Aplinkos tyrimai, inžinerija ir vadyba, 2013. Nr. 1(63), P. 37-47
Environmental Research, Engineering and Management, 2013. No. 1(63), P. 37-47
http://erem.ktu.lt

ISSN 1392-1649 (print)
ISSN 2029-2139 (online)

Trend in GHG Emissions from Northeast and West Coast Regions of India

Tongdi Jamir[1] **and Uday Shankar De**[2]
[1]*Department of Environmental Science, University of Pune, India*
[2] *Visiting faculty, Central Training Institute, Indian Meteorological Department, India*

crossref http://dx.doi.org/10.5755/j01.erem.63.1.2793

(received in November, 2012, accepted in March, 2013)

Climate change due to increasing concentrations of greenhouse gases (GHGs) has emerged as a serious global environmental issue. An attempt has been made to assess the GHG emissions in two geographical regions of India i.e. the Northeast Region (NER) and the West coast Region (WCR) during the period of 1980-2005. The analysis reveals an increasing trend in GHG emissions from the study regions except for CH_4, which shows a decreasing trend in Goa and Kerala. As far as state wise GHG emissions are concerned; Assam ranks first in CO_2, CH_4 and N_2O emissions from the NER. Konkan ranks first in CO_2 and CH_4 emissions, while Kerala ranks first in N_2O emissions representing the WCR. Analysis of the compounded annual growth rate reveals higher for the WCR in CO_2 and CH_4 emissions except N_2O where the NER remains the highest. In order to find the association between GHG emissions and climatic response, the mean air temperature for 26 stations in both regions were subjected to trend analysis. The findings show warming trends in the mean air temperature over a majority of the stations indicating a possible role by increased GHGs. Further, the analysis reveals a positive correlation of population and GHG emissions significantly at 99% for both the regions.

Keywords: *Climate Change, Correlation, Greenhouse gas, Population, Trend.*

1. Introduction

Climate change due to increasing concentrations of greenhouse gases (GHGs) in the atmosphere has emerged as a serious global environmental issue and poses a threat and challenge to mankind. The impact of human activities on climatic system is indisputable. But these socio-economic activities are related to the development which is also a key to the living being of global population. According to the World Meteorological Organization, the globally averaged mixing ratios of CO_2, CH_4 and N_2O reached a new height in 2008 with CO_2 at 385.2 ppm, CH_4 at 1797 ppb and N_2O at 321.8 ppb. According to IPCC (1996), CO_2, CH_4 and N_2O are the key GHGs that contribute to 60%, 15% and 5%, respectively, towards global warming.

Several researchers have documented the effects relating to emissions of CO_2, CH_4 and N_2O from energy and agricultural sectors on global and regional context. Many researchers in India have estimated emission inventories of different GHGs (Mitra 1991; ALGAS 1998; NATCOM 2004). Garg et al. (2001a) reported the emission growth of 6.3%, 1.2%, and 3.3% from CO_2, CH_4 and N_2O, respectively, in India during the period of 1990 - 1995. Gupta (2002) found an increase in CH_4 flux by 1.7 times relative to low soil organic carbon in the rice ecosystem. Investigation on N_2O emissions from India reveals that during the last 40 years, N_2O has increased by ~6.1 times from ~0.048 to 0.294 Tg (Prasad et al. 2003). On the other hand, maximum CH_4 is emitted from indigenous male cattle as reported by Singhal et al. (2005). In the study on the GHG emission scenario, Shukla (2006) found a secular increase in CO_2 and CH_4 emissions in all the scenarios; however N_2O grows faster than CH_4 emissions. In the findings of Sharma (2006), GHG emission grew at the rate of 4% per annum during the year 1990 and 2000. Further, Garg et al. (2006) reported that during the period of 1985 to 2005 the Compound annual growth rate (CAGR) was 5.3, 0.8 and 3.2% for the CO_2, CH_4

and N_2O, respectively, in the country. The latest report on GHG emission for the country reveals a significant growth in cement production (6.0%), electricity generation (5.6%) and transport (4.5%) during 1994-2007. However, there is a decrease in CH_4 emissions from agricultural sector. GHG emissions from energy, industry, agriculture, and waste sectors constituted 58%, 22%, 17% and 3% of the net CO_2 eq emissions, respectively (MoEF 2010).

Ogbeide (2010) developed an economic model to reduce CO_2 emissions with the least cost from cement plants, thereby reducing the emission by 23.6% per tonne of cement produced. Matson (2003) investigated N_2O flux from polluted aquatic systems in low-latitude regions. They found N_2O fluxes during green algae blooms and canals receiving pig-farm and urban inputs. Yan et al. (2005) developed a statistical model to relate CH_4 flux in the rice-growing season, the results showed that organic amendment and water regime were the top two controlling variables. The annual growth of CH_4 from enteric fermentation and manure management in China were 2.2% and 3.5%, while it is 3.0% for N_2O emission from manure management as reported by Zhou et al. 2007. Yang et al. (2009) have investigated the CH_4 and N_2O emissions from paddy fields in Taiwan and have found that intermittent irrigation and appropriate application of nitrogen fertilizer significantly reduces CH_4 emissions. Zhang et al. (2009) reported that a higher CH_4 emission in China was linked to gleyed paddy and alluvial plain soils while the lowest emission rate is associated with degleyed paddy and low mountainous-hilly soils.

Industrialization, urbanization, population growth and exploitations of natural resources will have an impact on the environment. The continued increase in the concentration of GHGs in the atmosphere will lead to climate change affecting humanity, flora and fauna. These two studied regions have huge coal, oil and natural gas reserves for thermal and cement plants generation, followed by a growth in number of vehicles, too. These regions experience tropical rainy climate and hence fit for paddy cultivation. The presence of tribal population with different religious and ethnic background has made the livestock rearing the dominant economic activity. Considering the above situation, estimation of GHG is essential, which will ultimately have an impact on the climate. In the light of the above discussions two extreme regions of India, namely the WCR and NER, (Figure 1) have been selected for this study.

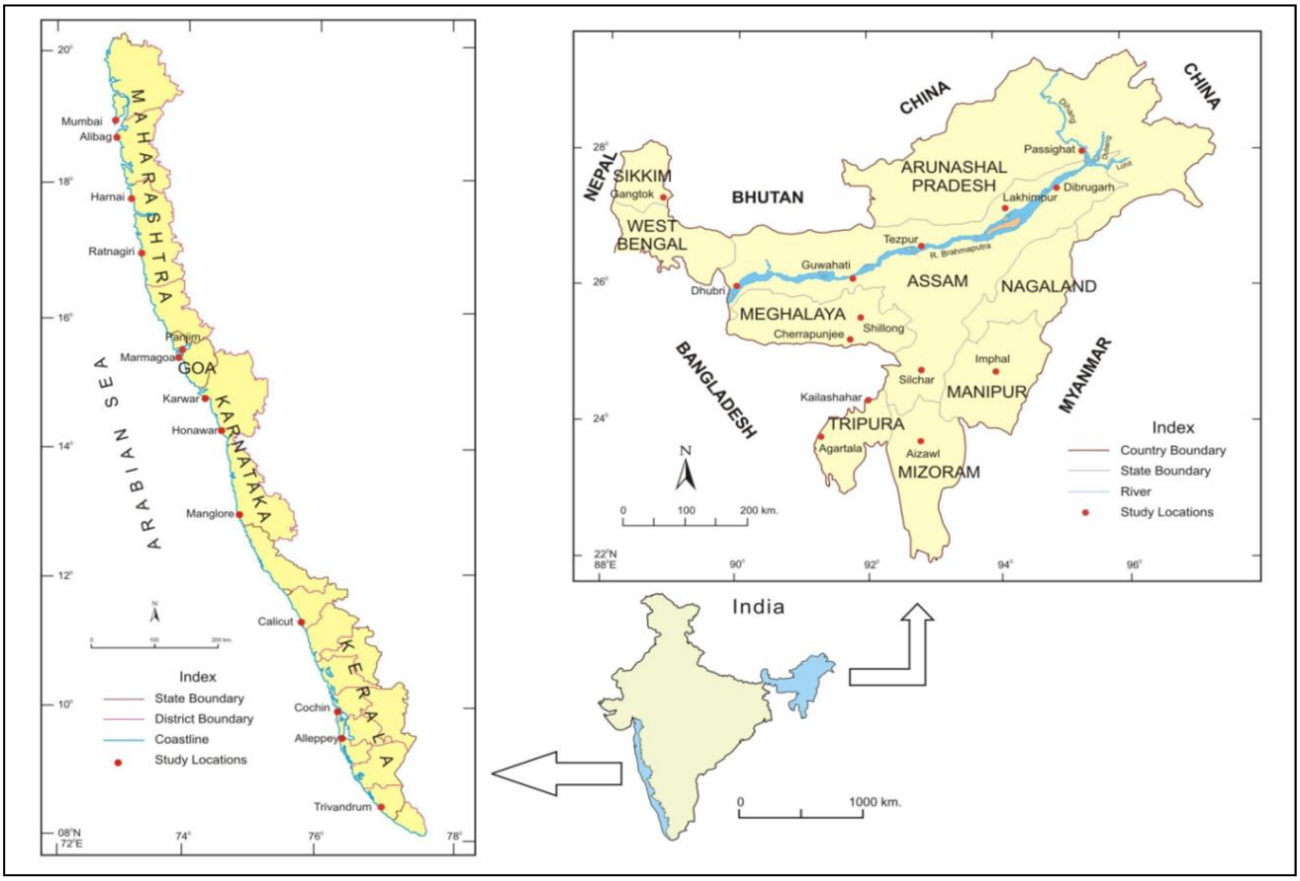

Fig.1. Study Area of NER and WCR

In the earlier scientific studies trends were not discussed, in this paper an attempt has been made to examine the trend in GHG emissions and climate response in terms of a climatic parameter. This has been achieved by the following objectives:

– to assess the trends in GHG emissions from the main sources on annual scale;
– to correlate the population growth with that of the GHG emissions ;
– to evaluate the GHG emissions and climate response using a climatic parameter.

2. Materials and methods

Annual activity data of coal consumption (cement and thermal power plants), diesel and petrol (transportation), livestock (population), paddy cultivation (hectares), liquefied petroleum gas (tonnes) and fuel wood consumption (tonnes), nitrogen fertilizers (tonnes) were collected for estimating CO_2, CH_4 and N_2O. The activity data from various sectors during the period of 1980-2005 were collected from the published documents of the Government of India, the State Government and reputed organizations such as the Centre for Monitoring Indian economy (CMIE), the Fertilizers Association of India (FAI), the Agricultural Statistics at a glance (Ministry of Agriculture, the Government of India), TEDDY- The Energy Data Directory and Yearbook. The activity data prior to 1980 were insufficient from most of the sectors, therefore the data for this study were used from 1980 onwards.

To estimate the GHG emissions from various sectors the IPCC 1996 methodology was used. The IPCC 1996 methodology implies that the activity data for a source category are multiplied by a respective emission factor to obtain emissions from that source category for a specific gas. The indigenously developed emission factors are used in this study. However, the IPCC default emission factor was used where the emission factor was not available. To calculate the total emission of a gas from all its source categories, the emissions are summed up over all source categories as follows: (Eq.1)

$$\text{Emissions of a Gas} = \Sigma \text{ Category } A \times EF \qquad (1)$$

where,
Emissions of a Gas = emissions of a given gas from all its source categories;
A = amount of individual source category utilized;
EF = emission factor of a given gas by type of source category.

For calculating CO_2, CH_4 and N_2O emissions from energy, transportation and agricultural sectors, respectively, the emission factors are given below (Table 1 a-e).

Table.1 (a). Emission Factors for Estimating CO_2

Sector	Types	NCV	Emission factor	References
		Energy sector		
Cement plant	Non-coking coal	19.63±0.4 TJ/Kt	26.13 t CO_2/TJ	Natcom, 2004
Thermal power plant	Non-coking coal	19.63±0.4 TJ/Kt	26.13 t CO_2/TJ	Natcom, 2004
		Transport sector		
2/3& 4 Wheeler	Petroleum	44.80 TJ/10^3 tons	18.9 t C/TJ	IPCC, 1996
LCV MCV & HCV	Diesel	43.33 TJ/10^3 tons	20.2 t C/TJ	IPCC, 1996

Note: NCV-Net Calorific Value; LCVMCV&HCV-Light Commercial Vehicle, Medium Commercial Vehicle & Heavy Commercial Vehicle

Table.1 (b). Emission Factors for Estimating CH_4

Livestock (*After* Singhal, K.K., *et al*, 2005)			
Sector	Emission factor	Sector	Emission factor
	Crossbred (Male)		Crossbred (female)
Adult	34.05 CH_4/head/year Kg	Adult	38.83 CH_4/head/year Kg
1-2 ½ years	19.67 CH_4/head/year Kg	1-2 ½ years	21.31 CH_4/head/year Kg
0-1 years	9.02 CH_4/head/year Kg	0-1 years	9.71 CH_4/head/year Kg
	Indigenous (Male)		Indigenous (Female)
Adult	29.42 CH_4/head/year Kg	Adult	35.97 CH_4/head/year Kg
1-3 years	16.36 CH_4/head/year Kg	1-3 years	15.39 CH_4/head/year Kg
0-1 years	7.60 CH^4/head/year Kg	0-1 years	7.39 CH_4/head/year Kg
	Buffalo (Male)		Buffalo (Female)
Adult	54.28 CH_4/head/year Kg	Adult	76.65 CH_4/head/year Kg
1-3 years	14.78 CH_4/head/year Kg	1-3 years	17.35 CH_4/head/year Kg
0-1 years	5.09 CH_4/head/year Kg	0-1 years	6.06 CH_4/head/year Kg

To determine the trend in GHG emissions, linear regression coefficients were used (Eq.2). For finding the level of significance at 0.05 and 0.01, Student's t-test was employed (Eq.3). Time series graphs were plotted for the entire periods of record.

This is a simple model which is expressed in the form of an equation:

$$Y = a + bX \qquad (2)$$

The statistical significance was determined by the Student's t-test in the following way:

$$t = \sqrt{\frac{r^2(N-2)}{1(1-r^2)}} \qquad (3)$$

Table.1(c). Emission Factors for Estimating CH_4

Paddy cultivation (Lowland and upland) (Reference- Natcom 2004)			Energy sector (Reference- IPCC, 1996)		
Sector	Types	Emission factor	Sector	Types	Emission factor
Rice cultivation	Continuously flooded	29.2 g/m^2 (Avg)	Household	LPG	0.2 g/Kg
Rice cultivation	I. Single aeration	9.12 g/m^2 (Avg)	Household	Fuel wood	0.006 Kg Kg^{-1}
Rice cultivation	I. Multiple aeration	3.6 g/m^2 (Avg)			
Rice cultivation	RF L & U (flood prone)	19.0±6.0 g/m^2 (Avg)			

Note: I- Intermittently, RFL-Rain fed lowland & U-Upland

Table.1 (e). Emission Factors for Estimating N_2O

Agriculture sector			
Sector	Types	Emission factor	References
Agriculture	Nitrogen Fertilizer	0.0125 Kg N^2O-N/Kg	IPCC,1996

Apart from the activity data for estimating the GHG emission, meteorological data the mean air temperature have been utilised in the study. Annual and seasonal time series were prepared from the monthly values. The monthly mean temperatures for 13 stations each in the NER and the WCR during the period ranging from 1901-2006 were used. The monthly mean air temperature values pertaining to winter (January-February), pre-monsoon/summer (March–May), monsoon (June–September), post-monsoon (October–December) and annual values were calculated over each station. The data were obtained from the Indian Meteorological Department (IMD), Pune, India. To determine the significance of the trend, Mann Kendall tau rank correlation coefficient (Kendall's τ) was used.

The Kendall tau rank correlation coefficient (Eq. 4) has been used to analyse the trends in temperature and rainfall parameters. The trends are tested at 95% and 99% level of confidence.

Relative values of all the time series under analysis are arranged by their ranks in a way that each term is assigned a number ranging from 1 to N (4).

$$p = \sum_{i-1}^{n-1} n_i \qquad (4)$$

Where

n_i = number of later terms whose value exceeds n_i (the elements) or k_i (the rank); then (5)

$$r = \left\{ \frac{4p}{N(N-1)} \right\} - 1 \qquad (5)$$

If the value of 'r' is +1, there is a perfect systematic positive trend, and if 'r' is -1, there is a systematic negative trend. The value of 'r' will be very near to zero when no significant trend is seen. The value of 'r' thus can be used as the basis of a significant test by comparing it with (6)

$$r(t) = \pm t_g \sqrt{\frac{4N+10}{9N(N-1)}} \qquad (6)$$

N-total number of elements in the time series, where t_g is the desired probability point of the Gaussian normal distribution. In the present study, t_g at 95% and 99% probability point has been taken for comparison. The results are discussed in the following paragraphs.

3. Results and discussion

3.1. Trends in carbon dioxide emissions

The annual emissions of CO_2 from different sources such as thermal power plant, cement plant and transportation sectors are reported in Table 2. In the NER, thermal and cement power plant are located at Assam only, these data are not available for the rest of the states, for this reason petrol and diesel consumption data have been used.

The Table 2 indicates an increasing trend in CO_2 emissions in all the Northeast states. The trends are significant at 99% level except for Assam. The maximum emissions are from the state of Assam where it is increasing by 48,597 Gg/year, while the lowest emission comes from Mizoram (2,013 Gg/year). The maximum CO_2 in Assam is attributed by the emission from thermal plant. For the rest of the states, the major emissions come from transportations sector consuming diesel followed by petrol. The least amount of emission from Mizoram can be ascribed to the less number of vehicles as compared to the rest of the states. During the last 25 years, every year 1,011motor vehicles has increased in Mizoram as compared to 20,159 in Assam.

Table.2 Trends in CO_2 Emissions (NER & WCR)

	List of sectors				Total CO_2 emissions		
NER	TPP	CP	Petrol	Diesel	Slope	R^2	SL
AP			1458.x	3751.x	5210.x	0.948	+**
Assam	16012x	2393.x	6233.x	17839x	48597x	0.310	+**
Meghalaya			2222.x	11553x	13776x	0.916	+**
Nagaland			815.8x	1886.x	2702.x	0.961	+**
Manipur			861.3x	1413.x	2274.x	0.917	+**
Mizoram			819.5x	1193.x	2013.x	0.949	+**
Tripura			1277.x	2731.x	4008.x	0.986	+**
Sikkim			496.8x	2230x	2726.x	0.796	+**
WCR							
Konkan	38844x	1914.x	30095x	80480x	50141x	0.993	+**
Goa			6531.x	17436x	23968x	0.953	+**
CK			3993.x	13894x	17888x	0.982	+**
Kerala		3360.x	42587x	92700x	13864x	0.982	+**

*Note: AP-Arunachal Pradesh, CK-Coastal Karnataka, TTP-Thermal Power plant, CP-Cement Plant, SL-Significant level, * Indicate 0.05% & ** 0.01% Significant level*

In the WCR, the CO_2 emissions from various sectors have been computed for the four sub-regions, namely Konkan, Goa, Coastal Karnataka (CK) and Kerala. In this region, thermal power stations are situated at Konkan area only, while the cement plants are found in Konkan and Kerala. These data are not available for Goa and CK, thus petrol and diesel consumption data have been used.

It is clear from Table 2 that all the sub-regions in the WCR indicate the trend increasing significantly by 99%. The highest rate of increase is reported at Konkan (50,141Gg/year), while the lowest is contributed by Kerala (13,864Gg/year). The maximum increase at Konkan is attributed by the emissions from thermal plant. This can be attributed to higher consumption of electricity from the most populated Indian metro-Mumbai metropolitan area (22, 252, 912 people, 2011 Census). In addition to this, the motor vehicles in Konkan have increased at a faster rate (89, 457/year) as compared to Kerala (10, 649/year).

Table. 3. Trends in CH_4 Emissions (NER & WCR)

	List of sectors				Total CH_4 emissions		
NER	Livestock	Paddy	LPG	Fuel wood	Slope	R^2	SL
AP	207.8x	0.394x	3.669x	0.037x	0.716x	0.994	+**
Assam	4476.x	-0.016x	59.27x	0.797x	6.510x	0.961	+**
Meghalaya	221.7x	0.075x	3.996x	0.147x	0.529x	0.985	+**
Nagaland	362.2x	0.066x	4.567x	0.111x	0.636x	0.921	+**
Manipur	110.8x	0.012x	7.001x	0.148x	0.419x	0.972	+**
Mizoram	0.262x	0.305x	6.732x	0.261x	0.485x	0.963	+**
Tripura	110.3x	0.824x	7.010x	0.018x	1.344x	0.996	+**
Sikkim	-1.862x	0.031x	1.493x	0.037x	0.079x	0.901	+**
WCR							
Konkan	543.0x	0.153x	221.3x	0.244x	5.619x	0.940	+**
Goa	-46.82x	0.594x	15.96x	0.037x	0.921x	0.92	+**
CK	91.13x	0.531x	24.39x	0.198x	1.345x	0.921	+**
Kerala	-1637.x	-1.020x	173.4x	1.186x	2.194x	0.509	+**

*Note: AP-Arunachal Pradesh, CK-Coastal Karnataka, SL-Significant level, * Indicate 0.05% & ** 0.01% Significant level*

3.2. Trends in methane emissions

Methane emissions from two important sources viz., agriculture (paddy cultivation and livestock) and energy (fuel wood and LPG) were considered. For paddy cultivation, emissions were calculated from different water regimes- rain fed, continuously flooded, intermittently flooded with single aeration and multiple aerations. On the similar line, the detailed information about emissions of CH_4 from the livestock population (cattle, crossbred and buffaloes) was collected. There are two sources from which CH_4 is emitted from livestock i.e., enteric fermentation and manure management. However, due to unavailability of the data from the manure management, the CH_4 emissions are estimated based on enteric fermentation only. The state wise trend in CH_4 emissions from agriculture and energy sectors are reported in Table 3. The Table indicates that all the states in the NER show an increasing trend significant at 99%. The maximum rate of an increase is observed at Assam (6.510 Gg/year), while the lowest is at Sikkim (0.079 Gg/year). The increase in Assam is contributed from the paddy cultivation followed by livestock, while the emissions from fuel wood and LPG are much smaller. The smallest emission from Sikkim is due to the decline in livestock population. The detailed analysis reveals that indication of the proportion of cross bred population showing an increase is not significant, on the other hand the population of indigenous cattle and buffaloes has drastically decreased this might be responsible for the minute emission of CH_4 in this state.

In the WCR, all the sub-regions show increasing trend significant at 99%. The faster rate of an increase in CH_4 is reported at Konkan (5.619 Gg/year), while the least is at Goa (0.921 Gg/year). The major contribution in the WCR comes from livestock population. When we compare the CH_4 emissions from a livestock sector, there is a bigger emission from Konkan as compared to Goa.

3.3. Trends in nitrous oxide emissions

The third important GHG considered in this study is N_2O. This emission comes from agricultural soil as a result of application of nitrogen fertilizers. The trend in N_2O emissions from agriculture is computed and reported in Table 4.

Table. 4. Trends in N_2O Emissions (NER & WCR)

NER	Slope	R^2	SL
AP	0.000x	0.947	+**
Assam	0.042x	0.871	+**
Meghalaya	0.000x	0.967	+**
Nagaland	0.000x	0.982	+**
Manipur	0.008x	0.970	+**
Mizoram	0.000x	0.883	+**
Tripura	0.003x	0.946	+**
Sikkim	0.000x	0.985	+**
WCR			
Konkan	0.016x	0.965	+**
Goa	0.000x	0.722	+**
CK	0.006x	0.983	+**
Kerala	0.021x	0.948	+**

*Note: AP-Arunachal Pradesh, CK-Coastal Karnataka, SL-Significant level, * Indicate 0.05% & ** 0.01% Significant level*

The Table indicates that there is significant rise in N_2O emission from all the states in NER, however the faster rate of an increase can be seen in Assam (0.042 Gg/year), while the least is found at AP, Meghalaya, Nagaland, Mizoram and Sikkim. The increase in Assam (31.5kg/per hectare) can be attributed to the high amount of nitrogen fertilizer per hectare of the net sown area as compared to the rest of the states (22.5 kg/per hectares). For the WCR, the trend analysis reveals that N_2O shows an increase from all the sub-regions. The faster rate of an increase is found at Konkan (0.016 Gg/year) with the least being at Goa (0.000 Gg/year), this is due to the excessive use of nitrogen fertilizer in agricultural fields. The consumption of fertilizer in Maharashtra is 52.7 (representing Konkan), while in Goa it is 22 kg/per hectares of nitrogen.

3.4. Compounded annual growth rate (CAGR) in GHG emissions

Carbon dioxide. CAGR of CO_2 emissions from energy (thermal plant and cement plant) and transportation sectors (petroleum and diesel) for the NER and WCR are reported in Table 5.

Table.5. Growth rate of CO_2, CH_4 and N_2O Emissions (NER & WCR)

	CO_2					CH_4					N_2O
NER	CP	TP	Petrol	Diesel	TE(Gg) CAGR	Paddy	Livestock	LPG	Fuel Wood	TE(Gg) CAGR	TE(Gg) CAGR
AP			8.0	5.3	5.94	1.94	2.4	9.86	2.88	2.3	10.07
Assam	5.6	2.4	4.7	3.7	2.95	-0.01	1.8	19.34	2.94	0.9	10.76
Meghalaya			6.5	8.3	7.7	0.41	1.24	7.77	2.87	1.19	3.39
Nagaland			4.9	4.6	4.75	0.48	5	11.13	2.87	1.81	8.67
Manipur			4.7	3.3	3.85	0.05	0.88	12.49	2.87	0.85	8.49
Mizoram			5.0	3.9	4.28	2.14	00	12.33	2.88	2.6	12.33
Tripura			8.6	4.7	5.71	2.85	0.65	12.78	2.87	2.35	8.28
Sikkim			8.1	12.3	10.94	1.17	-0.03	6.2	2.85	0.88	2.51
WCR											
Konkan	3.6	10.8	6.1	4.4	6.64	0.31	0.61	10.42	2.88	3.09	5.71
Goa			8.5	5.4	5.59	2.02	-1.07	16.40	2.88	2.43	1.62
CK			6.3	6.3	6.34	1.47	0.24	16.28	2.88	1.57	5.6
Kerala	4.1		6.9	5.6	5.93	-1.04	-2.16	18.91	2.88	1.31	2.55

Note: AP-Arunachal Pradesh, CK-Coastal Karnataka, CP- Cement Plant, TP-Thermal Plant, TE-Total Emissions; CAGR-Compounded Annual Growth Rate

The above Table indicates that CAGR of the total CO_2 emissions from different states in NER depicts the highest rate of 10.9% increase at Sikkim, while the lowest is observed in Assam (2.95%). The highest growth rate can be attributed to the CO_2 emissions from the consumption of diesel (12.3%). Further, there is a substantial increase in transportation (663vehicles/year) at Sikkim, which contributes to CO_2 emissions. While the lower rate of growth in Assam can be attributed to the decrease in emissions from thermal power plant (2.4%), which is due to the closing down of the plants. The thermal plant boilers are corroded due to high sulphur content in the coal; there are also difficulties in transportation of coal, high cost of production and mechanical problems. The above Table also reveals that in Assam, the growth rate is higher for cement plant (5.6%) as compared to other sectors; this is also reflected in the production of cement. From Table 5, it is observed that there is a faster growth rate in petrol as compared to diesel for all the states except Sikkim, where that of diesel increased by 12.3%. The highest growth rate of 8.6% in petrol is reported at Tripura, while the lowest 4.7% is at Assam and Manipur.

In the WCR, the total emission growth rate is highest at Konkan (6.64%), while the lowest is reported at Goa (5.59%). This increase is due to thermal power plant (10.8%), whereas at Goa, it is due to the diesel consumption (5.4%). As in NER, WCR also behaves in the same pattern, the maximum growth rate is found in petrol followed by diesel. The highest growth rate in petrol is reported at Goa (8.5%), while the lowest at Konkan (6.1%). It is to be noted that the CO_2 emissions from petrol consumption are increasing by 8.5% per year at Goa, the same can be supported by the vehicles population, which has increased in leaps and bounds (18, 155/year).

Methane. CAGR of CH_4 emissions estimated from two important sources - agriculture (paddy cultivation and livestock) and energy (fuel wood and LPG) are reported in Table 5. The above Table indicates that CH_4 emission growth rates are highest at Tripura (2.35%), while Sikkim accounts for the lowest (0.88%). The highest growth rate in Tripura can be attributed to the LPG (12.78%), whereas for Sikkim it is due to the decrease in livestock rearing (-0.03%). Amongst different sources of the CH_4 emissions; LPG accounts for the highest growth rate, where it varies between 19.34% per annum at Assam to 6.2% per annum at Sikkim. The faster growth rate is due to the phenomenal increase in the decadal population growth (18.85 %) (census 2001).

In the WCR (Table 5), CAGR is highest at Konkan (3.09%/year) and lowest at Kerala (1.31%/year). The higher growth is ascribed to an increase in LPG (10.42%), while the lowest is due to the decrease in paddy (-1.04%) and livestock rearing (-2.16%). Amongst different sources of CH_4 emissions the highest growth rate is noticed in LPG sectors, where it ranges from 10.42% to 18.91% at Konkan and Kerala, respectively. The growth rate at Konkan can be attributed to the high population of Mumbai Metropolitan Area. The growth rate from livestock population shows decrease by -2.16% at Kerala to -1.06% at Goa. There has been a drastic reduction in the availability of fodder for cattle, thereby restricting the number of cattle (Krishnakumar R 2003).

In the case of paddy cultivation, there is a decrease in the growth rate at Kerala by -1.04%. This can be attributed to the changes in agricultural land use, where the rice area dropped by 60% between 1975 and 2003, while the cultivation of coconut, rubber, arecanut and banana increased during 1955 to 2003 (Kumar 2005). There cropping is converted into cash crops as the income from the latter is high. Apart from this, the urban area is increasing by 66 sq km/year during the period from 1961 to 2001.

Nitrous Oxide. N_2O emissions come from agricultural soil due to the excess use of nitrogen fertilizers. This CAGR of N_2O emission from agriculture in the NER and the WCR is reported in Table 5. The above Table shows that Mizoram accounts for the highest growth rate (12.33%), while Sikkim denotes the lowest (2.51%). The highest growth rate can be attributed to higher consumption of nitrogen fertilizer per hectare (6.2 kg), while the lowest (2.5 kg) is due to the practice of traditional system of agriculture. Apart from this, there is a number of factors limiting the expansion of fertilizer use - defective distribution system, poor transport & communication system and inadequate institutional credit. In the WCR, the examination of CAGR reveals a faster rate of an increase in N_2O at Konkan (5.71). This is due to the higher consumption of nitrogen fertilizer per hectare (107.4 kg/ha), while Goa contributes to the lowest (1.62 kg).

3.5. Greenhouse gas emissions and climatic response

As observed in the earlier paragraphs, GHG emission has increased in the study regions. Generally, this increase would lead to warming on the global scale, but their regional ramifications are not fully understood. Keeping these uncertainties at the background, an attempt has been made to highlight the climate response in both regions, though it may not be fully associated with the emission growth there. For this, the mean air temperature for 13 stations each from the NER and WCR were used to find out the trend, and the results are reported in Table 6 along with the significant values. The Table indicates that 10 out of 13 stations show an increasing trend in the annual mean temperature. Three stations show significantly increasing trend, while 3 stations indicate quite an opposite a significantly decreasing trend.

Table. 6. Trend in the mean surface air temperature (NER & WCR)

NER	Data period	Annual	Winter	Summer	Monsoon	PM
Pasighat	1957-1993	+	+	-	+	+
Dibrugarh	1970-2000	+**	+	+	+	+**
Lakhimpur	1954-1993	+	+	+	+	+*
Tezpur	1940-1996	-**	-	-	-*	-
Guwahati	1903-2000	+	+	+*	-	+*
Dhubri	1946-1993	-*	-**	-	+	-**
Silchar	1951-1994	-**	-**	-**	-	-*
Gantok	1970-2000	+	-	-	+	+
Shillong	1903-2000	+**	+*	+	+	+**
Cherrapunjee	1903-2000	+	-	+	-	+
Imphal	1954-1998	+	+**	+	+	+
Kailashahar	1959-1996	+*	+	+	+*	+*
Agartala	1953-1992	+	-	-**	+**	+
WCR						
Mumbai	1901-2006	+**	+**	+**	+	+**
Alibag	1939-2002	+**	+	+	+**	+**
Harnai	1970-2002	+*	+	-	+*	+**
Ratnagiri	1901-2005	+**	+*	+	+	+**
Panjim	1964-2003	+**	+**	+**	+**	+*
Marmagoa	1970-2001	+	+	-	+	+
Karwar	1915-2003	+**	+**	+**	+**	+**
Honavar	1939-2002	+**	+*	+	+*	+**
Mangalore	1901-2004	+**	+**	+	+	+**
Calicut	1901-2000	+**	+**	+**	+**	+**
Cochin	1970-2000	+	+*	+	+	+
Alleppey	1944-2000	+**	+**	+**	+	+**
Trivandrum	1901-2004	+**	+**	+**	+**	+**

*Note: PM-Post monsoon,+ - Increasing, --Decreasing, * Indicate 0.05% & ** 0.01% Significant level*

During the winter and summer seasons mixed trends (increase/decrease) are reported, however it is significant only at few stations. The monsoon season is dominated by an increasing trend in 9 stations significant at 2, while 4 stations show a decreasing trend significant only at one. During the post monsoon season, 10 stations indicate an increasing trend in the temperature significant at 5, while 2 out of 3 stations show a significantly decreasing trend. The NER reflects warming trends in the mean temperature over the majority of the stations indicating possible role by increased GHGs. However, there are some cool pockets, where a cooling trend is observed. This reveals that other than GHG emissions, namely, local factors such as forest cover, cloud cover and rainfall etc may affect the temperature trends on the spatial patterns.

In the WCR, all 13 stations indicate a significantly increasing trend at 11 stations. It is observed that during all seasons there is an increasing trend significant by 95% and 99% except at 2 stations during the summer season. Since GHG emission shows an increasing trend, there appears a close association with the warming during all seasons. From these assessments, it is interesting to know that the climatic parameters like the mean air temperature have changed in majority of the stations in the WCR, as compared to the NER.

Our findings are in general agreement with that of Rupa Kumar et al. (1994), where they have identified an increase in the mean temperature over India due to an increase in the maximum temperature. The trends in the mean temperature confirm the findings of Kothawale et al. (2010). In their studies on maximum and minimum temperature data over India during the period of 1901–2007 they reported that annual mean maximum and minimum temperatures showed significant warming trends of 0.51°C, 0.72°C and 0.27°C (each 100 year), respectively. This warming was mainly due to the increasing temperatures in winter and post-monsoon seasons. The above researchers have concluded that the mean temperature has increased over India sub continent, however they have not identified the trend in GHG emissions and its response to climate.

3.6. Population growth and greenhouse gas emissions

Population is one of the primary factors influencing urbanization and industrialization, which are linked with economic growth. All of these have direct implications for energy/agricultural production and its consumption. The GHG emissions from the urban areas (e.g. industries and transportation) and rural areas (e.g., agriculture) have emerged as a more serious issue, because it has increased simultaneously with an increase in population. The general trend is that with the growth of the population there is an increase in economic activities and in proportion GHG emissions also increase. The above findings also conclude that there is an increasing trend in GHG emissions from all the sources in the study areas except for CH_4 in the WCR (Table 7).

Table. 7. Trend in GHG emissions from the study regions on the Annual Scale

CO_2	Thermal Power Plant	CH^4	Livestock
WCR	y = 38844x + 1E+06	WCR	y = -1.041x + 223.7
NER	y = 16012x + 3E+06	NER	y = 5.488x + 246.3
	Cement Plant		Fuel Wood
WCR	y = 8511.x + 32410	WCR	y = 1.666x + 38.02
NER	y = 5754.x + 64149	NER	y = 1.558x + 36.51
	Petrol		LPG
WCR	y = 83207x + 22405	WCR	y = 9.197x - 27.32
NER	y = 14186x + 14748	NER	y = 1.981x - 7.447
	Diesel		Paddy
WCR	y = 175598x + 1E+06	WCR	y = 1.693x + 570.6
NER	y = 42599x + 493710	NER	y = 0.258x + 138.3
N_2O	Nitrogen fertiliser		
WCR	y = 0.044x + 0.788	NER	y = 0.057x - 0.114

In order to understand whether there is any association of an increase in GHG and population growth; the correlation technique has been used and reported in Table 8. This Table indicates that in the NER and WCR, CO_2, CH_4 and N_2O show positive correlation with the population growth. The results are significant at 99% level in all the states. Thus, there is a link between increasing consumption, population growth and GHG emissions.

Table. 8. Correlation of GHG emissions and population in the study areas

NER	Slope	R^2
AP	y = 4.289x + 49237	0.945
Assam	y = 2.827x + 1E+07	0.313
Meghalaya	y = 3.417x + 1E+06	0.927
Nagaland	y = 22.59x - 21256	0.905
Manipur	y = 18.05x + 62210	0.919
Mizoram	y = 9.259x + 24764	0.952
Tripura	y = 13.42x + 2E+06	0.963
Sikkim	y = 3.608x + 33454	0.838
WCR		
Konkan	y = 0.782x + 1E+07	0.982
Goa	y = 0.700x + 91750	0.961
CK	y = 3.441x + 3E+06	0.984
Kerala	y = 2.255x + 2E+07	0.973

Note: AP-Arunachal Pradesh, CK-Coastal Karnataka

Some researchers have investigated the association of population with GHG emissions. Their studies show similarities with our results. Hamilton (2000) found strong correlation between changes in population and environmental impact in OECD countries over the period of 1982-1997. Their findings show a high correlation with GHGs. Marland et al. (2007) have found that a larger population leads to greater emissions. On a global scale, the average per capita carbon dioxide emissions from fossil fuels vary hugely from nation to nation, but the general trend is that emissions grow proportionally with the growth of population.

4. Conclusions

In a nutshell, it can be concluded that there is an increase in GHG emissions, and this might contribute to global warming at local, regional and global levels. Further, the analysis of population growth and GHG emissions shows positive correlation. Thus, significant steps should be adapted to reduce the GHG emissions from both regions. While development is a priority for most of the regions in India and other developing countries, policy makers have to adopt eco – friendly/ green technologies.

According to the Census 2011, in the NER, the population density is highest in Assam (397) followed by Tripura (350). A decadal growth rate (2001-2011) is highest in Meghalaya (22.8%), followed by Arunachal Pradesh (25.9%) and Mizoram (22.8%). In the WCR, the growth of population during the last decade (2001-2011) is less as compared to the NER, in Konkan (8.38%), Goa (8.2%), CK (7.28%) and Kerala (4.9%). However, the highest density of population is reported at Mumbai and Mumbai suburb with 48,215 and 19,255, respectively. For this reason the family welfare policy and diversification of industries in the area are needed, which will ultimately reduce the population growth rate.

The forest cover in the NER is 66% of the geographical area as against 21.05% at all India level (FSI 2011). The percentage area is high in all states except Sikkim (47.34%) and Assam (35.28%). In the WCR, the forest cover is lowest at Konkan 31.21% as compared to Goa (59.94%), CK (64%) and Kerala (44.44%). Carbon sequestration methods like planting of tropical fast growing trees should be encouraged for offsetting the increase emissions.

Thirdly, environmental education and awareness campaign reaching the rural and urban people will reduce environmental damages.

Acknowledgements

The authors are thankful to the Energy Research Institute, New Delhi, the Ministry of Forest and Environment and also the Ministry of Agriculture, the Government of India, New Delhi for allowing us to collect the relevant data for the present work. The authors are grateful to Sumana Bhattacharya (Winrock International, New Delhi) for fruitful discussion.

References

ALGAS.1998.India National Report on Asia Least cost greenhouse gas abatement strategy. ADB and UNDP, Manila, Philippines

Agricultural Statistics at a glance MoA. 1994-2007. Directorate of Economics and Statistics, Department of Agriculture and Cooperation (DAC), Ministry of Agriculture, Government of India

Hamilton, C. 2000. Applying the IPAT formula Population growth and greenhouse gas emissions in OECD countries- A paper to the Conference of the International Society for Ecological Economics Australian National University, 6th July 2000, The Australia Institute, Department of Premier and Cabinet, NSW.

CMIE.1996-2007. India's Energy Sector. Center for Monitoring of Indian Economy, Mumbai, India

Census of India. 2011. Provisional Population Totals India Series 1. Office of the Registrar General & Census Commissioner, India, Government of India, New Delhi

FAI. 1993-2007. Fertilizers and Allied Agricultural Statistics. Fertilizer Association of India, New Delhi

FSI. 2011. State of the forest report 2011. Forest survey of India, Ministry of Environment and Forest, Government of India, Dehradun

Garg, A., Bhattacharya, S., Shukla, P.R. and Dadhwal, V.K. Regional and sectoral assessment of greenhouse gases emissions in India. Atmospheric Environment, 2001a, 35, p. 2679–2695. http://dx.doi.org/10.1016/S1352-2310(00)00414-3

Gupta Prabhat, K., Sharma, C. and Sumana Bhattacharya, Mitra. Scientific basis for establishing country greenhouse gas estimate for rice-based agriculture: An Indian case study. Nutrient Cycling in Agroecosystem, 2002, 64, p.19-31. http://dx.doi.org/10.1023/A:1021117029359

Garg, A., Shukla, P.R. and Manmohan, Kapshe. The sectoral trends of multigas emissions inventory of India. Atmospheric Environment, 2006, 40, p. 4608–4620. http://dx.doi.org/10.1016/j.atmosenv.2006.03.045

http://www.censusindia.gov.in/census data 2001/projected population. pdf.

http://en.wikipedia.org/wiki/Mumbai.

IPCC. 1996. Climate Change 1995, impacts, adaptations and mitigation of climate change. Scientific – technical analysis, Intergovernmental Panel on Climate Change. Watson, R.T., Zinyowera, M.C., Moss, R.H. and Dokken, D.J. Cambridge University Press, USA

IPCC. 1996. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Cambridge University Press, New York

Krishnakumar, R. 2003. Beef without borders. Frontline, India's National Magazine from the publishers of THE HINDU, 20, 18, August 30 - September 12.

Kumar, B.M. Land use in Kerala: changing scenarios and shifting paradigms. Journal of Tropical Agriculture, 2005, 42, p.1-12.

Kothawale, D. R., Munot, A. A. and Krishna Kumar, K. Surface air temperature variability over India during 1901–2007, and its association with ENSO. Climate Research, 2010, 42, 89–104. http://dx.doi.org/10.3354/cr00857

Mitra, A.P. 1991. Greenhouse Gas Emission in India A Preliminary Report (Ed.). CSIR, June.

MoEF. 2010. India: Greenhouse Gas Emissions 2007. Indian network for Climate Change Assessment (INCCA), Ministry of Environment & Forests, Government of India

Matson, P. Patterns and controls of nitrous oxide emissions from waters draining a subtropical agricultural valley. Global Biogeochemical Cycles, 2003, 17, 3, 1080, http://dx.doi.org/10.1029/2002GB001991

Marland, G., T.A. Boden, R. J. Andres, A. L. Brenkert, and C. A. Johnston. 2007. Trends: A Compendium of Data on Global Change.Carbon dioxide Information Analysis Center, Oak Ridge National Lab, US Department of Energy, Oak Ridge, Tennessee

NATCOM. 2004. India's Initial National Communication to the United Nations Framework Convention on Climate Change (UNFCCC). Ministry of Environment and Forests, New Delhi

Ogbeide, S. O. Developing an optimization model for CO_2 reduction in cement production process. Journal of Engineering Science and Technology Review, 2010, 3, 1, p. 85-88.

Prasad, K.V., Ben, Stinner., Deb, Stinner., John, Cardina., Richard, Moore., Prabhat, K. Gupta., Harao, Tsuruta., Kiyoto, Tanabe., Badarinath, K.V.S. and Casey, Hoy. Trends in food production and nitrous oxide emissions from the agriculture sector in India: environmental implications. Regional Environmental Change , 2003, 3, p. 154–161. http://dx.doi.org/10.1007/s10113-002-0055-y

Rupa Kumar, K., Krishna Kumar K., and Pant G.B. Diurnal asymmetry of surface temperature trends over India. Geophysical, Research Letters, 1994, 21, 8, p. 677-680. http://dx.doi.org/10.1029/94GL00007

Singhal, K.K., Madhu, Mohini., Arvind, K., Jha, Prabhat., and Gupta, K. Methane emission estimates from enteric fermentation in Indian livestock: Dry matter intake approach, Current Science, 2005, 88, p.119-127.

Shukla, P.R. India's GHG emission scenarios: Aligning development and stabilization paths. Current Science, 2006, 90, p. 384-395.

TEDDY. 1993-2007. TERI Energy Data Directory and Yearbook. The Energy and Resources Institute, New Delhi

Sharma, .S, Bhattacharya, S., and Garg, A. Greenhouse gas emissions from India: A perspective. Current Science, 2006, 90, p. 326-332

Yan, X., Yagiw, K., Akiyamaw, H., and Akimoto, H. Statistical analysis of the major variables controlling methane emission from rice fields. Global Change Biology, 2005, 11, p. 1131–1141. http://dx.doi.org/10.1111/j.1365-2486.2005.00976.x

Zhou, J.B., Jiang, M.M., and Chen, G.Q. Estimation of methane and nitrous oxide emission from, livestock and poultry in China during 1949–2003. Energy Policy, 2007, 35, p. 3759–3767.

http://dx.doi.org/10.1016/j.enpol.2007.01.013

Yang, S.S., Lai, C.M., Chang, H.L., Chang, E.H., and Wei, C.B. Estimation of methane and nitrous oxide emissions from paddy fields in Taiwan. Renewable Energy, 2009, 34, p. 1916–1922. http://dx.doi.org/10.1016/j.renene.2008.12.016

Zhang, L., Yu, D., Shi, X., Weindorf, D., Zhao, L., Ding, W., Wang, H., Pan, J., and Li, C. Quantifying methane emissions from rice fields in the Taihu Lake region, China by coupling a detailed soil database with biogeochemical model. Biogeosciences, 2009, 6, p. 739–749. http://dx.doi.org/10.5194/bg-6-739-2009

Phd Tongdi Jamir – Department of Environmental Science, University of Pune, India.
E-mail: tongdi.jamir@gmail.com

Uday Shankar De – Visiting faculty, Central Training Institute, Indian Meteorological Department, Pashan, Pune, India.
E-mail: udayshankarde@gmail.com

Šiltnamio dujų emisijos Indijos šiaurės rytų ir vakarų pakrantės regionuose

Tongdi Jamir[1], Uday Shankar De[2]

[1] Aplinkos mokslų fakultetas, Pune universitetas, Indija
[2] Indijos meteorologijos skyrius, Centrinis mokymų institutas, Indija

(gauta 2012 m. lapkričio mėn., priimta spaudai 2013 m. kovo mėn.)

Didėjant šiltnamio efektą sukeliančių dujų (GHG) emisijoms, klimato kaita tapo rimta aplinkosaugine problema. Indijos Šiaurės rytų ir vakarų pakrantės regionuose buvo stengiamasi įvertinti GHG emisijų 1980–2005 m. tendencijas. Analizės rezultatai rodo, kad GHG emisijos nuolat didėja, išskyrus CH4, kurių kiekiai mažėjo Goa ir Keralos regionuose. Atlikus GHG emisijų ir temperatūros pokyčių stebėjimus, nustatyta tendencija, kad GHG emisijos daro tiesioginę įtaką klimato kaitai. Tolesnė analizė rodo, kad nuo gyventojų daugėjimo priklauso ir GHG emisijos (99 proc).