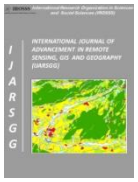
ISSN 2321–835
Research Article

IROSSS
Advancing Sciences and Social Sciences for Mankind

IJARSGG (2015) Vol.3, No.1a, 29-37

International Journal of Advancement in Remote Sensing, GIS and Geography



CLIMATE CHANGE MITIGATION STRATEGIES IN THE FORESTRY SECTOR OF KERALA, INDIA

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(Published Online: 9 March, 2015)

ABSTRACT: Climate change is generally recognized as one of the greatest challenges of this century. In the present paper, the climate change impact factors such as precipitation and atmospheric temperature are discussed in the context of Kerala State. The high resolution daily gridded dataset for a period of 100 years (1901-2000) provided by the Climate Research Unit Time Series (CRU TS- version 2.10) was used to analyse the long-term trend of rainfall and temperature in Kerala. The mean annual rainfall and seasonal rainfall over the State showed an insignificant declining trend. The number of wet days during the south-west monsoon increased significantly and decreased during pre-monsoon and winter seasons. However, throughout the State daily average, maximum and minimum temperatures increased irrespective of the season. Among different landuse systems, forests are particularly sensitive to climate change. The forest cover in the State seems to be stabilised to around 17,382 km^2. However, in the context of increasing anthropogenic activities, without adopting suitable strategies, forests cannot contribute to mitigate the ill effects of climate change. Several of the forest conservation measures already taken up by the Kerala Government also represent unintentional climate change mitigation measures. By strengthening or continuing with intentional programmes like social forestry projects and protection and conservation of forests, including sacred groves, adverse effects of climate change can be mitigated. With the long experience in promotion of forest conservation, participatory forest management and forest governance, the Kerala Forest Department can greatly facilitate comprehensive programmes for climate change mitigation.

KEYWORDS: Climate change, Kerala, monsoons, PFM, Social Forestry Programmes

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1. INTRODUCTION: Climate change is a global concern as the average temperature globally has increased by 0.8^0 C since 1900 (1) and the hottest 12 years observed globally since 1880 occurred between 1900 and 2005. Among different land-use systems, forests are particularly sensitive to climate change because the long life-span of trees does not allow for rapid adaptation to environmental changes (2). Studies have highlighted the possible impacts of climate change on tree species composition (3), tree growth and productivity [(4)- (5)], forest area and competition between species (6), quality and quantum of damage caused by natural disturbances (7) and protective functions of forests (8). At the same time, available literature also indicate the fact that forests can contribute towards mitigating impacts of climate change (9). However, the extent to which forests can help in mitigation and their ability to adjust in response to climate change are related to how well the forests are managed. In this context, detailed investigation on interaction between forests and climate change at regional scale is essential. Situated in the Western Ghats of India, one of the hotspots of biodiversity in the world, the state of Kerala is recognized as the "gateway of monsoon" to the country as it is the entry point of monsoon to the Indian subcontinent. The entire state is also one of the wettest places in the humid tropics. According to Forest Survey of India (10), the total forest cover in Kerala is 17,382 km^2, which is 44.73% of the State's geographical area. However, assessment of the quality of forest patches in terms of stand density, basal cover, species diversity, succession and regeneration patterns needs to be carried out to understand the potential of the existing forest cover in adapting to the changing climate as well as mitigating the effects of climate change. The study discusses the climatic changes in Kerala, with special reference to precipitation and atmospheric temperature. In the context of forestry sector, activities such as management of forests with high carbon uptake potential, reversal of the loss of forest cover, expansion of forests through reforestation and reduction of deforestation can also help in mitigating the effects of climate changes. While some such activities are intentional to mitigate impacts of climate change other are unintentional. In this paper, strengths and weaknesses of intentional and un-intentional mitigation practices in forest sector of Kerala are reviewed. The specific objective of this paper is to provide a base for evolving sound mitigation strategies for increasing the resilience of forests to the unfolding climatic changes.

2. METHODOLOGY

2.1. STUDY AREA: Kerala State (north latitudes between 8°17'30" and 12° 47'40" N and east longitudes 74°27'47" and 77° 37'12" E) is situated in the south-western parts of the Indian peninsula. The geographical area of the state is about 39,863 km^2 with three distinct physiographical zones namely coastal, midland and highand. The total population of the state is 31.84 million with population density of 819 persons per km^2.

2.2. CLIMATE IMPACT FACTORS: Gridded climate data were obtained from the Climate Research Unit (CRU) high-resolution Time Series version 2.1 (TS 2.1) (11). CRU TS 2.1 data are globally available at 0.5 decimal degrees (0.5 x 0.5 latitude and longitude for each month for a period of 100 years (1901-2000). For analysis, monthly averages of daily temperature (maximum, minimum and mean; °C), total monthly precipitation (mm) and wet days (daily precipitation more than 1 mm) were selected. For this study, data from 26 grids each of (0.5° x 0.5° latitude and longitude) were required to cover the full extent of Kerala State (Figure 1). For each grid, through CRU dataset, climate variable such as monthly average daily temperature (maximum, minimum and mean; °C), total monthly precipitation and wet days were collected for a period of 100 years (1901-2000). The state average value for each of the above mentioned climate variable was calculated using the data obtained for 26 grid points. Monthly mean, standard deviation and correlation coefficient (cv: standard deviation divided by mean, expressed in %) values for temperature (maximum, minimum and mean) total precipitation and wet days were computed. Season-wise viz., pre-monsoon (March-May), south-west monsoon (June-September), post-monsoon (October-November) and winter (Dec-February) variation in temperature and precipitation were also analyzed. The data were also subjected to trend analysis to find out the long-term changes in annual rainfall, temperature and wet days over Kerala for 1901-2000.

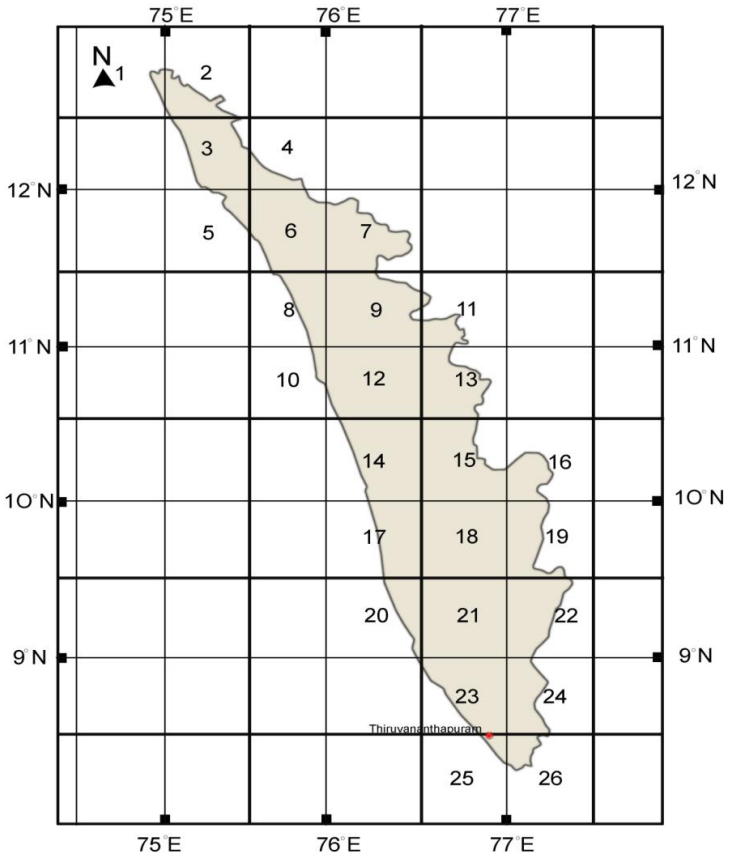

Figure I. Map showing the gridded regions in Kerala. Each grid (numerical numbers 1 to 26) is 0.5° x 0.5° in size.

2.3. MITIGATION STRATEGIES: Mitigation involves attempts to slow the process of global climate change. Among several actions that can be taken in the forest sector to promote mitigation include a) managing forests with high carbon uptake potential, b) expanding such forests through reforestation and afforestation, and c) reducing deforestation and reversing the loss of forest cover. Several conservation measures taken up in the forestry sector may represent intentional

or incidental mitigation measures. Thus, a comprehensive bibliographical investigation on forest policies and conservation and management programs implemented by the Government India and Government of Kerala was undertaken. Interviews were conducted with policymakers, forest managers, researchers, forests experts, non-government organizations and other relevant stakeholders to collect information and data on forests policies and management in Kerala and their strengths and weaknesses in mitigating the effects of climate change.

3. RESULTS AND DISCUSSION

3.1. CLIMATE CHANGE IMPACT FACTORS: The mean monthly rainfall, total number of wet days and atmospheric temperature (average, maximum and minimum) over Kerala from 1901 to 2000 are given in Table I. The annual normal rainfall over Kerala during this period was 2019 mm with a standard deviation of 334 mm (Table II). The seasonal rainfall for pre-monsoon (March-May), southwest monsoon (June-September), post-monsoon (October-November) and winter season (December-February) was 324±95 mm, 1581±327 mm, 201±55 mm and 23±13 mm respectively. The coefficient of variation (standard deviation divided by mean, expressed in %) of annual rainfall is 15.5% indicating that it is highly stable. The seasonal rainfall during pre-monsoon, monsoon and post-monsoon are also dependable as the coefficient of variations ranged from 21 to 29%. However, rainfall during winter is undependable as the coefficient of variation is very high (55.1%). The mean annual rainfall over the State showed a long-term insignificant declining trend (t=-0.428; df=98; P>0.05) (Figure II). The spatially averaged trends in total precipitation in different seasons over Kerala revealed the fact that in all seasons rainfall showed decreasing trend though not statistically significant (pre-monsoon: t=-0.794, monsoon: t=- 0.135, post-monsoon: t=-0.3079, winter: t=-0.507; P>0.05).

Months	Rainfall (mm)	Total number of wet days	Daily atmospheric temperature (^{o} C)		
			Average	Maximum	Minimum
January	13±14	1±1	24.70±1.68	29.76±0.51	19.6±0.5
February	16±20	1±1	25.65±1.56	30.78±0.52	20.5±0.5
March	28±25	2±1	27.07±1.50	32.01±0.45	22.1±0.4
April	104±51	5±1	27.93±1.47	32.51±0.44	23.3±0.4
May	191±86	8±2	27.46±1.42	31.53±0.56	23.4±0.5
June	504±191	17±3	25.60±1.44	28.96±0.50	22.2±0.5
July	533±179	17±3	24.80±1.46	27.94±0.45	21.6±0.4
August	356±137	15±3	25.03±1.45	28.17±0.33	21.8±0.3
September	189±76	9±2	25.40±1.43	28.90±0.38	21.9±0.4
October	250±79	11±2	25.49±1.51	29.26±0.38	21.7±0.4
November	151±78	7±2	25.11±1.65	29.15±0.47	21.1±0.5
December	40±35	2±1	24.57±1.75	29.13±0.49	20.0±0.5

Table I. Total rainfall (mm), total number of wet days, daily average, maximum and minimum temperature (^{o}C) in different months in Kerala from 1901 to 2000. Values are mean ± SD.

	Rainfall (mm)	Total number of wet days	Daily atmospheric temperature (^{o} C)		
			Average	Maximum	Minimum
Pre-monsoon	324±95	15±2	27.49±0.60	32.02±0.37	23.0±0.37
Southwest monsoon	1581±327	57±6	25.21±0.52	28.49±0.32	21.9±0.32
Post-monsoon	201±55	17±3	25.30±0.46	29.21±0.39	21.4±0.39
Winter	23±13	5±2	24.97±0.70	29.89±0.42	20.0±0.42
Annual	2019±334	94±6	25.73±0.30	29.90±0.30	21.6±0.3

Table II. Total rainfall (mm), total number of wet days, daily average, maximum and minimum temperature (^{o}C) in different seasons in Kerala from 1901 to 2000. Values are mean ± SD.

Analysis of spatially averaged trends of total wet days (wet days: daily precipitation (DP) more than 1 mm) in various seasons is useful to determine increase or decrease in water stress, which in turn is important for forest vegetation. The annual normal number of wet days in Kerala from 1901 to 2000 is 94 days with a standard deviation of 6 days (Table II). Spatially averaged trends of total number of wet days in a year did not show the significant decreasing tendency (t=-

0.477; P>0.05) (Figure III). It was also noticed that over 100 years the number of wet days during south-west monsoon increased significantly (t=2.686; P<0.05) while decreased during pre-monsoon and winter seasons (pre-monsoon, t= -3.492; winter, t=-6.21; P<0.05). However, the decrease observed in total number of wet days in post-monsoon was not statistically significant (t= -0.738; P>0.05). It is reported that the number of monsoon depressions formed during the south-west monsoon, strength of monsoon current and strength of tropical easterly jet stream are the important rain bearing systems during the south-west monsoon season (12). The frequency changes and fluctuations of the above weather systems in recent years over peninsula may be important reasons to varying rainfall and number of rainy days in Kerala. In addition to this, anthropological interventions leading to landuse and land-cover changes are also responsible either directly or indirectly for disrupting the earth-atmosphere continuum drastically (13) and they in turn may alter the distribution of local rainfall during winter and pre-monsoon season.

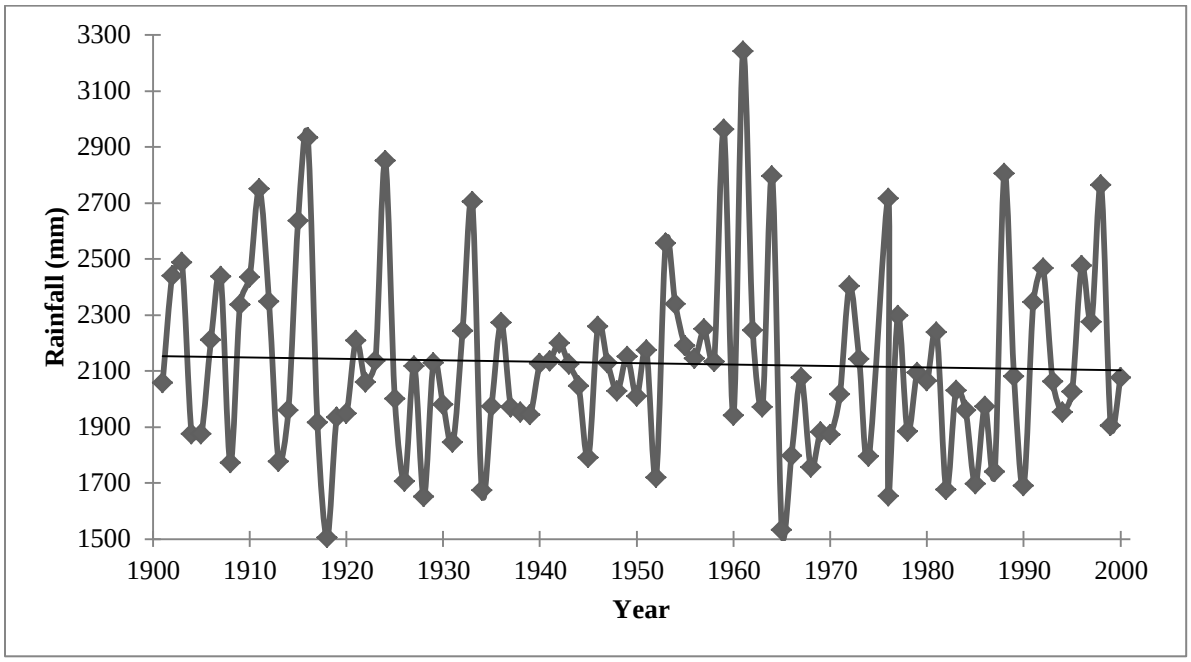

Figure II. Annual rainfall trends over Kerala from 1901 to 2000.

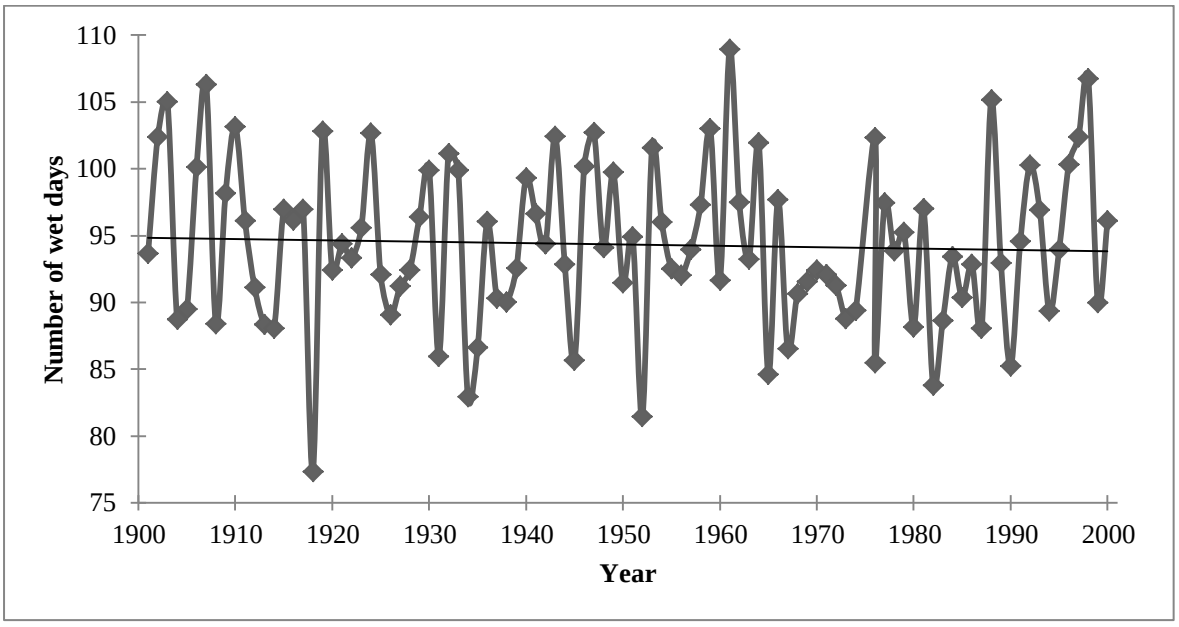

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Figure III. The trend of number of wet days in a year in Kerala from 1901 to 2000

The daily maximum temperature, minimum temperature and consequently the daily average temperature showed a significant increasing trend (daily maximum temperature, t= 7.84; p<0.01; daily minimum temperature, t= 7.45; p<0.01 and daily average temperature, t=7.35; p<0.01) (Figures IV, V and VI). Decade-wise percentage departure of all the three parameters also indicated a fact that from 1980 onwards the increase was drastic (Figure VII). In all seasons, a significant increasing trend in average daily temperature, daily maximum temperature and minimum temperature was also noticed (P<0.01-0.05). An increase in daily maximum temperature by 0.64^{o}C and daily minimum temperature by 0.23^{o} C over Kerala during the period of 49 years, commencing from 1956 to 2004 is also reported (14).

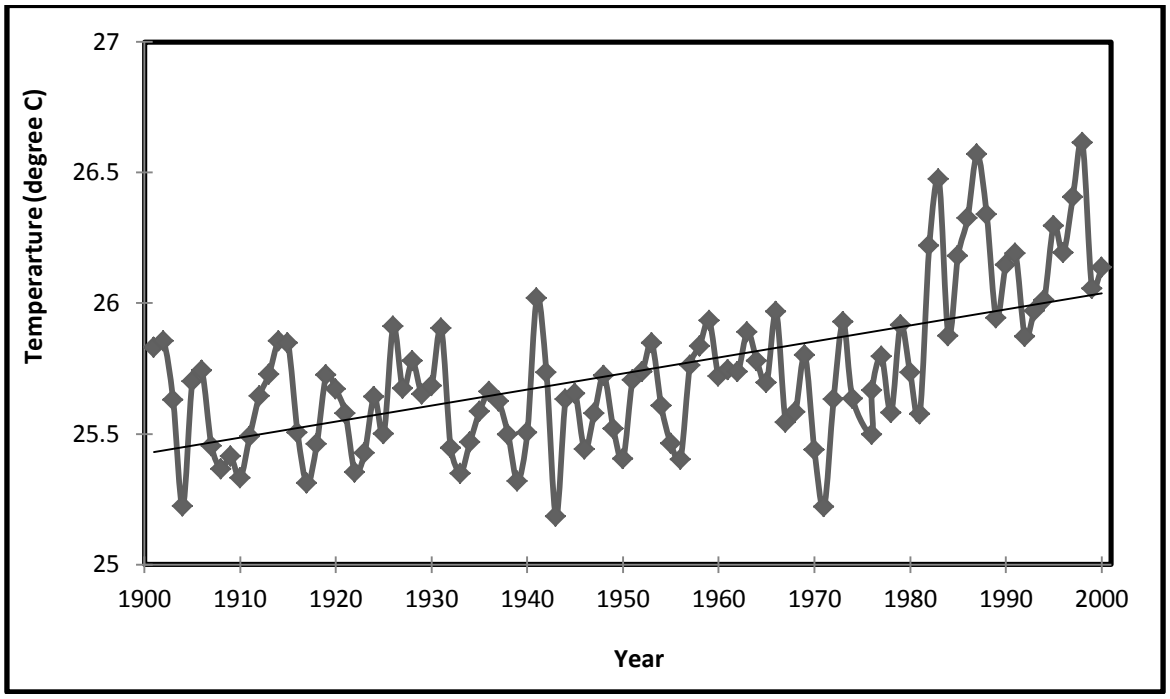

Figure IV. The trend of daily average temperature in Kerala from 1901 to 2000.

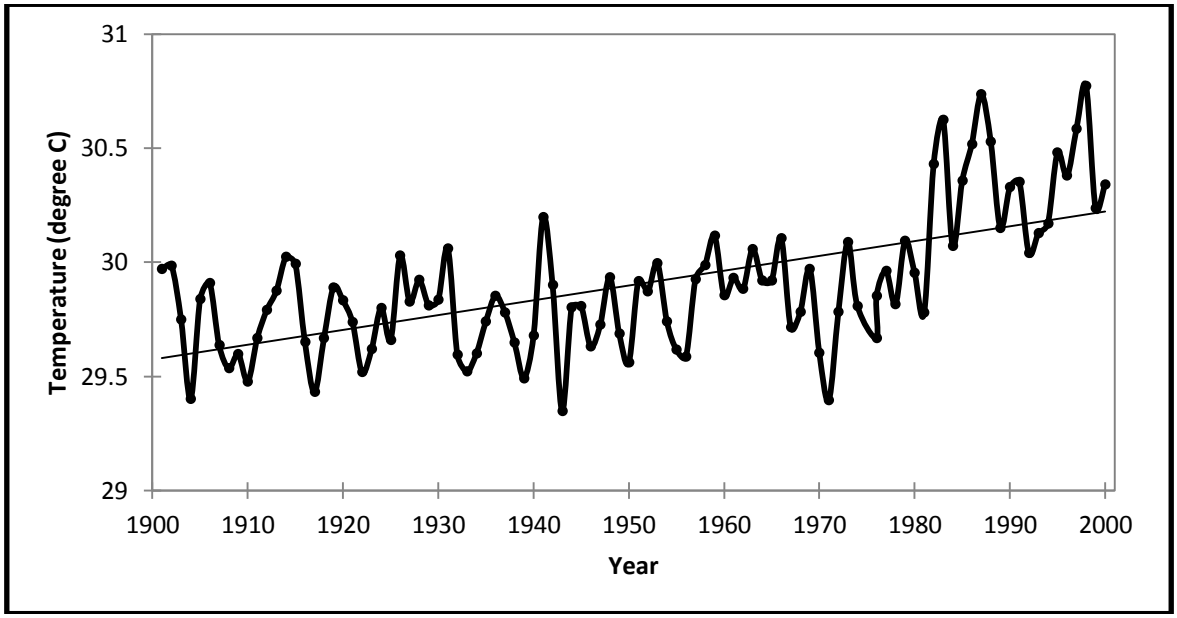

Figure V. The trend of daily maximum temperature in Kerala from 1901 to 2000.

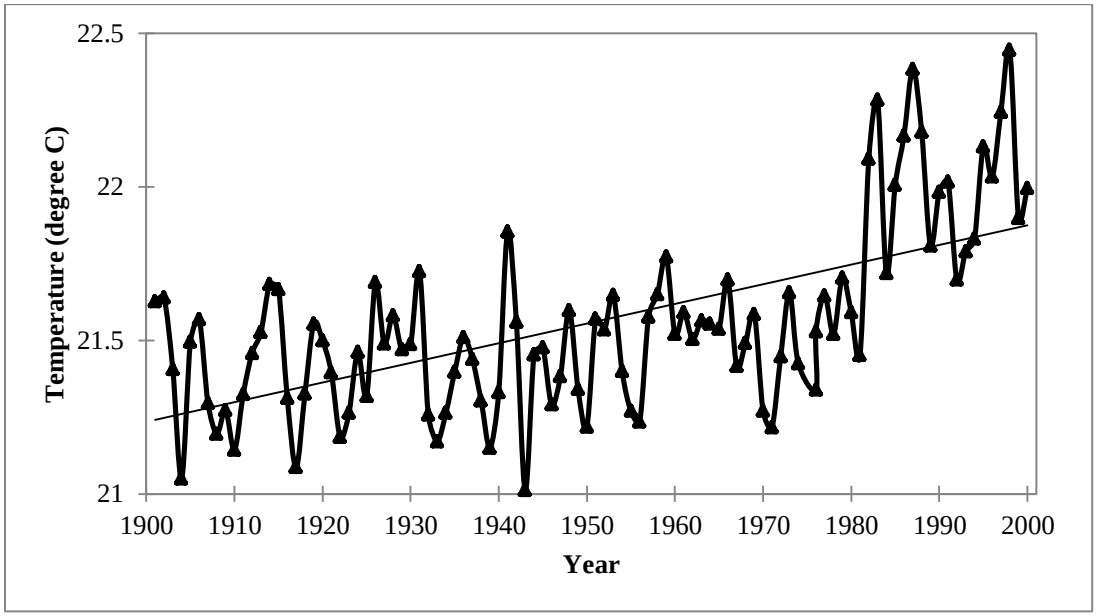

Figure VI. The trend of daily minimum temperature in Kerala from 1901 to 2000.

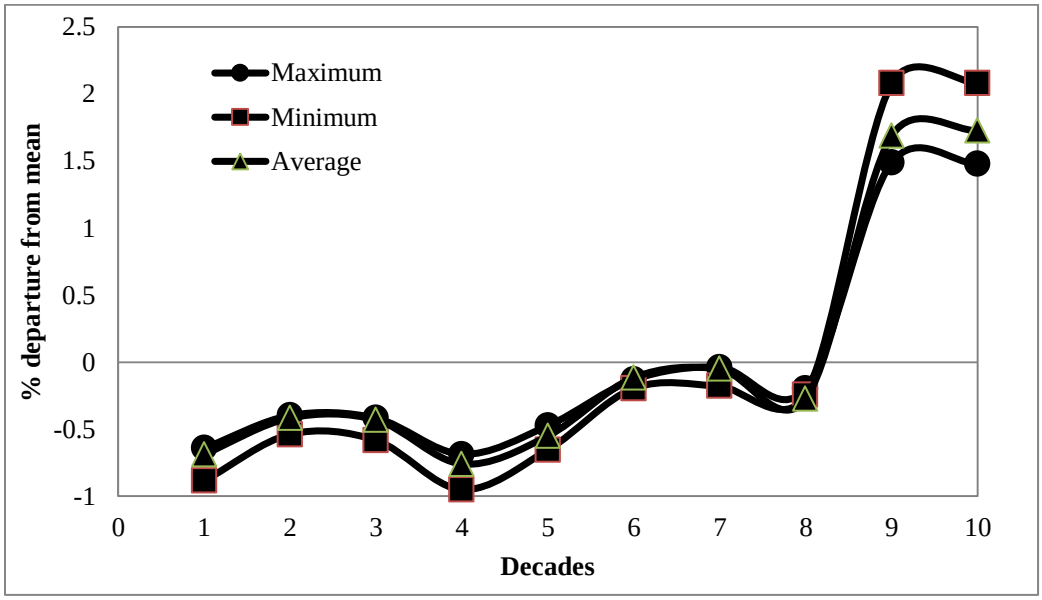

Figure VII. Decadal mean (% departure from average) of daily maximum (●), minimum (■) and average (▲) atmospheric temperature in Kerala from 1901 to 2000.

Analysis of trends of atmospheric temperature (daily average, maximum and minimum) thus clearly indicates that the annual temperatures are set to increase from a minimum of 26.8^{o}C to a maximum of 27.5^{0}C in the 2030s. It is also possible to project that temperatures will rise for all seasons from 1.5 to 2.2^{o}C, with no significant change in the rainfall in all seasons in the State.

3.2. MITIGATION PRACTICES IN FORESTRY SECTOR OF KERALA: The combined and individual influence of precipitation, wet days and temperature regimes that are changing in Kerala are expected to have influence on forest ecosystems. In this context, mitigation measures to slow the process of global climate change at regional scale are important. Mitigation involves attempts to slow the process of global climate change. Among several actions that can be

taken in the forest sector to promote mitigation include a) managing forests with high carbon uptake potential, b) expanding such forests through reforestation and afforestation, and c) reducing deforestation and reversing the loss of forest cover. It may be pointed out here that in Kerala, even before recognizing the impacts of climate change on forests (3) several policies and programmes for forest conservation have been implemented and such programmes can be regarded as un-intentional climate change mitigation activities. Subsequent to recognition of importance of forest in climate change mitigation the Kerala Government has initiated several afforestation, reforestation and avoided deforestation projects and they can be regarded as intentional climate change mitigation activities in the forestry sector. In the following section certain unintentional and intentional mitigation interventions undertaken in Kerala to combat climate change are discussed.

3.2.1. UNINTENTIONAL MITIGATION MEASURES: During 1949, under the Madras Preservation of Private Forest Act (MPPF), tree felling or alienation of land through sale, mortgage or leasing of private forests without the prior permission of the District Collector was prohibited. This Act, an example for unintentional activity to promote mitigation, helped to some extent to control the indiscriminate conversion of forests to agriculture in Kerala. However, the objectives of the Act were not fulfilled mainly due to facts like inadequacy of implementing machinery and incomplete survey of forests under government and private holdings (15).

During 1980s, the Kerala State has launched a Kerala Social Forestry Project with financial support from the World Bank. The Project was aimed to enhance the fuel wood and fodder stock of the State by planting around 85,300 ha area with a tree density of 4,900 per ha in public and private lands. A review of this Project by the Estimate Committee of the Kerala Legislature indicated that against a target of 85,300 ha the achievement was 98,000 ha (16). The survival rate of seedlings planted in forests and public lands was found satisfactory with over 80% at 1.5 years after planting and about 60% in later years (17).

The Forest Conservation Act 1980 enacted by the Government of India assumes wide ranging powers for regulating forest landuse decisions. Under this Act, the states have effectively lost all powers to modify forest landuse for non-forestry purposes without the prior sanction of the Central Government. It may also be pointed out here that a plantation policy to restrict timber harvesting in Wildlife Sanctuaries of India has been enacted. In sanctuaries of Kerala State, during final felling of teak plantations, felling was limited to only 25% of the mature trees. Subsequently, since 1985 clear felling of plantations at rotation age has also been stopped. In addition, in Kerala, since 1987 selection felling in natural forests has also been abandoned. All these actions have indirectly helped to maintain or increase the stand–level carbon stock in natural forests and wildlife sanctuaries of the State.

The National Forest Policy of 1988 of India also strengthened some of the efforts made by the State to ensure environmental stability and maintenance of ecological balance for sustenance of all life forms, including humans, animals and plants. The policy specifically stressed the need for safeguarding tropical rain/moist forests, particularly in areas like Arunachal Pradesh, Kerala and Andaman and Nicobar islands of the country.

During 1988, the Kerala Government has launched a World Bank aided Kerala Forestry Project to promote conservation of biodiversity and arrest the degradation of forest land, to improve productivity of wood and non-timber forest produces from forest and non-forest lands, and to improve the living condition of local people residing in and around forest area. According to the Implementation Completion Report of the World Bank (18), the Kerala Forestry Project has made significant progress towards arresting the retrograde trend in forest cover through the implementation of a series of treatment practices in natural forests. The Kerala Forest Projects were designed to assist the regeneration of these forests by promoting and protecting natural regeneration of desirable tree species, reeds, bamboos, canes, and non-timber forest products (NTFPs) from fire and biotic destruction. The forestry treatments under this project primarily emphasized on a micro-watershed approach combining treatments for forests in different categories of degradation. According to the World Bank's Implementation Completion Report (18), there has been at least 50 percent increase in fresh and established seedlings and saplings in over 50 percent of the sites, while many sites showed an increase of over 100 percent even at this early stage. With the expected continued protection, this regeneration will result in much improved high forest cover. The report also documented a dramatic reduction in the occurrence of fire in the forests of Kerala since the introduction of participatory fire protection programmes under the project. In addition, the forest areas covered by participatory forest management programmes showed a considerable decrease in the number of offences related to illegal harvesting of forest products.

The participatory approach to forest protection and management (PFM) adopted since 2000 in Kerala found to have a positive contribution to improving forest cover and potential yield as well as sustained improvement in the livelihoods of the rural communities involved. The adoption of PFM was slow for the first three years of the project, but it eventually exceeded the target number of Forest Protection Committees (Societies) or Vana Samrakshana Samithi (VSS), with a total

of 36,500 families being involved, most of which are poor and marginal (19). The stakeholder analysis indicated that the PFM, by and large, a successful venture in protecting and managing forests and improving the livelihoods of the communities involved. However, continuity of the Programme and positive attitudinal changes across the communities and Kerala Forest Department are needed for the sustainability of the Programme.

3.2.2. INTENTIONAL MITIGATION MEASURES: Afforestation programmes launched by the Social Forestry wing of the Kerala Forest Department since 2007 are the best examples for institutional and intentional programmes to mitigate the impacts of climate change. The programmes have been launched with a slogan `Global warming- Tree is the Answer' and with the participation and involvement of public. Following are the afforestation schemes launched in the State (19).

3.2.2.1. My Tree Programme (Ente Maram Scheme): In association with the Kerala Education Department, the Kerala Forest Department has implemented this programme. All students from Standard V to IX all over the State have participated in planting of trees in their own household compounds and in places available to them nearby, and nurturing them. Under this programme, during 2007 to 2010, nearly 42.12 lakh of seedlings were planted. It is reported that due to whole-hearted participation and involvement of student community, about 80% of the seedlings have survived in the field.

3.2.2.2 Our Tree Programme (Nammude Maram Scheme): This programme of planting in the college/school campuses was implemented by involving school and college teachers and students. For this programme, necessary seedlings have been supplied to the educational institutions during June 2008. A total of around 10.57 lakh seedlings were planted during 2008 to 2010.

3.2.2.3. Greening the Coast Scheme (Haritha Theeram Scheme): This project was aimed at the protection of the State's coastline from natural calamities by establishing a bio-shield of sand binding trees like *Casuarina equisetifolia* and shrubs wherever possible along the coast. Under this forestry activity, during 2007 to 2009, 163.4 ha of casuarinas and 14.65 ha of mangrove plantations were raised and around 22.52 lakhs of popularly demanded species were distributed to the public along the coastal belt.

3.2.2.4. Roadside planting of shade trees (Vazhiyoura Thanal Scheme): Under this scheme, planting of shade trees on roadsides with the participation of head load workers from various trade unions in the State was envisaged and during 2007 to 2009 around 1.22 lakh of seedlings were planted.

3.2.2.5. Greening Kerala Scheme (Haritha Keralam Scheme): This scheme was designed to create woodlands outside the forest areas. Under this people's programme, during 2009-2011 around 101.4 lakh seedlings have been planted in community lands, institutional lands, roadsides, railway-sides, river banks, areas surrounding ponds and lakes and other private lands including homesteads in villages of the State with the involvement of panchayaths, school children, senior students, youth organisations, religious institutions, NGOs, media establishments, civil society organisations and individuals.

3.2.2.6. Protection and Conservation of Sacred Groves: In Kerala, sacred groves represent a traditional method of forest conservation. The Government of Kerala has recognized the fact that protection and conservation of sacred groves is one option for mitigating the effects of climate change. Thus, the Kerala Forest and Wildlife Department joined hands with owners of sacred groves and local communities in implementing a new component, 'Protection and Conservation of Sacred Groves' under the Central Government sponsored scheme 'Intensification of Forest Management'.

CONCLUSION: The present study shows that absolute atmospheric temperature as well as form, timing and amount of precipitation over time in Kerala are changing considerably. Increase in temperature with decrease in wet days during southwest monsoon and post-monsoon seasons can affect both productivity and phenological patterns of the forest. Several forest conservation measures taken up in the State also represent unintentional and intentional activities to mitigate the effects of climate change. By strengthening or continuing with programmes like Kerala Social Forestry Project and protection and conservation of sacred groves, adverse effects of climate change can be mitigated. With its broad experience in the promotion of forest conservation, participatory forest management and forest governance, the Kerala Forest Department should continue to facilitate comprehensive approaches to the role of forests in climate change

mitigation. In addition, robust research programmes to develop appropriate forest policies and practices relating climate change mitigation are also required.

4. ACKNOWLEDGEMENTS: This project was sponsored by the Kerala Forest Department (KFD) under the Kerala Forest Development Fund (KFDF). Thanks are due to K.V. Sankaran, Director, KFRI for his support and encouragement.

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