 2001 was not suitable for generating national level estimates of growing stock and other parameters as the inventory was confined to only group of districts or State at different point of time. Therefore, to generate the national level estimates of TOF, the sampling design was modified in 2001. As per the modified design, the country was stratified into 14 physiographic zones based on the similarities in vegetation, climate, soil etc. 60 districts spread over the entire country representing all the physiographic zones were selected for the detailed inventory of TOF in a cycle of 2 years. The district-based methodology adopted in 2001 was again modified in 2016 to meet the data requirement at national and international levels. As per the modified design, FSI has switched over from district to grid-based design. The country has been stratified into uniform grids of size 5km x 5km. This grid layer has been obtained from National Remote Sensing Centre (NRSC). The cycle for the TOF inventory in the new design has been kept at 10 years.

As per ISFR 2019, the total extent of TOF at the country level is 8.94 % of the total geographical area of the country whereas in case of Tamil Nadu (TN), it is 13,605 km^2 which is 10.46 % of geographical area of the state. The growing stock in TOF in TN is 76.30 million cubic metre (70.24 million cubic metre in ISFR 2011) which shows an increasing trend. One ha of TOF in TN is having a growing stock of 56.08 cubic metre which is slightly above the national average. The total carbon stock in TOF of TN is 118.28 million tonnes.

6.NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) IN ASSESSING VEGETATION:

NDVI is probably one of the most robust indices for estimating vegetation in remote sensing. The NDVI is a simple indicator of photosynthetically active biomass. NDVI helps to differentiate vegetation from other types of land cover (artificial) and determine its overall state. The chlorophyll pigment in a healthy plant absorbs most of the visible red light, while the cell structure of a plant reflects most of the near-infrared light. However, season, type of plant and regional peculiarities to be taken into account to interpret NDVI values (EOS). NDVI in conjunction with hybrid method of unsupervised classification and supervised classification helps in differentiating between trees and agricultural crops. (ISFR,2019)

7. POTENTIAL AREA FOR AFFORESTATION AND AGRO-FORESTRY:

Greening of Urban Spaces, Agro-forestry, afforestation on Culturable Wastelands, plantations along highways, railways tracks and canals are very important in expanding area under TOF and simultaneously raising carbon stock. A study done on NDC forestry target by FSI in 2019 highlighted an estimated value of 43.16 million hectare of land availability for plantation in the country. The study described the best possible different scenarios and magnitude of actions required for achieving the Nationally Determined Contributions (NDC) target for creating additional carbon sink through additional forest and tree cover in the country by 2030.

In order to raise the growing stock of TOF and thereby to increase the carbon stock, various plantation approaches were highlighted by Ashutosh et al. (2019). According to their findings; tree planting on culturable wastelands & other available lands in the villages, tree planting along roads (National Highways, State Highways and Other Roads), railway lines including Railway Siding, rivers & Canals etc.

Availability of areas for afforestation in TN is given below in Table 2

Table2: Land Available for Afforestation and Agro-forestry

S.No.	Type of Land	Area (in Ha)
1.	Wasteland	325,000
2.	Agroforestry	625,000
3.	Along National Highways	88,500
4.	Plantation along other roads	193,300
5.	Plantation along railways and railways sidings	4,340
6.	Urban Green Spaces	1,263,560
	Total	2,499,705

(FSI Technical Information Series, Vol 1, No 3,2019)

8.AFFORESTATION TECHNIQUES AND PEOPLE'S PARTICIPATION:

Most of the areas where afforestation will be undertaken are poor in nutrients, susceptible to soil & water erosion and biotic interference etc. For an afforestation programme to be successful, people's participation and cooperation is essential. Before taking any afforestation activity, soil and moisture conservation activities has to be undertaken for the success of afforestation. In case of problematic soil like acidic or alkaline, suitable ameliorative measures to be taken before afforestation. Regarding choice of species, preference should be given to pioneer & native species and choice of local people.

8.CASE STUDY OF VARDAH CYCLONE:

As a demonstration of how the state of TN in India is affected by the vagaries of nature caused by climate change, a case study of Vardah cyclone which devastated the green cover of Chennai (Capital of TN) and nearby areas, is presented. Warming of the surface ocean from anthropogenic (human-induced) climate change is likely to fuel more powerful tropical cyclones. The destructive power of individual tropical cyclones through flooding is amplified by rising sea level, which very likely has a substantial contribution at the global scale from anthropogenic climate change. In addition, tropical cyclones precipitation rates are projected to increase due to enhanced atmospheric moisture associated with anthropogenic global warming (CLIMATE.GOV).

On 12th of December,2016, Cyclone Vardah had a landfall near Chennai on the eastern coast of India. During landfall the speed of the Winds were estimated at 105 km/hr. 18 people died due to the cyclone in Chennai and its suburbs and it caused extensive damage to roads, supplies, and power infrastructure. It has caused massive damage to green cover in Chennai and nearby areas (Wikipedia 2). An attempt was made to estimate the damage by comparing NDVI before the cyclone and after the cyclone. Non-availability of cloud free satellite images is a problem with coastal areas. The result of comparison of NDVI values for the Greater Chennai Corporation which is spread over 118,900 ha is given in the table given below:

Table 3: Comparison of Land class before and after Vardah Cyclone using NDVI in Greater Chennai Corporation Area

S. No	Land Class	September, 2016 (Before Vardah Cyclone) (in Ha)	February,2017 (After Vardah Cyclone) (in Ha)	Change (in Ha)	% change
1	Water	5812	5855	43	0.74
2	Urban & Barren Area	74640	84415	9775	13.10
3a	Sparse Vegetation	16927	19220	2293	13.55
3b	Dense Vegetation	21521	9410	-12112	-56.28
4	Total Vegetation(3a + 3b)	38448	28630	-9819	-25.54
5	Total	118900	118900		

The above table shows a loss of 9819 ha of vegetation which is 8.26% of the total area. As per the random sampling done, it was found that there is a loss of 9 trees per ha. The average per tree volume was 3.2 m^3 esimated from fallen trees in the sample plot. So the total C loss due to Vardah cyclone comes to 33580.98 ton of C using a conservative Universal Wood Density of 0.2 ton/m^3 (Ramachandran, 2007) and a factor of .5 for carbon estimation from the weight. It can be seen that event like Vardah has caused a loss of 33580.98 ton of C which needs to be repelenished to mitigate the adversities due to climate change.

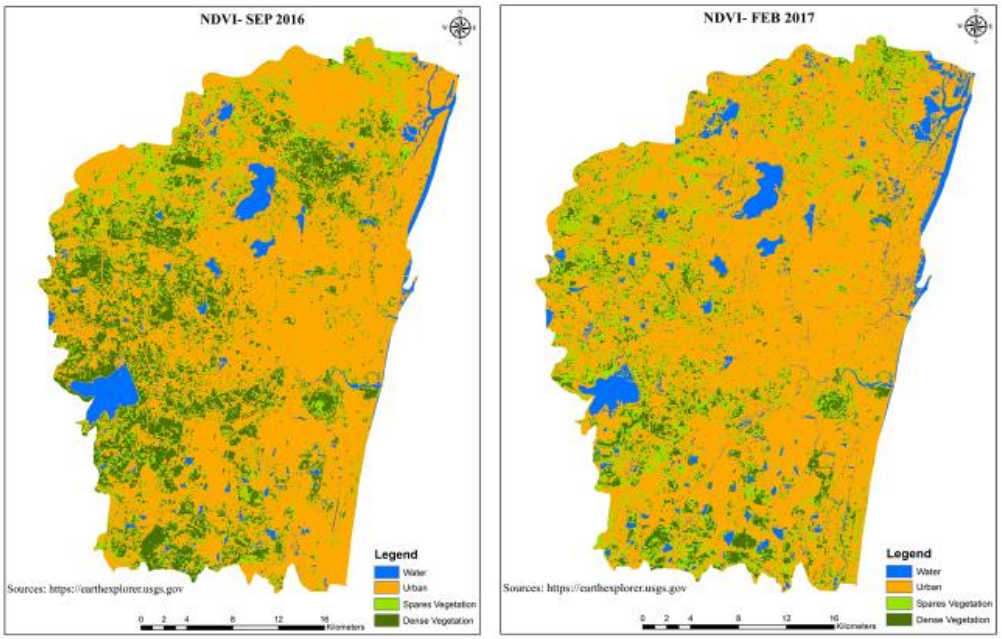

Fig1: Land use classification based on NDVI before (Left) and after (Right) Vardah cyclone in Greater Chennai Corporation

9.CONCLUSION AND RECOMMENDATION:

To achieve the INDC goal of creating additional carbon sink of 2.5 to 3 billion ton of CO_2 equivalent through additional forest and tree cover by 2030, it is imperative that afforestation is done in additional areas in the state of TN as mentioned in para 7 with appropriate techniques with people's participation and cooperation.40 % of the Additional carbon sink will come from TOF areas. Other damages like electricity supply restoration, water supply restoration, rebuilding of city infrastructure etc can be done in matter of weeks or months. But if green cover is lost due to disaster like cyclone etc, its restoration is a long-term process and it may take even 50 years or more to restore C back to previous level. It is also important to keep the C sink intact in view of natural disaster like Tropical Cyclone for the coastal state like TN. Appropriate financial allotment is to be done to achieve the INDC goal which will go a long way in achieving Sustainable Development Goals (SDGs) and good life even for the poorest of the poor.

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