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   REVIEW OF LITERATURE

   NEED/IMPORTANCE OF THE STUDY

   STATEMENT OF THE PROBLEM

   OBJECTIVES

   HYPOTHESES

   RESEARCH METHODOLOGY

   RESULTS & DISCUSSION

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   RECOMMENDATIONS/SUGGESTIONS

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   ACKNOWLEDGMENTS

   REFERENCES

   APPENDIX/ANNEXURE

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ASSESSING THE IMPACT OF POPULATION EXPLOSION ON GLOBAL ENVIRONMENT

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ABSTRACT

Historically, the world population used to grow very slowly from about 2.5 million at the beginning of urbanization and it grew to some 50 million around the time of the black plague of the middle ages. It is only with the industrial, scientific and medical revolution and during the era of colonial expansion of the western powers that the number of the population risen as unmanageable thereby climbing to the dizzying heights. During the 20th century, the world's population increased almost fourfold, from 1.6 to 6 billion. Until very recently, there were fears that in the next century, if the explosion is not checked by wise leaders of the world, the world population would explode to some 12 billion leaving little room for wilderness areas to preserve wildlife and putting extreme pressure on food production, water and non-renewable resources. The increase of population increases the demand for more food, cars and energy. To satisfy their food requirement, they will have to clear forests in order to grow crops for food. Deforestation may result in destruction of homes of the most diverse wild-animals and plants again resulting in the extinction of many species, possibly including hundreds that are yet unidentified by scientists. It also adds to the problem of global warming, because trees naturally absorb carbon dioxide from the atmosphere. When there are trees, they take in carbon dioxide from the air and turn it into oxygen and release it back into the air again. When the trees are cut down, the carbon dioxide is released back into the air and helps trap heat near the earth and raises the temperature which may contribute in global warming. Therefore, the explosion of population should be checked in such a way the resources on the earth may be used sufficiently and economically preserving some non-renewable resource even for the future use.

KEYWORDS
Carbon dioxide, deforestation, global warming, non-renewable resources, population explosion, wild animals and plants.

INTRODUCTION
In these days, the number of world population is enormously increasing more than ever before. Most of poor countries overpopulated in such a way there could arise striking food shortage. Overpopulation is defined as the condition of having more people than can live on the earth in comfort, happiness and health and still leave the world a fit place for future generations. A population explosion occurs when there is a significant increase in numbers of people in a location in such a way it is difficult to supply necessary resources to maintain and sustain the existence of life of all living things including human being. Some effects include a pressure upon resources as there are more people (e.g. Food has to be distributed among more people), prices of goods will increase as the demand for the products increase (higher demand means higher prices, ecological disturbance will take place when more people go for more use of resources. According to some scientists, the greatest threat to the future may come from overpopulation.

During this century, the world's population has grown rapidly, doubling from 2 to 4 billion between 1925 and 1976, and reaching 5.3 billion by 1990 (Paul, 1993, p.22). Much of this growth occurred after World War II.

Some of the possible reasons for rapid growth of population after 1945 were peace, using fertilizers for mechanization farming, urbanization, industrialization, more income generation and medical facilities. In the 1950s and '60s, authors and policy makers who worried about rapid population growth noted that improved sanitation and health care in the postwar period helped more children survive infancy and enabled adults to live longer. It was common in nineteenth-century Europe for one-quarter of all infants to die before the age of 2.5 years, and one-half of adults by age 37.5. But a century later, one-fourth had not died until age 62.5, and one-half had not died until age 72.5(Hauser, 1971, p. 107). Consequently, the rapid growth of the world's population over the past hundred years is believed as resulted from a difference between the rate of birth and the rate of death. As it may be known by all of us, in the past, infant and childhood deaths and short life spans used to limit population growth. In today's world, thanks to improved nutrition, sanitation and medical care, more babies survive their first few years of life. The combination of a continuing high birth rate and associated low death rate is creating a rapid population increase in many countries such as Asia, Latin America and Africa. The rapid explosion of human population around the world affects all people through its impacts on the economy and environment. The current growth rate of population is now a significant burden to human well-being.

Improved sanitation and health care in the postwar period helped more children survive infancy and enabled adults to live longer and fueled the explosion of population after the World War II. For instance, while the world's population increased annually by 20 million people during the 1940s, it increased by more than 50 million every year in the 1950s, 65 million a year in the 1960s (My T., 1975). In 1966, the United Nations estimated that world population would reach 7.5 billion by the end of the century (Philip M., 1971). These projections persuaded government officials around the world that rapid population growth was a serious problem and that steps should be taken to slow it down. In 1969, President Nixon announced that the U.S. government would "give population control and family planning a high priority," and called on other governments to take "prompt action" to slow population growth (Bonnie). And in 1974, the United Nations convened its first world population conference in Bucharest, Romania. At the time, government officials expected that population growth would lead to a series of problems: food shortages and hunger, conflict and war, environmental destruction, and the depletion of natural resources. Events in the mid-1970s initially seemed to confirm their worst fears.

Widespread public recognition of population growth as a global social problem emerged slowly in the 1950s and '60s. It was assisted by the publication of two books with the same title: *The Population Bomb*. In 1954, T. O. Greissimer published a pamphlet with this title that was widely distributed by the Hugh Moore Fund, a private foundation started by the Dixie Cup Corporation. In it, Greissimer argued that "the population bomb threatens to create an explosion as disruptive and dangerous as an explosion of the atom bomb, and with as much influence on prospects for progress or disaster, war or peace (Ibid, p.40). Then in 1968, Paul Ehrlich published a book with the same title that borrowed some of Greissimer's ideas and extended them to explore the environmental consequences of population growth. These two books, and the work of private philanthropical groups like the Hugh Moore Fund, and the Population Council, a group organized in 1952 by John D. Rockefeller III, helped bring rapid population growth to the attention of policy makers and the public (Ibid, p.37).

The availability of sufficient food and sanitation facilities lowered death rates in countries around the world. As a result, people continued to have children at pre-1950 rates. Because people adjusted their behavior slowly to changed circumstances, healthier babies and longer lives contributed to world population grew rapidly. Policy makers concerned about population growth worried that it would result in a series of social, political, and environmental problems. First, they thought that the growing population had or would soon outstrip the amount of food available to eat, resulting in a Malthusian crisis: *too many people, too little food*. "The battle to feed all of humanity is over," Ehrlich argued. "Sometime around 1958, the stork passed the plow." He expected this to lead to widespread hunger and starvation. "In the 1970s," Ehrlich predicted in 1968, "the world will undergo famines hundreds of millions of people are going to starve to death. . ." Ehrlich and others who supported this view were often called "Malthusians" because this argument relies on Robert Malthus's 1798 *Essay on Population*, which proposed that "the power of population is indefinitely greater than the power in the earth to produce subsistence [food] for man."

The growing gap between population and food supply would lead first to starvation, population control advocates expected. And the onset of starvation would lead to a second problem: war. As one population control group explained in a 1967 newspaper ad, "There can be no doubt that unless population is brought under control at an early date, the resulting human misery and social tensions will inevitably lead to chaos and strife to revolutions and wars, the dimensions of which it would be hard to predict." During the 1960s, many U.S. government officials viewed social unrest, communist insurgency, and guerrilla warfare in poor countries as the likely political product of "overpopulation."

Third, the new Malthusians argued that a growing population would increase levels of pollution and waste, which would result in environmental degradation. As Ehrlich wrote, "The causal chain of [environmental] deterioration is easily followed to its source. Too many cars, too many factories, too much detergent, too much pesticide . . . inadequate sewage treatment plants, too little water, too much carbon dioxide all can be easily traced to *too many people*." But in 1990 he still maintained that "Global warming, acid rain, depletion of the ozone layer, and exhaustion of soils and ground water are all related to population size."

And fourth, the new Malthusians believed that the growing population would consume finite natural resources such as minerals and oil at an accelerated rate, resulting in raw material shortages and rising prices for the goods produced by industrial societies. As the Club of Earth argued in 1988, "Overpopulation and rapid population growth are intimately connected with . . . [the] rapid depletion of non-renewable resources. . . ." Because they expected rapid population growth to lead to starvation, war, environmental degradation, and the depletion of natural resources, private groups and government officials began advocating population control in the late 1960s and early 1970s. And they urged governments to adopt programs that would slow population growth. These included the creation of educational family planning programs, the distribution of contraceptives, and sometimes the provision of clinics that performed abortions and sterilizations, usually on a voluntary but sometimes on an involuntary basis. Population control advocates in government and the private sector believed that rapid population growth was such an urgent problem that drastic steps needed to be taken quickly. Some even advanced the concept of triage as a way to address the problem.

STATEMENT OF THE PROBLEM

Now-a-days, the number of world population is increasing at an alarming and astonishing rate. According to some scientists, the greatest threat to the future may come from overpopulation. Overpopulation and rapid population growth are intimately connected with the rapid depletion of non-renewable resources. Some effects include a pressure upon resources as there are more people (e.g. Food has to be distributed among more people), prices of goods will increase as the demand for the products increase (higher demand means higher prices, ecological disturbance will take place when more people go for more use of resources. To mitigate food shortage, the simplest solution is to increase the area of cultivation land and plant it with the food crops. To this effect, they cleared forests and planted food crops. When forests are cut down, they released carbon dioxide gases into the air which highly contributed for global warming. In 1974, scientists discovered that man-made gases called chlorofluorocarbons (CFCs) that were used in aerosol sprays, solvents, and Styrofoam destroyed the ozone layer, which protects people and plants from the sun's damaging rays. They also observed that the increase of populations contributed to most of the atmospheric pollution resulting from CFC use. The same is true of global warming. During the mid-1980s, scientists discovered that the burning of fossil fuels and forests had increased the level of carbon dioxide in the atmosphere. They predicted that high carbon dioxide levels would trap heat in the atmosphere and make the planet warmer. Rapidly rising temperatures could create serious problems for people in different settings, scientists argue. Rising temperatures could melt polar ice and raise sea levels, inundating islands and low-lying coastal plains where millions live. A one-meter rise would flood deltas on the Nile, Po, Ganges, Mekong, and Mississippi Rivers, displacing millions of people and swamping the croplands now used to feed them. Higher sea levels could drown coral reefs, destroying the fish and ruining the livelihood of people who depend on reefs in the Caribbean and the Pacific. And warmer water could increase the strength of hurricanes and typhoons, causing greater damage for people living along their path in the Western Atlantic and Western Pacific. The insurance industry is particularly concerned about this prospect because windstorms caused $46 billion in losses between 1987 and 1993.

Higher temperatures could also disrupt agriculture. While farmers in northern latitudes North America and northern Europe and Asia could benefit from higher temperatures, longer growing seasons, and higher levels of carbon dioxide (which plants use to grow), even modest increases could devastate farmers in tropical zones in Asia, Africa, and Latin America. Rice yields decline significantly if daytime temperatures exceed 95 degrees, and in many Asian countries, temperatures are already near this limit. One group of scientists predicted that cereal prices could increase between 25 and 150 percent by the year 2060, a development that would cause hunger and starvation for between 60 million and 350 million poor people, most of them in the tropics.

Because of increased number of people, they are highly involving in deforestation. They are using more cars in number. They are using more energy for cooking and heating. There are, for example, sound environmental and social reasons to reduce energy consumption and car use and slow deforestation. Because these activities also release vast quantities of carbon dioxide, efforts to curb the consumption of fossil fuels and wood might also reduce global warming. (The carbon dioxide released by these activities accounts for about half of all greenhouse gases.) The same is true for other activities that produce other greenhouse gases.

People are attempting to satisfy their food demand from different sources. To this effect they increased the number of cows to get meat, milk and milk byproducts. However, the increased number of cows contributed for deforestation and resulted in hunger on the part of human being because of global climate change effect. A reduction of world cow herds would reduce hunger and deforestation, and also curb emissions of methane, which makes up about 18 percent of all greenhouse gases. The ban on CFCs, scheduled to take effect at the turn of the century, will slow destruction of the ozone layer, about which there is no serious scientific dispute, and reduce its contribution (about 14 percent) to global climate change. And if nitrogen fertilizer use was curbed, the problems associated with groundwater pollution could be addressed and nitrous oxide levels in the atmosphere (about 6 percent of the total) could be reduced. However, in the case of nitrous oxide, fertilizer reductions could adversely affect global food supplies and contribute to hunger, which suggests that efforts to curb fertilizer use should be approached with great caution.

Because of explosion of population, the people around the world are using more energy from different sources like fire, petroleum or fuel. For example, to get energy from fire they have to cut down forests for firewood. These would result in releasing more carbon dioxide into the air which may be thought as a major source for global warming. When they want to get energy from fuel, they have to buy the petroleum from the countries endowed with it. This, in turn, hurts the economy of the countries buying fuel from fuel rich countries.

These and others related problems pushed the researcher to investigate the case based on Descriptive Research with the help of secondary date from published texts on globalization in order to arrive at possible solutions as the findings of the study.

OBJECTIVE OF THE STUDY

The general objective of this study is to communicate the effects of problems of population explosion to the people of the world to generate awareness about the problems associated with the alarming increase of population and push everybody to contribute and heed towards slowing down the number of population all over the world at the earliest.

SPECIFIC OBJECTIVES

- To show the impact of population explosion to the people of world
- To make the world leaders heed and take corrective actions towards the explosion of population.
- To generate awareness of the danger of population explosion to householders and make them limit the number of their children thoroughly understanding the impact of the problem and the devastation it causes if not mitigated.

RESEARCH QUESTIONS

- Is population explosion mercy or curse to our planet at present? How?
- If it is curse, then how it can be checked?
- Who is more responsible for global warming, the advanced or underdeveloped countries? Why?

SIGNIFICANCE OF THE STUDY

The number of world population is increasing at an alarming rate. If it continues at the same rate, it is becoming a real danger, worry and curse to the earth. As it is obvious to many of us, we are increasing the number of our children sometimes not knowing the consequences of it. Other times, we are increasing the number of them simply being shy of cultural products like children are wealth gifted from God and people should not involve themselves in checking of such blessings and they should bear as many children as possible. The importance of this study is to generate the awareness of the danger of population explosion and make every concerned body understand the problem and make the decision on the number of his/her children in such a way that the planet (earth) could provide them all necessary facilities of life. Because the increase of population if not supported by economicy it is curse rather than mercy. It becomes mercy only when it is managed appropriately and commensurately with the available resources on the earth.

METHODOLOGY OF THE STUDY

The present study is based on Descriptive Research with the investigation of secondary data. The secondary data are collected from the published sources on globalization.

SCOPE OF THE STUDY

The study is entirely focused on consequences of the explosion of population based on Descriptive research with the assistance of secondary data from the texts written on globalization. The study is about the impact of explosion of population on environment all over the world.

FINDINGS OF THE STUDY

1. Overpopulation is resulting in a striking food shortage because more farm land is being used for urbanization and industrialization in larger quantity in order to accommodate the exploding large number of population. Thus, the greatest threat to the future may come from overpopulation (*too many people, too little food*).
2. Much of the growth of population occurred after World War II due to peace, using fertilizers for mechanization farming, urbanization, industrialization, more income generation and medical facilities (improved sanitation and health care).
3. To maintain the life of people on the earth, the scientists and other concerned bodies should focus on innovations and increase productivity in many folds from the available smaller farm land employing advanced technologies as to feed more people.
4. A growing population would increase the levels of pollution and waste, which would result in environmental degradation. Too many cars, too many factories, too much detergent, too much pesticide, inadequate sewage treatment plants, too little water, too much carbon dioxide all can be easily traced to *too many people*.
5. The growing population would consume finite natural resources such as minerals and oil at an accelerated rate, resulting in raw material shortages and rising prices for the goods produced by industrial societies. Moreover, unbalanced utilization of resources may ultimately lead to the depletion of natural resources.
6. The number of population, thus, should be checked as increasing of population is believed as to leading to the destruction of population thereby creating acute shortage of resources necessary for existence of life.
7. To minimize global warming, every person in the world has to plant one seedling every year personally initiating the Motto “one seedling for one person”. Then, the plants absorb the carbon dioxide thereby releasing oxygen and global warming can be checked.
8. Rich countries are more disturbing the environment though industrialization and deforestation. They have to fund the projects of poor countries in order to plant trees to maintain the environmental balance.

CONCLUSION

Now-a-days, the number of world population is significantly increasing. The increase of population has been followed by food shortage. To produce more food crops, they involved themselves in deforestation and planting more food crops. To that effect, they cleared or cut-down more trees from the forest. The cut-down of trees contributed to releasing more carbon-dioxide into the air. That, in turn, contributed to global warming. To curb these all problems resulting from the expansion of population, it should be checked as more increase may mean danger to population itself. Finally, for what is happening all over the world, the advanced countries should take more responsibility as they are more disturbing environment in which human being can live through industrialization and technological advancement.

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ADAPTATION TO CLIMATE CHANGE THROUGH FOREST CARBON SEQUESTRATION IN TAMILNADU, INDIA

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ABSTRACT

In India 21.02 percent of the geographical area is covered by forest land and the National Forest Policy of India treats forests as an environmental and social resource. Moreover India has a target of bringing one-third of its land cover under forest cover by launching the Greening India Mission programme. Adaptation is needed to cope with climate change and to protect the most vulnerable systems and society. Using forests and trees as part of a strategy to cope with impacts of climate change, forests become part of a climate strategy for adaptation. This paper presents an assessment of carbon sequestration potential of the existing forests of India and Tamilnadu, a state of India, and afforestation programmes of Tamilnadu for carbon sequestration, as a tool of adaptation to climate change. Estimates of carbon in above-ground biomass made with the annual rate of biomass increment given by Forest Survey of India and the results show that 116 million tones of CO_2 sequestrated by Indian forests per year and it is 5.4 million tonnes for the forests of Tamilnadu. Afforestation also contributes significantly as an option to adapt climate change as per the estimates made in this paper. The assessment made in this paper does not include the forest disturbances in estimating the carbon sequestration.

KEYWORDS

Carbon sequestration, adaptation, biomass growth, afforestation and climate change.

INTRODUCTION

Climate Change is the term which is pronounced often in the present era, as a global environmental problem. A notable rise in the level of Green House Gases (GHGs – Carbon dioxide, Methane and Nitrous Oxide) results variations in the global surface temperature which causes heat waves, cyclones, floods, salinisation of coastal line, irregular monsoon, adverse effect on agriculture, desertification, water scarcity and health problems to the living organisms. Carbon in the form of carbon dioxide (CO_2) forms the core in the GHG emissions because all organic materials contain carbon. These GHG emissions were justified on the ground of industrial development which creates employment generation, economic growth and improve the standard of living of people. Rapid industrialization has not only increased the concentration of GHGs in the atmosphere, it has also reduced the planet's capacity to absorb GHGs by land-use changes including deforestation (Government of Tamilnadu Demand Note 15, 2010).

All organic materials contain carbon, whether it is a smallest vitamin molecule or long polymer chains of proteins and DNA. Carbon in the form of CO_2 released as a waste of oxidation, combustion of fossil fuels and in the respiration of organisms has a tremendous effect on the climate, since it is a green house gas (ESA21). The CO_2 is a major green house gas that contributes to earth's global warming. Over the past two centuries, its concentration in the atmosphere has greatly increased because of human activities, primarily as a result of combustion of fossil fuels, a leading cause of building up of greenhouse gases, warm the atmosphere by allowing sunlight to reach the surface of the earth's atmosphere and prevent the heat to escape from the earth's atmosphere acting as an insulating blanket. India occupies third position in the world with highest GHG emissions and it's total GHG emissions were 1.8 billion metric tonnes equivalent of CO_2, about 4.9 percent of global emissions in 2005 as per the estimates of World Resources Institute and as per Ministry of Environment and Forest estimates India's carbon dioxide emissions alone were 1.4 billion tonnes in 2008, or about 1.3 tonnes per capita (MoEF, 2009).

Carbon in the atmosphere is in two forms: solid and gas. The atmospheric CO_2 taken by the trees through photosynthesis stored in trees in solid state. Respiration of living organisms and combustion of fossil fuels put back more carbon to the atmosphere in gaseous form. Generally, the rate of emission of CO_2 is greater than the absorption which affects the carbon balance in the atmosphere. The level of CO_2 has increased from about 292 ppm to 360 ppm over the last 100 years (ESA21). There are two important ways to prevent GHG emissions: (a) reduce the fossil fuel consumption and (b) speed up the rate of carbon sequestration (a temporal process that removes carbon from the atmosphere) (Bhadwal and Singh, 2002). The later gained importance because carbon sequestration practices enhance the quality of soil, water, air and wildlife habitat. Carbon sequestration is the process by which atmospheric carbon dioxide is taken up by trees, grasses and other plants through photosynthesis and stored as carbon in biomass and soils. Trees have much more woody biomass to capture CO_2 and so they are considered as nature's most efficient carbon sinks (www.pww.org). Carbon sequestration will capture and secure carbon in the atmosphere and an alternative to control atmospheric emission of carbon.

Among the alternative ways of carbon sequestration, tree planting has greatest potential because trees grow in all extreme conditions, tolerate annual climate fluctuations and yield additional benefits to the society along with sequestration of atmospheric carbon. Trees planted in tropical climates, will sequester atmospheric CO_2 at an average of 50 pounds of CO_2 per tree per year (info@treesftf.org). Forests are major carbon sinks and the activities that alter forests significantly affect the amount of CO_2 in the atmosphere (Gorte and Ramseur, 2008) and forests have the potential of stabilizing atmospheric carbon in the near term (20-50 years) and provide time to develop fundamental technological solution in the form of reduced carbon emission energy sources (Sedjo, 2001). Apart from these, sufficient lands are available for growing trees and sequestration is relatively inexpensive to reduce atmospheric carbon naturally (Kolshus, 2001). It is estimated that the forests of the World store 283 Giga tonnes of carbon in their biomass. Hence periodic assessment of growing stock of carbon is essential to know the changes that are taking place in total carbon pool overtime and it is an urgent need of the hour (FSI, 2005).

OBJECTIVES

The purpose of the present paper is (i) to assess the carbon sequestration potential of existing forests in Tamilnadu, and (ii) to examine the potential of afforestation programmes in Tamilnadu as a tool for climate change adaptation.

METHODOLOGY

The forest types and their respective share in the total forest area of Tamilnadu and of India were taken from the Forest Survey of India, 2009. The total forest area of Tamilnadu and India were multiplied by the respective share of different forest types to measure their area in square kilometers. It was multiplied by 100 to convert the area in hectares. Further it was multiplied by per hectare annual biomass increment to get annual growth of standing biomass as mentioned by Forest Survey of India 1995, reported by Lal and Singh, for different types of forests in India. The annual carbon sequestration is usually taken as 50 percent of the annual biomass increment measured in terms of tC/ha (Ravindranath, Somashekhar and Gadgil, 1997, Bhadwal and Singh, 2002 and Poffenberger et al, 2002). Therefore the annual biomass growth of different forest types was divided by two and that was taken as annual carbon sequestration of the particular type of forest. Further, the carbon sequestration is multiplied by 3.67 to get the carbon dioxide (CO_2) sequestration of the forests of Tamilnadu and India because 1 ton carbon is equal to 3.67 tonnes of CO_2 (C=12 and O=16, Therefore CO_2 =12+16+16 = 44, 44/12=3.67).

NEED FOR ADAPTATION

Adaptation refers to "changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change" (IPCC, 2001). Adaptive measures were used to tackle the problem of climate change in right manner which has immediate effect and high responsiveness to reduce anthropogenic activities causing climate change with the participation of local community. Climate change is affecting every aspect of human and natural systems of the planet although they vary in sensitivity and adaptive capacity (Nkem et al, 2008). The need to develop appropriate policies for adaptation is widely acknowledged and the factors which hindered the development of adaptation policies are identified (Locatelli, 2008). Land use change, socio-economic pressures and forest policies are the drivers of changes in forests. Rising atmospheric CO_2 concentration and climate change are added stress to forests which will affect the forest cover, biodiversity, species composition, biomass productivity and regeneration (Murthy, Tiwari and Ravindranath, 2010).

It is possible to respond to climate change through the development of adaptation strategies (Nkem et al, 2008). Adaptation is the only way to deal with the inescapable impacts of climate change, therefore dedicated efforts are needed to mainstream adaptation in national, sectoral and local development plans (Murthy, Tiwari and Ravindranath, 2010). Hence adaptation is needed to cope with climate change and to protect the most vulnerable systems and society.

FOREST CARBON SEQUESTRATION AND CLIMATE CHANGE ADAPTATION

The negotiations towards a new agreement on climate change, within the framework of UNFCCC, put forests at the heart of the climate change agenda (www.Copa-Cogeca.eu). Forests cover more than 4 billion hectares of the Earth's land surface area and contain huge reservoirs of carbon in their vegetation and soils (www.iufro.org). Forest biomes store as much as 10 times more carbon in their vegetation than the non-forest biomes (Gorte and Ramseur, 2008). The recognized importance of forests in adapting climate change has led countries to study the forest carbon budgets and initiate the assessment of enhancing and maintaining carbon sequestration of their forest resources (IPCC, 2000). Forests actively contribute to the environmental stability of the world and have economic, cultural and recreational value.

Sequestration stores CO_2 removed from the atmosphere or captured from emissions and stores it in another form naturally and so carbon sequestration should not be excluded from any serious discussion of policy options (Leistra, 2002). Forest sector offers carbon sequestration opportunities through afforestation, reforestation and existing plantations (Gera, 2008) and increase the carbon stocks on the land base through afforestation, reforestation, agroforestry and forest restoration (Bowling, 2002). Afforestation is planting trees on lands that have not grown trees in recent years, such as abandoned cropland (Gorte, 2007). Afforestation will sequester more carbon than reforestation and provide a broad array of other environmental benefits (Gorte and Ramseur, 2008).

In India 21.02 percent of the geographical area is covered by forest land and the National Forest Policy of India treats forests as an environmental and social resource. Moreover India has a target of bringing one-third of its land cover under forest cover by launching the Greening India Mission programme. Under this mission the thrust to afforestation has been given with a target to afforest additional 10 Mha of degraded forest land (Murthy, Tiwari and Ravindranath, 2010). The CO_2 removal by India's forests and tree cover is enough to neutralize 11.25 percent of India's total GHG emissions at 1994 level. It is clear that India's forest is serving as a major mode of carbon sequestration in India (SFR, 2009). Hence, afforestation is a best option to adapt the effect of climate change for developing countries with varied climatic conditions like India, and especially the study area Tamilnadu. All potential forestry sector activities will make significant contribution to socio-economic and environmental benefits including reducing carbon emission or expanding carbon sinks (Ravindranath, Sudha and Rao, 2001).

CARBON SEQUESTRATION POTENTIAL OF EXISTING FORESTS IN TAMILNADU

Tamilnadu has 23,338 square kilometers of forest area which is only 17.94 of the geographical area of 1, 30,058 square kilometers of the State as per Forest Survey of India, 2009. The forests in Tamilnadu classified as tropical wet evergreen, tropical semi evergreen, tropical moist deciduous, littoral and swamp, tropical dry deciduous, tropical thorn, tropical dry evergreen, subtropical broadleaved hill, montane wet temperate and plantations. The tropical dry deciduous forest occupies the major part of forest land in Tamilnadu, covers 10961.85 square kilometers, 46.97 percent of the forested area which is followed by plantations, 4893.98 square kilometers (20.97%) and tropical thorn forests, 3012.94 square kilometers (12.91%). All the other types of forests mentioned earlier individually accounts less than 10 percent in the forest area of Tamilnadu and littoral and swamp forest accounts the least, 95.69 square kilometers (0.41%) only.

TABLE 1: CARBON SEQUESTRATION POTENTIAL OF EXISTING FORESTS IN TAMILNADU

Forest Types	Percentage in total forest area	Area (in km^2)	Annual biomass increment (t/ha)	Annual biomass growth (tC)	Annual Carbon Sequestration(tC)	Total CO_2 Intake (tCO_2)
Tropical wet evergreen	3.30	770.15	1.20	92418	46209.0	169587
Tropical semi evergreen	3.66	854.17	1.18	100792	50396.0	184953
Tropical moist deciduous	8.12	1895.05	0.80	151604	75802.0	278193
Littoral and swamp	0.41	95.69	1.07	10239	5119.5	18789
Tropical dry deciduous	46.97	10961.85	0.66	723482	361741.0	1327590
Tropical thorn	12.91	3012.94	0.73	219945	109972.5	403599
Tropical dry evergreen	1.61	375.74	0.62	23296	11648.0	42748
Subtropical broadleaved hill	1.01	235.71	1.09	25692	12846.0	47145
Montane wet temperate	1.04	242.72	1.37	33253	16626.5	61019
Plantations	20.97	4893.98	3.20	1566074	783037.0	2873746
Total	100	23338.00	----	2946795	1473397.5	5407369

Source: FSI, 2009 Lal M and Roma Singh, 2000

1 ton C = 3.67 tons of CO_2

The total forest area of Tamilnadu was classified under various forest types with their respective shares in the total forest area. It was multiplied by per hectare annual biomass increment to get annual growth of standing biomass as mentioned by Forest Survey of India 1995, reported by Lal and Singh, for different types of forests in India. The annual carbon sequestration is usually taken as 50 percent of the annual biomass increment measured in terms of tC/ha (Ravindranath, Somashekhar and Gadgil, 1997, Bhadwal and Singh, 2002 and Poffenberger et al, 2002). Further, the carbon sequestration is multiplied by 3.67 to get the carbon dioxide (CO_2) sequestration of the forests of Tamilnadu because 1 ton carbon is equal to 3.67 tonnes of CO_2.

From the table 1, existing forests of Tamilnadu is sequestrating more than 5.4 million ones of CO_2 per year which is equal to 1.47 million ones of carbon sequestration, contributes to reduce atmospheric carbon significantly. The average carbon sequestration potential and CO_2 intake is 0.63 tonnes and 2.32 tonnes per hectare respectively for the existing forests in Tamilnadu. The plantations record the highest contribution to carbon sequestration (783037 tonnes) and CO_2 intake (2.87 million ones) because the per hectare biomass increment of plantations is high and it accounts one-fifth of the forested area in Tamilnadu. The annual biomass growth is 2.95 million ones per year and average biomass growth per hectare is 1.26 tonnes per annum.

The potential for carbon sequestration is large, but there are large variations in the estimates as factors such as land availability and the rate of carbon uptake complicate the calculations (Kolshus, 2001) and the amount of carbon sequestered in a forest is constantly changing with growth, death and decomposition of vegetation (Gorte, 2007).

Aggarwal et al (2006) estimated that 5.24 tons of carbon sequestered by the forests under protection annually. Poffenberger et al (2002) estimated that in India the above ground mean annual growth of degraded forests was 3 tons of carbon per hectare and some of the earlier studies estimated 1tC/ha for unclassed forests.

CARBON SEQUESTRATION POTENTIAL OF EXISTING FORESTS OF INDIA

India has 690,899 square kilometers of forest area which covers 21.02 percent of the geographical area of 32,87,263 square kilometers as per Forest Survey of India, 2009. The forests of India classified as tropical wet evergreen, tropical semi evergreen, tropical moist deciduous, littoral and swamp, tropical dry deciduous, tropical thorn, tropical dry evergreen, subtropical broadleaved hill, subtropical pine, subtropical dry evergreen, montane wet temperate, Himalayan moist temperate, Himalayan dry temperate and alpine and sub alpine forests. The tropical moist deciduous forest occupies the major part of forest land in India, covers 234352.94 square kilometers, 33.92 percent of the forested area which is followed by tropical dry deciduous forests, 208375.13 square kilometers (30.16%) and tropical wet evergreen forests, 60453.66 square kilometers (8.75%). All the other types of forests mentioned earlier accounts the remaining 27.17 percent of the forest area of India.

TABLE 2: CARBON SEQUESTRATION POTENTIAL OF EXISTING FORESTS OF INDIA

Forest Types	Percentage in total forest area	Area (in km^2)	Annual biomass increment (t/ha)	Annual biomass growth (tC)	Annual Carbon Sequestration (tC)	Total CO_2 Intake (tCO_2)
Tropical wet evergreen	8.75	60453.66	1.20	7254439	3627219.5	13311895
Tropical semi evergreen	3.35	23145.11	1.18	2731123	1365561.5	5011611
Tropical moist deciduous	33.92	234352.94	0.80	18748235	9374117.5	34403011
Littoral and swamp	0.38	2625.42	1.07	280920	140460.0	515488
Tropical dry deciduous	30.16	208375.13	0.66	13752758	6876379.0	25236310
Tropical thorn	5.11	35304.94	0.73	2577261	1288630.5	4729274
Tropical dry evergreen	0.29	2003.61	0.62	124224	62112.0	227951
Subtropical broadleaved hill	0.38	2625.42	1.09	286171	143085.5	525124
Subtropical pine	5.99	41384.85	1.32	5462800	2731400.0	10024238
Subtropical dry evergreen	0.36	2487.24	0.65	161671	80835.5	296666
Montane wet temperate	3.45	23836.02	1.37	3265535	1632767.5	5992257
Himalayan moist temperate	3.79	26185.07	1.54	4032501	2016250.5	7399639
Himalayan dry temperate	0.28	1934.52	2.10	406249	203124.5	745467
Alpine and sub-alpine	3.79	26185.07	1.51	3953946	1976973.0	7255491
Total	100	690899.00	----	63037833	31518916.5	115674422

Source: FSI, 2009 Lal M and Roma Singh, 2000

1 ton C = 3.67 tons of CO_2

The total forest area of India was classified under various forest types with their respective shares in the total forest area. It was multiplied by per hectare annual biomass increment to get annual growth of standing biomass as mentioned by Forest Survey of India 1995, reported by Lal and Singh, for different types of forests in India. Fifty percent of the annual growth of standing biomass was taken as carbon sequestration potential of existing forests in India and it was multiplied by 3.67 to get total CO_2 intake of the forests of India.

From the table 2, existing forests of India is sequestrating more than 116 million tonnes of CO_2 per year which is equal to 32 million tonnes of carbon sequestration, contributes to reduce atmospheric carbon of the globe. The average carbon sequestration potential and CO_2 intake is 0.46 tonnes and 1.67 tonnes per hectare respectively for the existing forests of India. The tropical moist deciduous forests record the highest contribution to carbon sequestration (9.4 million tonnes) and CO_2 intake (34 million tonnes) because it occupies one-third of the forested area in India. The annual biomass growth is 63 million tonnes per year and average biomass growth per hectare is 0.91 tonnes per annum.

The carbon sequestration potential of the existing forests of Tamilnadu and India are compared in terms of per hectare biomass growth, carbon sequestration and CO_2 intake. Tamilnadu accounts only 3.4 percent of forest area of India but it sequestrates 6.24 percent of the total carbon sequestration of the forests of India. When comparing the average per hectare biomass growth, it is 1.26 for Tamilnadu and 0.91 for India. The average per hectare carbon sequestration and CO_2 intake is 0.63 tonnes and 2.32 for Tamilandu, 0.46 and 1.67 for India. It reveals that in all manners Tamilnadu is doing better than the average of India.

FOREST PROTECTION AND AVOIDED EMISSIONS

Forest protection prevents the release of carbon stored in trees and in the forest soil to the atmosphere. Forest protection not only protects the forests from degradation and deforestation but avoid emissions of GHGs to the atmosphere also. Forest eco-systems capture and store CO_2, making a major contribution to adapt climate change, but if they are destroyed or burned they turn as a source of CO_2 emissions. Tropical deforestation and forest degradation accounts for approximately 17 percent of global green house gas emissions (www.Copa.Cogeca.eu). Rigid state control and indiscriminate removal of trees by industries degraded the forests in the past and raised the CO_2 emissions. Part of the vast degraded areas and degraded pasture areas is available for reforestation and afforestation for meeting biomass demands as well as carbon sequestration. The government supported afforestation, reforestation and conservation activities could be largely on state or community owned forest and degraded lands (Ravindranath, Sudha and Rao, 2001).

SUSTAINABLE FOREST MANAGEMENT (SFM)

Sustainable Forest Management is a way of achieving the goals outlined by the UNFCCC with respect of forests. SFM is a system of forestry practices that aims to maintain and enhance the economic, social and environmental values of all types of forest and it plays an important role in climate change adaptation. Using forests and trees as part of a strategy to cope with impacts of climate change, forests become part of a climate strategy for adaptation. The study area Tamilnadu is the southern state of India with a geographical area of 1, 30,058 square kilometers which constitutes 3.96 percent of geographical area of India. By considering the features, it is divided into four major regions namely, Coastal plains, Eastern Ghats, Central Plateau and Higher Mountains. In the total geographical area of Tamilnadu, 17.59 percent were recorded forest area which is 22,877 square kilometers (SFR, 2009). Due to anthropogenic impact and biotic pressure, a sizeable part of the forests in Tamilnadu had undergone changes in their structure and composition. Illicit cutting and removal of trees, encroachment of forest land, sandalwood smuggling, forest fire, grazing, ganja cultivation, illicit distillation, poaching of wildlife and theft of medicinal plants etc. pose a threat to the protection of forest resources. Table 3 explains the diversion of forest land for various reasons.

TABLE 3: DIVERSION OF FOREST LAND IN INDIA AND TAMILNADU – A COMPARISON

Year	India		Tamilnadu	
	No. of cases	Area diverted (in hectares)	No. of cases	Area diverted (in hectares)
2006	664	10978.41	1	4.17
2007	443	6633.5	5	13.14
2008	363	6377.55	3	5.81
2009	78	1853.26	1	1.18
Total	1547	25677.58	10	24.30

www.tamilnadustat.com

To adapt the ill-effects of climate change several afforestation programmes have been undertaken in the state in recent years which will help to increase the forest and tree cover and absorb more carbon from the atmosphere (Government of Tamilnadu Demand Note 15, 2010). With this aim TamilNadu Government had initiated Schemes namely Afforestation Programmes in Tamilnadu, sustainable management of forest and wildlife, Joint Forest Management (JFM), Tamilnadu Afforestation Project, National Afforestation Programme , Integrated Forest Protection Scheme and Urban Afforestation programme – To achieve the goal of programmes like sustainable management of forest and wildlife the financial support of Rs.3135.01 crores from the State, Central and external aids are provided .In Tamilnadu the JFM is started during the year 1997-98 and the aim of JFM is to bring about complete transformation of livelihoods so that forest dependent communities take up other viable vocations and need not revert to illicit activities in the forest (Kaushal, 2009). In Tamilnadu, 200 villages are selected for JFM programme and Village Forest Councils established at the village level for the participation of people in forest protection and conservation. There are 1367 Joint Forest Management Committees (JFMCs) managing about 0.48 million hectrares of forest area as on March, 2005, which is about 21 per cent od the forest area of the state (FSI, 2005). There is a considerable change in the condition of natural forests in after the formation of JFMCs (Mishra and Singh, 2009). Regarding TAP,the first phase of this project was implemented at a cost of Rs. 688 crores for the period of 8 years from 1997-98. An extent of 4.8 lakh hectares of degraded forests and community lands has been covered, 1,75,000 forest dependent villagers benefited through alternate employment and 60 million person days of employment created. Phase II of TAP was implemented for a period of 8 years upto 2012-13 to cover another 1,77,500 hectares of degraded forests. The National Afforestation Programme(NAP) is an umbrella scheme which establishes linkages between rural development, employment generation and forest conservation. This scheme was implemented in 2002-03 through 32 Forest Development Agencies and to the extent of 50,695 hectares of degraded forests were preserved under this scheme. The Integrated Forest Protection Scheme was implemented by the Forest Department with the share of 3:1 by the Government of India and State. The important objective of the scheme is to control forest fires and strengthen forest protection measures in Tamilnadu. Urban Afforestation programme was implemented with an outlay of 4.0 crores to mitigate pollution because trees act as effective carbon and methane sinks.

CARBON SEQUESTRATION POTENTIAL OF AFFORESTED AREA IN TAMILNADU

The unavailability of time series data regarding the coverage of afforestation programmes is a major draw back in estimating the carbon sequestration potential of specific afforestation programmes in Tamilnadu. Another discrepancy is the afforestation programmes and environmental conservation activities are interrelated. Therefore two major afforestation programmes TAP and NAP in Tamilnadu, were considered for estimating the carbon sequestration potential of afforested area in Tamilnadu.

TABLE 4: CARBON SEQUESTRATION POTENTIAL OF AFFORESTATION PROGRAMMES IN TAMILNADU

Afforestation Programme	Area forested (in hectares)	Carbon sequestration (tC/ha)	Annual Carbon Sequestration (tC)	Annual CO_2 intake (t CO_2)
TAP Phase - I (1997-98 to 2004-05)	480000	0.63	302400	1109808
TAP Phase – II (2005-06 to 2009-10)	88750	0.63	55913	205201
NAP	50695	0.63	31938	117212
Total	619445	----	390251	1432221

Source: Tamilnadu Forest Department Report

∗ The average carbon sequestration potential is taken from the results of earlier estimate.

∗∗ Phase II of TAP is a current programme; hence the average area covered per year is used for estimation.

The carbon sequestration potential of the afforestation programmes in Tamilnadu is arrived by multiplying the average per hectare sequestration of the forests of Tamilnadu with the area forested by various afforestation programmes. It gives the annual carbon sequestration from that the annual CO_2 intake of the forested area is derived. From the table 4, it is clear that the afforestation programmes contribute to reduce the atmospheric CO_2 significantly. From the two selected afforestation programmes, TAP and NAP, the afforestation and prevention of degradation of forests is made upto the extent of 6.2 lakh hectares. This aforested area sequestrates 3.9 lakh tonnes of carbon and scrubs 14.3 lakh tonnes of CO_2 from the atmosphere per year. It proves that afforestation is the affordable and natural way to reduce the accumulation of CO_2 in the atmosphere and prevents the earth from the evil impacts of climate change.

STRATEGIES NEEDED

- Need for establishing a forest monitoring system with complete data on multi-date forest area change, carbon emissions from land uses change, carbon changes in remaining forest areas and significant emissions from other carbon pools.
- Assessment of existing national forest monitoring framework and capacities, and identification of gaps in the existing data sources.
- Forest area change assessment for understanding of deforestation drivers and factors

- National carbon monitoring system established for historical period and future monitoring. With National and international reporting on forest carbon changes.
- Changes in carbon stocks due to land use change, changes in forest areas and remaining forests
- Analysis of drivers and factors of forest change such as processes affecting forest change, socio-economic drivers, spatial factors, forest management and land use practices, and spatial planning
- Establishment of reference emission level and regular updating data and knowledge on deforestation and forest degradation processes, associated GHG emissions, drivers and expected future developments.

CONCLUSION

Climate is the interaction of all of the components of the Earth's system. Adaptation though carbon sequestration concentrate on single factor that is, CO_2 emissions in a complex problem of climate change. Sequestration activities could potentially be organized in either centralized government or decentralized market processes. Government involvement in the production of a marketable commodity is usually justified by the failure of private markets to correctly provide public goods, usually from ignoring the non-financial social costs or social benefits of economic activities such as carbon and global warming.

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