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Mitigating Global Greenhouse Gas Emission: The Role of Trees as a Clean Mechanism For CO_2 Sequestration

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ABSTRACT

Purpose: *Globally, increase in average mean temperature of the earth has been a hindrance to human-health development, agricultural productivity including environmental sustainability. The situation is exacerbated by continual/increase in gas flaring, mismanagement of land that releases nitrous oxide (N2O) including ecological-disturbances and imbalance. To reduce the impact of greenhouse gas emission, especially in low-income regions, then using a bio-approach becomes imperative.*

Research Method: *The work adopted a theoretical approach (data mining), x-raying/amplifying the important role trees plays in our environment towards reducing greenhouse gas emission.*

Findings: *Trees has been found/confirmed to be able to capture and lock carbon in the form of CO2 in their biomass, thereby helping in reducing the amount of CO2 content in the atmosphere. Findings of this study revealed that trees act as a clean mechanism that can be used, and has been able to reduce CO2 content out of the atmosphere. Several reviewed research findings indicated a significant ($p<0.05$) increase in carbon sequestration potential of various tree species.*

Research Limitations: *Field verification for data obtained through data mining was only verified through literature search.*

Originality/value: *The outcome of the study presented a view that trees can statistically act as a clean biological mechanism approach towards environmental, agricultural including human health sustainability in the face of climate change.*

Keywords: *Climate Change; Caron sequestration; Clean Mechanism, Greenhous gas, Gas emission*

INTRODUCTION

Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect experienced as global warming. The Intergovernmental Panel on Climate Change, IPCC (2000) identified: Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) as the primary greenhouse gases in the Earth's atmosphere. The Kyoto Protocol (2000) have identified, other greenhouse gases in the atmosphere caused by human-activities in addition to the naturally occurring ones, and these Man-made greenhouse gases include: sulphur hexafluoride

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(SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), which contribute to increase in global temperature.

Climate Change (CC) has been recognized as one of the major threats to food security, environmental sustainability including human-health development in the twenty-first century (Christensen *et al*., 2007; Seager *et al*., 2007). The Intergovernmental Panel on Climate Change (IPCC) concludes that climate has changed over the past century, in which human activities have had an influence on these changes, and that climate is expected to continue to change in the future (IPCC, 2007). Even under conservation scenarios, future climate change is likely to include further increase in global mean temperature (above 2°C - 4°C) with significant drying in some regions (Christensen *et al*., 2007; Seager *et al*., 2007), as well as increase in frequency and severity of extreme droughts, hot extremes, and heat waves (IPCC, 2007, Steri *et al*., 2008).

The threat that climate change poses to agricultural production does not only cover the area of crop husbandry, but also include livestock, and in fact the total agricultural sector. Climatic impact, that especially increases in average mean temperature affect human development directly or indirectly, acting like a hindrance to global sustainability (IPCC, 2007). Direct effect of climate variability such as extreme; air temperature, humidity, wind speed and other climate factors influence humans in various ways including increase in human-health complications (Steri *et al*., 2008), in animal; growth performance, milk production can be negatively affected (Manning and Nobrew, 2001).

From time immemorial, trees have always been a source of income, food, raw material serving an esthetic value. Trees including all green plants utilize CO_2 in addition to solar radiation and water for production of its food (carbohydrate-CHO), which is needed for the day-to-day running of the plant biological system.

Clean Mechanism (CM) is one of the sustainability techniques, although not new, but still uncommon to many scientists. A technique has been adopted by the United Nations Framework Convention on Climate Change (UNFCCC, 2000). This mechanism allows public and private entities (bodies/project partners) to engage in carbon sequestration process using eco-friendly/clean approaches, with the sole aim of reducing global mean temperature to stabilize at 2°C, where parties unable to arrive at this accepted 2°C emission reduction agreement, been liable to fund the sequencing counties in form of "Carbon Credit" (UNFCCC, 2013). Clean Mechanism, often regarded by UNFCCC as Clean Development Mechanism (CDM) is an emission reduction strategy, defined as a set of interventions towards reducing greenhouse gases using sustainable approaches. The CDM approach towards reducing the world heating temperature has been experimented by UNFCCC including limited number of Scientists, and found to be an effective approach/way of reducing CO_2 content in the atmosphere, thereby limiting the increase of global temperature. Apart from being an emission reduction strategy, CM is an environmentally friendly approach of improving degradable lands, especially for Agroforestry system (Global Canopy Programme, 2008).

Against the rapid increase in global mean temperature, and for consistent reduction in content of atmospheric CO_2, which is the bulk of the greenhouse gases, the need for this work arises, with the aim of x-raying and reviewing/amplifying the Clean Mechanism approach to CO_2 sequestration, while presenting the role of trees in reduction of global greenhouse gas emission, with it associated carbon auditing tool.

Afforestation in the Sense of Clean Mechanism

Afforestation, has been looked at as the direct human-induced conversion of land that has not been forested for a period of at least 50 years, to forested land through planting, seeding and/or the human-induced promotion of natural seed sources (UNFCCC, 2013). Afforestation is an activity included under the CDM Afforestation/Reforestation category. There are a range of definitions for afforestation: some definitions are based on phrases such as "has not supported forest in historical time;" others refer to a specific period of years and some make reference to other processes, such as "under current climate conditions." The IPCC Guidelines define afforestation as the "planting of new forests on lands which, historically, have not contained forests" (IPCC, 2000).

Afforestation/Reforestation (A/R) CDM is a project category and sectorial scope under the CDM through which eligible projects can generate emission reduction offsets from carbon sequestration by forests. It is currently the only forest carbon category eligible to earn credits under the compliance markets of the Keyoto Protocol.

Tropical deforestation, including both the permanent conversion of forests to croplands and pastures and the temporary or partial removal of forests for shifting cultivation and selective logging, is estimated to have released on the order of 1-2 PgC/yr (15-35% of annual fossil fuel emissions) during the 1990s (IPCC, 2000). The magnitude of emissions depends on the rates of deforestation, the biomass of the forests deforested, and other reductions in biomass that result from forest use. If, in addition to carbon dioxide, one considers the emissions of methane, nitrous oxide, and other chemically reactive gases that result from deforestation and subsequent uses of the land, then one could probably predict or be afraid that the world may overheat and flame-up one day if we do not continually sequester the emitting gases. Annual emissions during the 1990s accounted for about 25% of the total anthropogenic emissions of greenhouse gases (IPCC, 2000). Trends in the rates of tropical deforestation are difficult to predict, but an estimated rates shows that, another 85 to 130 PgC will be released over the next 100 years (IPCC, 2013). Emissions decline easily as degraded or abandon lands are forested or regenerated (Forest Peoples Programme, 2012; Global Canopy Programme, 2008) as in (Figure 01).

Figure 01: Afforastation programme in Tropical Africa

Source: Global Canopy Programme (2008).

Deforestation, and its Role in the Natural Environment

One of the consequences of deforestation is that the carbon originally held in forests is released to the atmosphere, either immediately if the trees are burned, or more slowly as unburned organic matter decays. Only a small fraction of the biomass initially held in a forest ends up stored in houses or other long-lasting structures. Most of the carbon is released to the atmosphere as carbon dioxide, but small amounts of methane and carbon monoxide may also be released with decomposition or burning. Cultivation also oxidizes 25-30% of the organic matter in the upper meter of soil and releases that to the atmosphere (Global Canopy Programme, 2008). Reforestation reverses these fluxes of carbon. When forests are regrown, they withdraw carbon from the atmosphere and accumulate it again in trees and soil. Although deforestation, itself, may not release significant quantities of methane or nitrous oxide, these gases are often released as a consequence of using the cleared land for cattle or other ruminant livestock, paddy rice, or other crops, especially those fertilized with nitrogen (FAO, 2010; Global Canopy Programme, 2008).

Forests cover a total of 4 billion hectares worldwide, equivalent to 31% of the total land area (FAO, 2010; Forest Peoples Programme, 2012). Although this figure may seem high, the world's forests are disappearing. Between 1990 and 2000 there was a net loss of 8.3 million hectares per year, and the following decade, up to 2010, where it was a net loss of 6.2 million hectares per year (FAO, 2010). Although the rate of loss has slowed, it remains very high, with the vast majority occurring in tropical regions (FAO, 2010). Besides the devastating effects tropical forest loss has on biodiversity and forest-dependent communities, a major consequence of deforestation and forest degradation is the release of heat-trapping carbon dioxide into the atmosphere. Forests provide vast carbon sinks that when destroyed emit CO_2 into the atmosphere, either by burning or degradation of organic matter (Amazon Institute of Environmental Research, 2005). CO_2 is one of the most potent greenhouse gases and the primary component of anthropogenic emissions (United States Environmental Protection Agency, 2012). UNFCCC (2013) report presents a view that the conversion of forests to other land uses is responsible for around 10% of net global carbon emissions. Solving the problem of deforestation is a prerequisite for any effective response to climate change/global warming programme.

Table 01: Analysis of growth and carbon storage Capacity of tree species

Tree Species		H (m)		DBH (cm)		CW (m)		V_{tree} (m^3)		C_{tree} (ton)	
Chinese banyan (*Ficus microcarpa*)	711	6.42	15	30.22	158	6.12	23.5	0.43	10.16	0.17	3.95
Madagascar almond (*Terminalia boivinii*)	862	7.51	19.54	16.66	52.8	4.85	15	0.13	0.96	0.05	0.37
Golden rain tree (*Koelreuteria henryi*)	1106	5.03	13.52	11.6	69	3.52	10.4	0.04	1.51	0.02	0.59
Camphor tree (*Cinnamomum camphora*)	726	6.46	14.5	17.85	55.93	4.4	13.7	0.12	1.6	0.05	0.62
Golden shower tree (*Cassia fistula*)	528	7.66	16	18.14	59	5.81	13.5	0.14	1.59	0.05	0.62
Blackboard tree (*Alstonia scholaris*)	370	9.37	18.12	31.25	118	5.24	12.1	0.47	8.92	0.18	3.47
Big-leaf mahogany (*Swietenia macrophylla*)	749	6.17	15	13.75	48.2	2.74	14.3	0.08	0.88	0.03	0.34
Indonesian cinnamon (*Cinnamomum burmannii*)	914	3.98	11.83	9.16	36	2.57	9	0.02	0.48	0.01	0.19
Indian beech (*Pongamia pinnata*)	545	5.09	10.41	13.08	65.44	4.08	10.7	0.04	0.87	0.02	0.34
Bengal almond (*Terminalia catappa*)	341	6.05	10.8	18.25	45.07	5.77	16.2	0.1	0.52	0.04	0.2

Source: Wang et al., (2015)

Role of Trees (Forests) Beyond the Conventional View-Point

Forests provide essential ecosystem services beyond carbon storage and emissions offsetting – such as health (through disease regulation), livelihoods (providing jobs and local employment), water (watershed protection, water flow regulation, rainfall generation), food, nutrient cycling and climate security. Protecting tropical forests therefore not only has a double-cooling effect, but also reduce carbon emissions and maintains high level of evaporation from the canopy (Intergovernmental Panel on Climate Change, IPCC, 2013), forest also plays a vital role in the continued provision of essential life-sustaining services. These services provided by trees (forest) are essential for the well-being of people and the planet, however they remain precious and highly-valued and therefore cannot compete with the more immediate gains delivered from converting forests into commodities (Forest Peoples Programme, 2012; Global Canopy Programme, 2008). Ecosystem services operate from local to global scales and are not confined within national borders; all people are therefore reliant on them and it is in our collective interest to ensure their sustained provisioning into the future.

Data presented in (Table 01) was estimated based on the equation:

$$\text{Csingle\_tree} = V \times BD \times BEF \times (1 + R) \times CF \quad (2)$$

Where,

Csingle_tree = individual tree carbon storage (tons C),

V = individual tree volume (m3), BD = basic wood density

(tons/m3), BEF = biomass expansion factor, R = root:shoot

ratio, and CF = forest carbon fraction, H=height of trees

The results of Wang *et al.,* (2015) reported growth performance and carbon sequestration ability of trees, where the researcher stated golden rain tree (Table 01), with 1,106 individuals (7.93% of the total number of trees) been able to capture and look atmospheric $CO_{2,}$ further proofing that, on a spatial scale various tree species significantly ($p<0.05$) reduced the emission rate of CO_2 in the study area. Report of Wang *et al*.(2015) also presented a view that trees species used in the experiment captured and looked carbon at 0.05 tons carbon and the tree carbon storage of all trees in the sampling plots was 672.20 tons C. Other studies have also proofed that increased in lengthy growing period of trees enhances the carbon sequestration potential of the surrounding atmosphere.

Contribution of Forest Degradation and Deforestation to Global Carbon Emissions

Forest degradation and deforestation of the world's tropical forests are cumulatively responsible for about 10% of net global carbon emissions (Parker *et al*., 2009). Therefore, tackling the destruction of tropical forests is core to any concerted effort to combat climate change (Parker *et al*., 2009). Traditional approaches to halting tropical forest loss have typically been unsuccessful, as can be seen from the fact that deforestation and forest degradation continue unabated, especially in tropical sub-Saharan Africa (Forest Peoples Programme, 2012). To combat this trend REDD (Reducing Emissions from Deforestation and forest Degradation) incentivizes was introduced in systematic management of global forest, especially with regards to a clean mechanism techniques. REDD is a break from historic trends of increasing deforestation rates and greenhouse gases emissions. It is a framework through which developing countries are rewarded financially for any emissions reductions achieved, associated with a decrease in the conversion of forests to alternate land uses (Parker *et al*., 2009). Having identified current and/or projected rates of deforestation and forest degradation, a country taking remedial action to effectively reduce those rates will be financially rewarded relative to the extent of their achieved emissions reductions (Transparency International, 2012). REDD provides a unique opportunity to achieve large-scale emissions reductions at comparatively low abatement costs (Phelps *et al*., 2012). By economically valuing the role forest ecosystems play in carbon capture and storage, it allows intact forests to compete with historically more lucrative, alternate land uses resulting in their destruction (Parker *et al*., 2009).

Human Activities and Greenhouse Gas Emission

The stocks of greenhouse gases in the atmosphere (including carbon dioxide, methane, nitrous oxides and a number of gases that arise from industrial processes) are rising, as a result of human activity. The current level or stock of greenhouse gases in the atmosphere is equivalent to around 430 (ppm) CO_2 (IPCC, 2010), compared with only 280 ppm before the Industrial Revolution (IPCC, 2010). These concentrations have already caused the world to warm by more than half a degree Celsius and will lead to at least a further half degree warming over the next few decades, because of the inertia in the climate system (IPCC, 2010).

Even if the annual flow of emissions did not increase beyond today's rate, the stock of greenhouse gases in the atmosphere would reach double pre-industrial levels by 2050 - that is 550 ppm CO_2 (carbon equivalent-e^-) and would continue growing thereafter (IPCC, 2010; Transparency International, 2012). But the annual flow of emissions is accelerating, as fast-growing economies invest in high-carbon infrastructure and as demand for energy and transport increases around the world. IPCC view presents that: the level of 550ppm CO_2e^- could be reached as early as 2035. At this level there is at least a 77% chance - and perhaps up to a 99% chance, depending on the climate model used - of a global average temperature rise exceeding 2°C (IPCC, 2010).

Climate Change: A Grave Threat to the Developing World

Climate change is a grave threat to the developing world and, a major obstacle to continued poverty reduction across its many dimensions. First, developing regions are at a geographic disadvantage: they are already warmer, on average, than developed regions, and they also suffer from high rainfall variability. As a result, further warming will bring poor countries high costs and few benefits (IPCC, 2010; Ecosystem Marketplace, 2012). Second, developing countries - in particular the poorest - are heavily dependent on agriculture, the most climate-sensitive of all economic sectors, and suffer from inadequate health provision and low-quality public services. Third, their low incomes and vulnerabilities make adaptation to climate change particularly difficult (IPCC, 2010; Ecosystem Marketplace, 2012). Because of these vulnerabilities, climate change is likely to further reduce already existing low incomes and increase illness and death rates in developing countries. Falling farm incomes will increase poverty and reduce the ability of households to invest in a better future, forcing them to use up meagre savings just to survive. At a national level, climate change will cut revenues and raise spending needs, worsening public finances (Ecosystem Marketplace, 2012).

Many developing countries are already struggling to cope with their current climate. Climatic shocks cause setbacks to economic and social development in developing countries. The impacts of unabated climate change, - that is, increases of 3 or 4°C and upwards - will be to increase the risks and costs of these events very powerfully. Impacts on this scale could spill over national borders, exacerbating the damage further. Rising sea levels, and other climate-driven changes could drive millions of people to migrate: more than a fifth of Bangladesh could be under water with a 1m rise in sea levels, which is a possibility by the end of the century (IPCC, 2010). Climate-related shocks have sparked violent conflict in the past, and conflict is a serious risk in areas such as West

Africa, the Nile Basin and Central Asia.

Climate Change Impact at the Higher and Lower Altitude Regions

In higher latitude regions, such as Canada, Russia and Scandinavia, climate change may lead to net benefits for temperature increases of 2 or 3°C, through higher agricultural yields, lower winter mortality, lower heating requirements, and a possible boost to tourism (Ecosystem Marketplace, 2012). But these regions will also experience the most rapid rates of warming, damaging infrastructure, human health, local livelihoods and biodiversity (IPCC, 2017). Developed countries in lower altitudes will be more vulnerable - for example, water availability and crop yields in southern Europe are expected to decline by 20% with a 2°C increase in global temperatures (Ecosystem Marketplace, 2012). Regions where water is already scarce will face serious difficulties and growing costs (Ecosystem Marketplace, 2012; IPCC, 2017).

The increased costs of damage from extreme weather (storms, hurricanes, typhoons, floods, droughts, and heat waves) counteract some early benefits of climate change and will increase rapidly at higher temperatures. Based on simple extrapolations of 1PCC (2017), costs of extreme weather alone could reach 0.5 - 1% of world GDP per annum by the middle of the century, and will keep rising if the world continues to warm (BioCarbon Fund, 2011; Ecosystem Marketplace, 2012; IPCC, 2017).

What we Need to do to cut-down Greenhouse-gas Emissions

- Reducing demand for emissions-intensive goods and services
- Increased efficiency, which can save both money and emissions
- Action on non-energy emissions, such as avoiding deforestation
- Switching to lower-carbon technologies for power, heat and transport

Mitigation/adaptation costs will differ considerably depending on which combination of these methods is used, and in which sector it is applied.

Rates of Tropical Deforestation

According to the FAO (2001), the highest rates of deforestation (in 106 ha/yr during the 1990s) occurred in Brazil (2.317), India (1.897), Indonesia (1.687), Sudan (1.003), Zambia (0.854), Mexico (0.646), the Democratic Republic of the Congo (0.538), and Myanmar (0.576). These rates are higher than the reported net changes (increased) in forest area (FAO, 2001), because the net changes include both losses of natural forests and increases in plantations. For India, the increase in plantations was greater than the loss of natural forests, thus giving a positive net change in total forest area. For the tropics as a whole, however, the annual rate of forest loss (natural forests and plantations combined) was negative (about 0.62% of forest area) (FAO, 2001). Relative rates of loss were lower in tropical Latin America (0.45%/yr) and higher in tropical Asia (0.78%/yr), despite the large increase in plantations there.

The rates of deforestation reported from field studies and surveys (FAO, 1995, 2001) are generally higher than estimates based on remote sensing, but this is not always the case, as this can be observed in the work of Hansen and DeFries (2004) which used satellite data to report rates higher than those reported by FAO (2001) in 5 out of 6 countries, presenting a view that the situation in loss of forest to other land-uses is very high.

Table 02: Annual Carbon losses from gross loss of tropical forest cover and other wooded land for period of 1990–2000 and 2000–2010 (values in 10^6 tC yr^{-1})

	Central & South America	Africa	Southeast Asia	Global
Period 1990–2000				
Our study with Ecozone/IPCC	670.8	236.8	420.5	1328
Our study with Maximum Saatchi	622.6	265.8	349.5	1238
Our study with Average Baccini/Saatchi	443.4	178.7	265.2	887
Our study with Minimum Saatchi	306.5	102.1	237.1	646
FAO (2010)	357.7	264.2	201.7	824
Period 2000–2010				
Our study with Ecozone/IPCC	677.1	200.8	360.7	1239
Our study with Maximum Saatchi	649.7	220.7	367.1	1237
Our study with Average Baccini/Saatchi	464.8	147.7	267.1	880
Our study with Minimum Saatchi	322.6	43.5	235.5	602
FAO (2010)	340.1	241.3	297.7	879
Baccini *et al.* (2012) for period 2000–2005	470	230	110	810
Harris *et al.* (2012a,b) for period 2000–2005	440	110	260	810

Source: FAO (2010); Achard et al., (2004)

Data presented in Table 02 indicated that increased amount of carbon is emitted to the atmosphere, as a result of increased loss of tropical forest. It can also be noted that as the number of years increases, emission of CO_2 also increases, thereby necessitating rapid afforestation programme to safeguard the warming earth.

Carbon Stored in Forests Removals and Changes as a Result of Deforestation

Most of the world's terrestrial carbon is stored in forests. Forests cover about 30% of the land surface and hold almost half of the world's terrestrial carbon (IPCC, 2010; Ecosystem Marketplace, 2012; Forest Peoples Programme, 2012; Global Canopy Programme, 2008). If only vegetation is considered (soils ignored), forests hold about 75% of the living carbon per unit area, forests hold 20 to 50 times more carbon in their vegetation than the ecosystems that generally replaces them (Ecosystem Marketplace, 2012; Forest Peoples Programme, 2012), and this carbon is released to the atmosphere as forests are transformed to other uses.

Table 03 shows the relative losses of carbon that result from using forests. The losses in biomass range from 100% for permanently cleared land to zero % for non-destructive harvest of fruits, nuts, and latex (extractive reserves) (Forest Peoples Programme, 2012). Losses of carbon from soil also occur if soils are cultivated.

Tropical forests account for slightly less than half of the world's forest area (Forest Peoples Programme, 2012), yet they hold about as much carbon in their vegetation and soils as temperate-zone and boreal forests combined. Trees in tropical forests hold, on average, about 50% more carbon per hectare than trees outside the tropics (Forest Peoples Programme, 2012, Biocarbon Fund, 2012). Thus, equivalent rates of deforestation will generally cause more carbon to be released from the tropical forests than from forests outside the tropics. Although the soils in temperate zone and boreal forests generally hold more carbon per unit area than tropical forest soils, only a fraction of this carbon is lost with deforestation and cultivation (Houghton *et al.*, 2001, Biocarbon Fund, 2012).

Table 03: Percent of initial carbon stocks lost to the atmosphere when tropical forests are converted to different kinds of land use.

Land Use	expressed as % of initial carbon stocks	
	Vegetation	Soil
Cultivated land	90-100	25
Pasture	90-100	12
Degraded croplands and pastures	60-90	12-25
Shifting cultivation	60	10
Degraded forests	25-50	<10
Logging	10-50	<10
Plantations*	30-50	<10
Extractive reserves	0	0

* *Plantations may hold as much or more carbon than natural forests, but a managed plantation will hold, on average, 1/3 to 1/2 as much carbon as an undisturbed forest because it is repeatedly harvested.*

Source: Amazon Institute for Environmental Research Publication (2005)

Data presented in Table 03 indicated that conversion of forest land to cultivated land emit huge amount of CO_2 into atmosphere. This calls for the need for afforestation to at least remedy the challenge and act as a sustainability approach. Data from Table 3, also shows that degraded forest land is also a contributory factor to carbon emission, with its soil degradation ability at <10%. For soils, the carbon stock lost are to a depth of 1 m. The loss of carbon may occur within 1 year, with burning, or over 100 years or more, with some wood products (Amazon Institute for Environmental Research Publication (2005).

Table 4 presents the potentials of trees to act as a sink to greenhouse gases. One can quickly observed the huge potential tropical forest holds in carbon capturing as indicated in data presented in Table 2 from the work of Achard *et al.*, (2004).

Table 04: Annual Carbon removals from forest regrowths accumulated over one decade for periods 1990–2000 and 2000–2010 (values in 10^6 tC yr^{-1}).

	Central + South America		Africa		Southeast Asia		Global	
	Estimate	Range	Estimate	Range	Estimate	Range	Estimate	Range
1990–2000								
Our study with Average Baccini/Saatchi	57.7	27.1	30.4	15.1	26.4	11.3	115	54
Our study with Ecozone map	59.2		24.4		19.7		103	
Achard *et al.,* (2004)							35	
Pan *et al.,* (2011)	807	403	242	121	526	263	1575	496
2000–2010								
Our study with Average Baccini/Saatchi	62.4	29.5	6.8	3.5	27.5	11.0	97	44
Our study with Ecozone map	63.4		5.1		20.7		89	
Pan *et al.,* (2011)	858	429	271	135	593	297	1722	539
Baccini *et al.,* (2012) for period 2000–2005							710	

Source: Achard et al., (2004)

Current Carbon Emissions Status to the Atmosphere from Tropical Deforestation

There is considerable evidence that carbon emissions from deforestation underestimate total emissions. That is, the carbon stocks in many forests are decreasing without a change in forest area. Examples include losses of biomass associated with selective wood harvest, forest fragmentation, ground fires, shifting cultivation, browsing, and grazing (Barlow *et al.*, 2003; Laurance *et al.*, 1998, 2000; Nepstad *et al.*, 1999), and accumulations of biomass in growing and recovering (or secondary) forests are slow.

Estimates of carbon emissions from the degradation of forests (expressed as a percentage of the emissions from deforestation) range from 5% for the world's humid tropics (Achard *et al.*, 2004) to 25-42% for tropical Asia (Flint and Richards, 1994; Houghton and Hackler, 1999; Iverson *et al.*, 1994) to 132% for tropical Africa (Gaston *et al.*, 1998). In this latter estimate, the loss of carbon from forest degradation was larger than from deforestation. The fraction of total emissions attributable to deforestation, as opposed to degradation (reduction of biomass) within forests, varies by region and is not well documented.

Despite the large variability, the range of estimates of current emissions of carbon from tropical deforestation and degradation is nearly identical to the range obtained from an independent method based on temporal and spatial variations in atmospheric concentrations of CO_2 and models of atmospheric transport (Gurney *et al.*, 2002).

Past Emissions of Tropical Carbon Changes in Land Use

The long-term tropical flux represents about 60% of the global net flux of 155 PgC over a wide period, before ~1940 (Archard *et al.*, 2004; DeFries *et al.*, 2002). Emissions of carbon from outside the tropics were higher than emissions from the tropics. The current emissions estimated by Archard *et al.,* (2004) and DeFries *et al.,* (2002) can be observed in Fig. 2, which shows an ever increasing trend in carbon emission. It is very unlikely that emissions of carbon from tropical deforestation were ever greater in the past than they are at present.

The total net flux of carbon from changes in land can be compared to use approximately half of the carbon emitted from combustion of fossil fuels over a certain period. However, before the first part of the twentieth century, the annual net flux of carbon from land-use change was greater than annual emissions from fossil fuels (Archard *et al.*, 2004 and DeFries *et al.*, 2002).

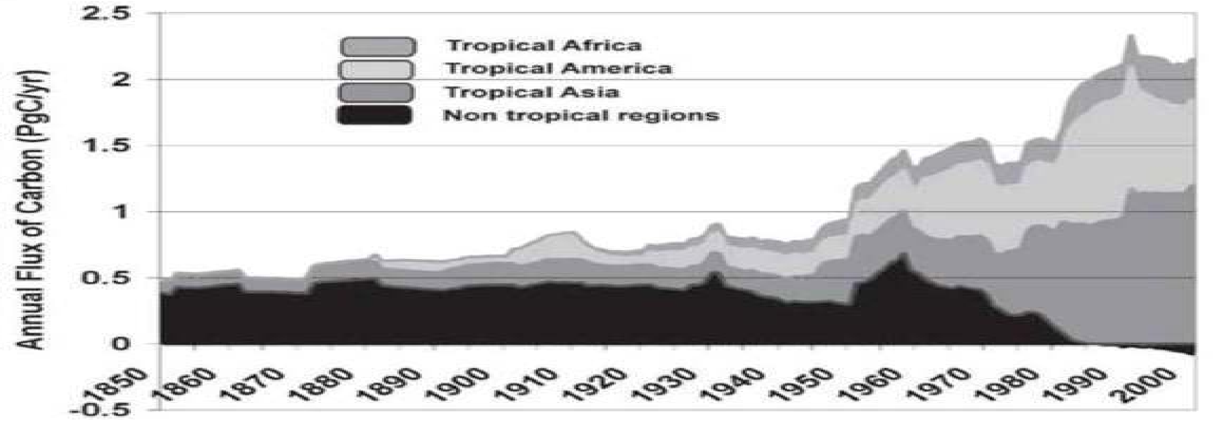

Figure 02: **Annual emission of carbon from changes in land use over the period 1850 t0 200. Essentially all of the emissions were from tropical countries in the 1990s, nearly half from tropical Asia**

Source: Amazon Institute for Environmental Research Publication : Tropical Deforestation and Climate Change (2005)

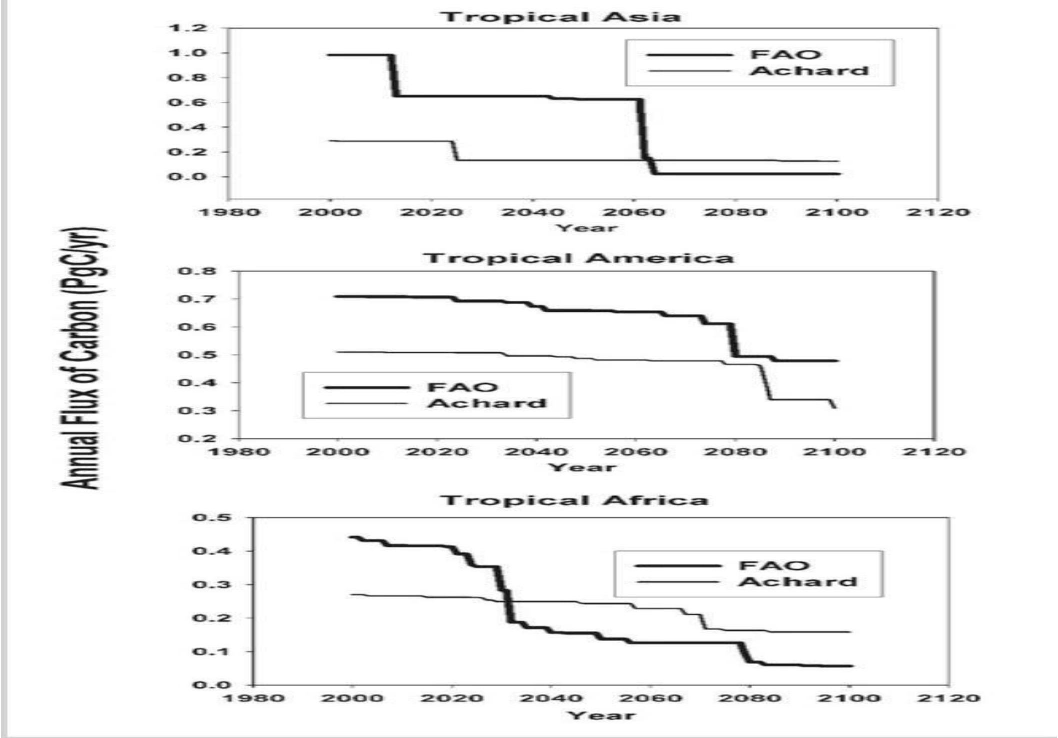

Figure 03: **Annual emissions of carbon from tropical deforestation assuming that rates of deforestation for the 1990s continue in the future. Abrupt reductions in emissions occur as a country's forest area reaches 15% of its area in 2000. The largest declines, under the projection based on FAO data, result from the near elimination of forests in (Asia) Myanmar, Indonesia, and Malaysia; (America) Peru; and (Africa) Benin, Ivory Coast, Nigeria, and Zambia.**

Source: Amazon Institute for Environmental Research Publication : Tropical Deforestation and Climate Change (2005).

Majority of the emission of carbon from changes in land use in tropical regions was huge between the year 1850 to 2000, presenting a view that tropical deforestation has a negative impact on world climate, as shown in (Figure 2) the figure presented also shows that tropical Africa deforestation has been high followed by America and Asia. It must be kept in mind that these regions hold more to global climatic sustainability.

Temporary Certified Emission Reduction (tCER) Versus Long-Term Certified Emission Reduction (lCER) Approach Associated with CDM

Carbon credits earned from sink activities (sequestration credits) under the CDM are based on the quantity of carbon removed from the atmosphere and the period of time during which the carbon remains removed from the atmosphere. Thus, these credits would ideally be quantified not in tonnes but in tonneyears (UNFCCC, 2013). However, the CDM rules provide for a simplified accounting approach instead of the exact tonneyear approach. Since carbon stocks in a forest plantation change over time, these credits when expressed in terms of tonnes can be either timesliced (tCERs, measured as different tonnage valid through fixed timechunks) or tonnesliced (lCERs, measured as fixed tonnage spanning across different periods). Thus, a tCERs is equal to the net anthropogenic GHG removals by sinks achieved by a project activity since the start of the project. An lCERs is equal to the net anthropogenic GHG removals by sinks achieved by the project activity since the previous certification of the project (UNFCC, 2013). Mathematically, the two approaches correspond to computing the same quantity of the area under the curve: $y = f(x)$ which can be expressed either as

$$A = \int y\, dx$$

or

$$\text{as } A = \int x\, dy$$

The accounting rules presented by UNFCCC (2013) state expiration period, and residual liability for maintenance of carbon stocks as been different for tCERs and lCERs. While tCERs expire at the end of the Kyoto Protocol commitment period subsequent to the commitment period for which of these are issued, lCERs expire at the end of the crediting period of the project activity. Both tCERs and lCERs carry their expiry date as an additional element in their serial number, and thus both are autoexpiring credits. However, the lCERs expire after much longer period of time than the tCERs, and therefore the lCERs carry a residual liability for periodic reverification of the continued presence of the carbon stocks in the project area for which these were issued. In absence of the periodic reverification, the lCERs have to be 'reversed' (i.e. cancelled). When tCERs and lCERs are used by an Annex I Party (The parties that financially support carbon sequestration) for the purpose of meeting compliance of its commitment under the Kyoto Protocol.

Methodological Tool for Carbon Auditing in CDM

Estimation of Emissions of Greenhouse Gases Methodology makes use of universal equation laid-down by UNFCCC and IPCC (2000) for Monitoring Carbon in CDM Afforestation/Reforestation in-other to mitigate greenhouse effect:

i.) Emission of non-CO_2 GHGs resulting from burning of biomass and forest fires within the project boundary in year t is estimated as follows:

$$GHG_{E,t} = GHG_{SPF,t} + GHG_{FMF,t} + GHG_{FF,t} \text{ ..Eqn. 1}$$

Where:

$GHG_{E,t}$ = Emission of non-CO_2 GHGs resulting from burning of biomass and forest fire with the project boundary in year *t*, t CO_2-e

$GHG_{SPF,t}$ = Emission of non-CO_2 GHGs resulting in site preparation in in year *t*, t CO_2-e

$GHG_{FMF,t}$ = Emission of non-CO_2 GHGs resulting from use of fire from use of fire to clear the land of harvest residue prior to replanting of the land or other forest management, in year *t*, t CO_2-e

$GHG_{FF,t}$ = Emission of non-CO_2 GHGs resulting from fire in year *t*, t CO_2-e

t = 1, 2, 3,……years counted from the start of the A/R CDM project activity

ii.) *Emission of CO_2 GHGs resulting from burning of fossil fuel and biomass in year t is estimated as following the equation by IPCC (2000) with Amendment by* UNFCCC (2003):

$$.001 \times \sum_{i=1}^{m} \text{ABURN,i,t} \times {}^{B}\mathit{TREE,i,ti} \times \mathit{COMFi} \times EF_{CH4j} \times GWP_{CH4} + EF_{N2O,I} \times GWP_{N2O} \text{.......... Eqn. 2}$$

Where; = $\sum_{i=1}^{m}$ ABURN,i,t Sum of $A_{BURN,}$ and mean biomass of ${}^{B}{}_{TREE}$

COMF = Combustion and emission factors

GWP = Global Warming potential

EF = Emission factor

i = Number of years

.001 = Constant

CONCLUSIONS

From the various data adopted and used in this paper, it could be concluded that various tree species significantly increase CO_2 sequestration and in-turn act as a mitigation strategy towards greenhouse gas sinks. Outcome of the study presents that: deforestation releases carbon, principally as CO_2, to the atmosphere. The finding further confirms that when the organic carbon stored in trees and soil is oxidized through burning and decay they also release carbon as CO_2 into the atmosphere. Other greenhouse gases, such as: CH_4 and N_2O, have been confirmed/amplify to be emitted as a result of the conversion of forests to agricultural lands, among other land uses. Emissions of greenhouse gases from deforestation have been shown to be huge, contributing to the enhanced greenhouse gas effect experience in form the of global warming.

Literature review outcome from this finding also presents a view that greenhouse gases are from anthropogenic and natural sources. The work x-rayed and confirms that at constant deforestation, especially tropical deforestation more greenhouses gases especially carbon in the form of CO_2 is liable to be released at a large quantity into the atmosphere thereby increasing global temperature. The work also presents an outcome that carbon auditing in the various carbon pools is possible using the tool as prescribed by UNFCCC.

REFERENCES

Achard F., H. D. Eva, P. Mayaux, H. J. Stibig, and A. Belward. (2004). Improved estimates of net carbon emissions from land cover change in the tropics for the 1990s. Global Biogeochemical Cycles 18: GB2008, doi:10.1029/2003GB002142.

Amazon Institute of Environmental Research. (2005). Tropical Deforestation and Climate Change. Edited by Paulo Moutinho and Stephen Schwartzman. http://www.edf.org/sites/default/files/4930_TropicalDeforestation_and_ClimateChange.pdf. Retrieved 30/9/2018.

Barlow, J., C. A. Peres, B. O. Lagan, and T. Haugaasen. (2003). Large tree mortality and the decline of forest biomass following Amazonian wildfires. Ecology Letters 6:6-8.

Biocarbon Fund. (2011). BioCarbon Fund Experience: Insights from Afforestation and Reforestation Clean Development Mechanism Projects: Summary. http://www.biocarbonfund . [Accessed August, 2019]

Christensen J H, Hewitson B, Busuioc A, Chen A, Gao X, Held I, Jones R, Kolli R K, Kwon W-T, Laprise R, Magaña Rueda V, Mearns L, Menéndez C G, Räisänen J, Rinke A, Sarr A and Whetton P. (2007). Regional Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt K B, Tignor M and Miller H L (eds)]. Cambridge University Press. Cambridge, United Kingdom and New York, NY, USA.

DeFries R. S., R. A. Houghton, M. C. Hansen, C. B. Field, D. Skole, and J.Townshend. (2002). Carbon emissions from tropical deforestation and regrowth based on satellite observations for the 1980s and 90s. Proceedings of the National Academy of Sciences 99:14256-14261.

Ecosystem Marketplace. (2012). State of the Forest Carbon Markets 2012: Leveraging the Landscape. http://www.ecosystemmarketplace. [Accessed August, 2019]

FAO - Food and Agriculture Organization. (2001). Global Forest Resources Assessment 2000. Main Report. FAO Forestry Paper No. 140, FAO, Rome, Italy.

FAO. (2010). Global Forest Resources Assessment. Main report. http://www.fao.org/docrep/013/i1757e/i1757e.pdf. Retrieved 30/9/2018.

Flint, E. P., and J. F. Richards. (1994). Trends in carbon content of vegetation in south and southeast Asia associated with changes in land use. Page 201-299 *in* V. H. Dale, editor. Effects of land use change on atmospheric CO_2 concentrations: South and Southeast Asia as a case study. Springer-Verlag, New York, USA.

Forest Peoples Programme. (2012). Forest peoples. Numbers across the world. http://www.forestpeoples.org/sites/fpp/files/publication/2012/05/forest-peoples-numbers-across-world-final_0.pdf . Retrieved 30/9/2018.

Gaston, G., S. Brown, M. Lorenzini, and K. D. Singh. (1998). State and change in carbon pools in the forests of tropical Africa. *Global Change Biology 4*.

Global Canopy Programme. (2008). Forests now in the fight against climate change. Forest Foresight Report 1.v4. http://www.globalcanopyprogramme . Retrieved 31/9/2018.

Gurney K. R., R. M. Law, A. S. Denning (2002). Towards robust regional estimates of CO_2 sources and sinks using atmospheric transport models. Nature 415:626-630.

Houghton, R. A., and J. L. Hackler. (1999). Emissions of carbon from forestry and land-use change in tropical Asia. Global Change Biology 5:481. https://doi.org/10.1046/j.1365-2486.1999.00244.x

IPCC (2013) Intergovernmental Panel on Climate Change. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. https://doi.org/10.1017/cbo9781107415324.023

IPCC, (2000). Intergovernmental Panel on Climate Change. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. https://doi.org/10.1017/cbo9781107415324.023

IPCC, (2017). Intergovernmental Panel on Climate Change. www.ipccglobalannualreport. Retrieved 31/6/2019.

IPCC (2007). https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg3_full_report-1.pdf Retrieved 29/6/2019

IPCC. (2010). Climate change 2001: the scientific basis. Contribution of working group I to the third assessment report of the Intergovernmental Panel on Climate Change. *In* J. T. Houghton, , Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. A. Johnson, editors. Cambridge University Press, Cambridge, United Kingdom and New York, New York, USA. https://doi.org/10.1002/qj.200212858119

Iverson, L. R., S. Brown, A. Prasad, H. Mitasova, A. J. R. Gillespie, and E. E. Lugo. (1994). Use of GIS for estimating potential and actual forest biomass for continental South and Southeast Asia. Pages 67-116 *in* V. H. Dale, editor. Effects of land use change on atmospheric CO_2 concentrations: South and Southeast Asia as a case study. Springer-Verlag, New York, USA. https://doi.org/10.1007/978-1-4613-8363-5_3

Laurance W. F., P. Delamônica, S. G. Laurance, H. L. Vasconcelos, and T. E. Lovejoy. (2000). Rainforest fragmentation kills big trees. Nature 404: 836. https://doi.org/10.1038/35009032

Laurance W. F., S. G. Laurance, and P. Delamônica. (1998). Tropical forest fragmentation and greenhouse gas emissions. Forest Ecology and Management 110:173-180. https://doi.org/10.1016/s0378-1127

Manning M, Nobrew C 2001. Technical Summary Impact,Adaption and Vulnerability: A Report of WorkingGroup II of the Intergovernmental Panel on ClimateChange. In: J McCarthy, OF Canziani, NA Leavy, JD Dekken, C White (Eds.): Climate Change 2001:Impact, Adaption and Vulnerability. Cambridge:Cambridge University Press, pp. 44-65.

Nepstad D. C., A. Veríssimo, A. Alencar, C. Nobre, E. Lima, P. Lefebvre, P. Schlesinger, C. Potter, P. Moutinho, E. Mendoza, M. Cochrane, and V. Brooks. (1999). Large-scale impoverishment of Amazonian forests by logging and fire. Nature 398:505-508. https://doi.org/10.1038/19066

Parker, C., Mitchell, A., Trivedi, M., Mardas, N., and Sosis, K. (2009). The Little REDD+ Book. Global Canopy Programme, Oxford

Phelps, J., D. A. Fries, and E. L. Webb. (2012). Win-win REDD+ approaches belie carbon-biodiversity trade-offs. *Biological Conservation* 154: 53-60. https://doi.org/10.1016/j.biocon.2011.12.031

Transparency International. (2012). Keeping REDD+ clean. A step-by-step guide to preventing corruption. Transparency International, Berlin, Germany

UNFCCC (2013). United Nations Framework for Climate Change, Annul Report. http://www.unfcccreport2013 . [Accessed August, 2018]

UNFCCC (2000).Carbon dioxide control, Annul Report. http://www.unfcccreport2016. [Retrieved 30/6/2019]

United States Environmental Protection Agency. (2012). Greenhouse gas emissions. https://www.epa.gov/sites/production/files/signpost/cc.html. Retrieved 30/9/2018.

Pan, A., Richard A. Birdsey, Jingyun Fang, Richard Houghton, Pekka E. Kauppi, Werner A. Kurz, Oliver L. Phillips, Anatoly Shvidenko, Simon L. Lewis, Josep G. Canadell, Philippe Ciais, Robert B. Jackson, Stephen W. Pacala, A. David McGuire, Shilong Piao, Aapo Rautiainen, Stephen Sitch[7]Daniel Hayes (2011). A Large and Persistent Carbon Sink in the World's Forests *Science* 19 Aug 2011: Vol. 333, Issue 6045, pp. 988-993 DOI: 10.1126/science.1201609

Seager, R., Ting, M., Isaac H., Kushnir, Y., Lu, J., Vecchi, G., Huei-Ping H., Harnik, N., Leetmaa, A.,Ngar-Cheung L., Cuihua L., Jennifer V., Naomi N. (2007). Model Projections of an Imminent Transition to a More Arid Climate in Southwestern North America. *American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005. https://doi.org/10.1126/science.1139601*

Wang, X. L., Y. Feng, and V. R. Swail(2015), Climate change signal anduncertainty in CMIP5-basedprojections of global ocean surfacewave heights,J. Geophys. Res. Oceans,120, 3859–3871, doi:10.1002/2015JC010699