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Greenhouse Gas emissions from the field Burning of Crop residues for the state of Gujarat

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ABSTRACT

The quantity of greenhouse gases emitted and the source responsible for its emission are necessary to determine the solution for climate change and its impact. In Gujarat a large part of crop residue is burnt in the fields since the farmers do not have any worthwhile use of this waste and the combine-harvester leaves, a large part of this residue in the field itself in the form of long stems and the roots. And thus these burnings of crop residue lead to the emission of greenhouse gases. The main objective of this study was to calculate the GHG emissions from the burning of crop residues for the state of Gujarat.CO_2, CH_4 and N_2O emission from crop residue burning were calculated for the year 1980 to 2011 for the state of Gujarat. For each plant gross CO_2 equivalent emission and emission intensity (footprint) was determined for 31 years (1980 to 2011) to study an emission trend. As a result, Crop residue burning emissions are increasing by the year, but the emission intensity remains constant with the 12.54*10^{-3} Gg/ton productions respectively. This is because, the manner in which production/consumption changes over the years, in the same manner, their respective emissions also change. As the crop production increases the emissions also increases, but the emission intensity of the each crop remains the same. Thus the emission intensity of the crop residue burning shows no performance improvement from the last 30 years.

Keywords: Greenhouse Gases, Carbon dioxide, Methane, Nitrous oxide, Burning of Crop Residues.

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INTRODUCTION

Biomass burning is a global phenomenon and can be an important contributor to poor air quality worldwide (Yang *et al.*, 2008). Biomass burning includes forest fires, prescribed burning of savannas, and crop residue burning in the fields. Typically, the biomass burning intensifies in late March, reaching a maximum in May. It represents a significant source of chemically and radiatively important trace gases and aerosols to the atmosphere, thereby resulting in a large perturbation to global atmospheric chemistry (Crutzen and Andreae, 1990). This change in composition of the atmosphere may have a direct or indirect effect on the radiation balance of earth affecting its climate and contributing to global climate change (Streets *et al.*, 2003; Koppmann *et al.*, 2005).

Several researchers have estimated the emission of different species from crop residue burning using IPCC factors, but they have covered only few gaseous pollutants (N_2O, CH_4, NO_x, and SO_2) (Venkataraman *et al.*, 2006; Sahai *et al.*, 2007); or from a specific area and crop (Badrinath *et al.*, 2006; Sahai *et al.*, 2007). The total biomass burnt globally has been estimated as 6,800 (Crutzen *et al.*, 1979), 8680 (Levine, 1990), and 8600 (Andreae and Merlet, 2001) Tg/year, of which the share of the agricultural waste is estimated to be 1900, 2020 and 540 Tg/year, by the respective workers. Biomass burning, in general, continues to be associated with large information gaps and uncertainties, especially for the developing world regions like the Indian sub-continent. Streets *et al.*, 2003 have stressed the urgent need for biomass burning studies in the Indian region.

India is an agrarian economy. A vast majority of land is used for farming and a wide range of crops is cultivated in its different agro ecological regions. With a production of 93.9 million tons of wheat, 104.6 Mt of rice, 21.6 Mt of maize, 20.7 Mt of millets, 357.7 Mt of sugarcane, 8.1 Mt of oilseed crops, in the year 2011-12 (MoA, 2012), It is but natural that a huge volume of crop residue is produced both on-farm and off-farm.

The Ministry of New and Renewable Energy (MNRE, 2009), Govt. of India has estimated that about 500 Mt of crop residues are generated every year. The generation of crop residue is highest in Utter Pradesh (60 Mt) followed by Punjab (51 Mt) and Maharashtra (46 Mt). The cereal crop (rice, wheat, maize, millets) contributes to 70%, while rice crop alone contribute 34% to the crop residues (MNRE, 2009: Pathak *et al*., 2009) had estimated that, 28.73 Mt crop residues has been generated from the state of Gujarat out of 3.81 Mt crop residues has been burnt in the field.

Nivetan *et al*., 2014 estimated that the generation of cereal crop residues was highest in the states of Uttar Pradesh (72 Mt) followed by Punjab (45.6 Mt), West Bengal (37.3 Mt), Andhra Pradesh (33 Mt) and Haryana (24.7 Mt). Uttar Pradesh contributed maximum to the generation of residue of sugarcane (44.2 Mt) while residues from fibre crop was dominant in Gujarat (28.6 Mt) followed by West Bengal (24.4 Mt) and Maharashtra (19.5 Mt). Rajasthan and Gujarat generated about 9.26 and 5.1 Mt residues, respectively from oilseed crops.

FBCR (Field Burning of Crop Residue) contributed about 44 and 14% of the non-biofuel biomass and total biomass burning, respectively in India in the year 2000. The total dry residue generated are estimated as 217, 239 and 253 Tg, of which 45, 60 and 63 Tg of dry biomass are estimated to be subjected to FBCR in the years 1994, 2005 and 2010, respectively. Wheat and rice crops together accounted for about 76% of this. Burning of such huge amount of biomass is estimated to emit 22.4, 24.4 and 26.1 Tg of carbon; 0.30, 0.33 and 0.35 Tg of nitrogen oxide; 4.18, 4.59 and 4.86 Tg carbon dioxide equivalent of greenhouse gases (GHG, viz., CH_4 and N_2O; which is over 1% of the Indian agriculture sector GHG emissions); 2951, 3,240 and 3,431 Gg of CO; and 120.8, 132.9 and 140.6 Gg NO_x emissions in 1994, 2005 and 2010, respectively (Shivraj *et.al.,* 2010).

Shivraj *et al*., 2010 have calculated the methane emission from field burning of crop residue. The FBCR in India in the year 2000 contributed an estimated 1.8% and 13.6% of the Asian and Indian CH_4 emissions from all types of biomass burning, taking into account the estimates of Streets *et al*., 2003. The total Indian FBCR CH_4 emissions are estimated as 88.6, 132.7, 149.6, 156.4, 164.2 and 174.0 Gg for the years 1980, 1990, 1994, 2000, 2005 and 2010, respectively. Rice, wheat and sugarcane together accounted for about 73.3, 110.4, 126.0, 136.6, 136.1 and 148.6 Gg in the years 1980, 1990, 1994, 2000, 2005 and 2010, respectively.

Bhattacharya and Mitra (1998) estimated 144.6 Gg CH_4 emissions for the year 1990 from this source. The major share in emissions from the main crops, i.e. rice, wheat and sugarcane from major states in the year 1994 and 2005 have also been estimated. For example, for rice, out of the total Indian emission of 54.1 and 59.5 Gg, the states of U.P, Punjab, Haryana, W.B., Orissa, Andhra Pradesh and Bihar together contributed 36.1 and 41 Gg; for wheat, out of the total Indian emission of 56.2 and 60.4 Gg, the states of U.P, Punjab, Haryana, W.B., Orissa, Andhra Pradesh and Bihar together contributed 51.9 and 55.3 Gg; and for sugarcane, out of the total Indian emission of 15.8 and 16.2 Gg, the states of U.P, Punjab, Haryana, W.B, Orissa, Andhra Pradesh and Bihar together contributed 15.5 and 15.8 Gg, respectively.

Streets *et al.,* 2003 have provided estimates for N_2O emissions from the field burning of crop residue. The total Indian N_2O emissions have been estimated as 2.1, 3.0, 3.3, 3.5, 3.7 and 3.9 Gg for 1980, 1990, 1994, 2000, 2005 and 2010, respectively. Rice, wheat and sugarcane together emitted 1.61, 2.42, 2.8, 3.0, 3.0 and 3.2 Gg N_2O in the years 1980, 1990, 1994, 2000, 2005 and 2010, respectively.

In Gujarat a large part of crop residue is burnt in the open fields since the farmers do not have any worthwhile use of this waste. In India, the total residue generation from the Rice and Wheat crop for the year 1994 was 133138 Gg out of which 3734 Gg generated from the state of Gujarat. In the Year 2000 Gujarat contributes only 1% in the rice and Wheat field residue burning

(Source: Trace gases emission from field burning of crop residue by S.C.Garg).In the year 2009, Gujarat total crop residue generation was 28.73 Mt yr^{-1} with the residue surplus of 8.90 Mt yr^{-1} and total India residue generation was 501.76 Mt yr^{-1} and residue surplus was 140.84 Mt yr^{-1}. Thus we can inferred that Gujarat contributes 5.72% in India (Source: MNRE-Ministry of New and Renewable Energy,2009). The Generic methodology has been followed for estimation of methane and nitrous oxide emission. 2006 IPCC Guideline for National Greenhouse Gas Inventories volume 4.

METHODOLOGY

The Generic methodology has been followed for estimation of methane and nitrous oxide emission. 2006 IPCC Guideline for National Greenhouse Gas Inventories volume 4, chapter 2 has been referred for the methodology.

Equations Used

Equation: Generic Method equation to estimate the emission from crop residue burning

$$L_{fire} = A * \text{Fraction remaining in the field} \times C_f \times G_{ef} \times 10^{-3}$$

Where, Fraction remaining in the field= 0.2, C_f= combustion factor and G_{ef}=Emission factor for each GHG.

Activity Data, Emission Factor

The Activity data has been taken from the Gujarat Agriculture Statistics at a Glance 2012-11. And the Emission Factor is as follow:

Emission factor:

Table 1: Emission factor for crop residue burning

Sr no	Crop	Combustion Factor C_f
1	RICE	0.8
2	WHEAT	0.9
3	COTTON	0.8
4	MAIZE	0.8
5	MILLET(JOWAR)	0.8
6	MILLET(BAJRA)	0.8

7	SUGARCANE(LEAVES)	0.8
8	RAPESEED-MUSTARD	0.8
9	GROUNDNUT	0.8

Table 2: Emission factor for each greenhouse gases

Emission factor for each GHG [g GHG kg dm burnt^-1]	
CH_4 Emission Factor	N_2O Emission Factor
2.7	0.07

RESULTS & DISCUSSION

Crop Residue Burning Emission

Based on annual production, area covered, residue generation and emission factor (combustion factor), the calculation has been carried out for the eight major crops viz. rice, Wheat, cotton, maize, Millet, sugarcane, rapeseed-mustard and groundnut. Table-3 gives the annual production, methane and nitrous oxide emissions, its carbon dioxide equivalent emissions and crop residue burning emission-intensity for the years 1980 to 2011 of the state of Gujarat.

Table 3: Methane and Nitrous oxide Emission of crop residue burning from Gujarat-1980 to 2011

Gujarat-Crop Residue Burning Emissions					
Year	Annual Production (In Million Tonnes 10^6)	CH_4 emissions Tonne CH_4	N_2O emissions Tonne N_2O	CO_2 Equivalent(Gg)	10^{-3} Gg/Tonne Emission Intensity
1980	72.50	4.00	0.10	116.12	12.74
1981	81.65	4.50	0.12	130.64	12.74
1982	74.01	4.09	0.11	118.83	12.74

1983	76.79	4.24	0.11	123.19	12.74
1984	81.72	4.51	0.12	131.06	12.74
1985	61.75	3.40	0.09	98.81	12.74
1986	56.86	3.12	0.08	90.65	12.74
1987	36.40	2.01	0.05	58.23	12.74
1988	76.14	4.20	0.11	121.90	12.74
1989	82.12	4.51	0.12	131.07	12.74
1990	74.17	4.09	0.11	118.73	12.74
1991	63.16	3.49	0.09	101.30	12.74
1992	85.24	4.69	0.12	136.23	12.74
1993	74.67	4.11	0.11	119.30	12.74
1994	98.12	5.42	0.14	157.36	12.74
1995	94.06	5.18	0.13	150.30	12.74
1996	105.79	5.18	0.13	150.30	12.74
1997	114.09	5.81	0.15	168.69	12.74
1998	122.71	6.73	0.17	195.39	12.74
1999	91.07	5.00	0.13	145.12	12.74
2000	65.25	3.58	0.09	103.99	12.74
2001	86.62	4.74	0.12	137.73	12.74
2002	82.11	4.50	0.12	130.63	12.74
2003	135.56	7.43	0.19	215.86	12.74
2004	122.24	6.72	0.17	195.27	12.74

2005	155.21	8.53	0.22	247.66	12.74
2006	163.52	9.01	0.23	261.64	12.74
2007	188.07	10.40	0.27	301.90	12.74
2008	171.25	9.44	0.24	274.22	12.74
2009	153.48	8.45	0.22	245.39	12.74
2010	209.52	11.61	0.30	337.05	12.74
2011	192.88	10.67	0.28	309.77	12.74

Crop residue burning of Gujarat contributes to the methane emission by 4, 3.40, 4.09, 5.18, 3.58, 8.53, 11.61 Gg for the years 1980, 1985, 1990, 1995, 2000, 2005 and 2010 respectively, and Nitrous oxide emissions by 0.1, 0.09, 0.11, 0.13, 0.09, 0.22 and 0.3 Gg for the years 1980, 1985, 1990, 1995, 2000, 2005 and 2010 respectively.

When analyzed the decadal trend of the methane emission has risen by 2% during 1980-90, 2.5% during 1991-2000 and 125% during 2001-11 whereas the nitrous oxide emission has risen by 10% during 1980-90, 44% during 1991-00 and 133% during 2001-11. From the calculation, it can be clearly observed that by the 20th century the methane and nitrous oxide emission has drastically increased.

As per the results, CO_2 equivalent emission from the Crop residue burning in Gujarat was dominated by cotton residue with 5077 Gg, followed by the wheat (1068 Gg), rice (366 Gg), maize (254 Gg), sugarcane (65 Gg), millet (48.7 Gg), groundnut (37.9 Gg) and rapseed mustard (1.13 Gg) emission in the year 2011. The Cotton residue emission rate has increased by 385% over the years 1980-2011. The Wheat residue emission rate has increased by 200%, whereas the rice residue emission has increased by 131% over the years 1980-2011.

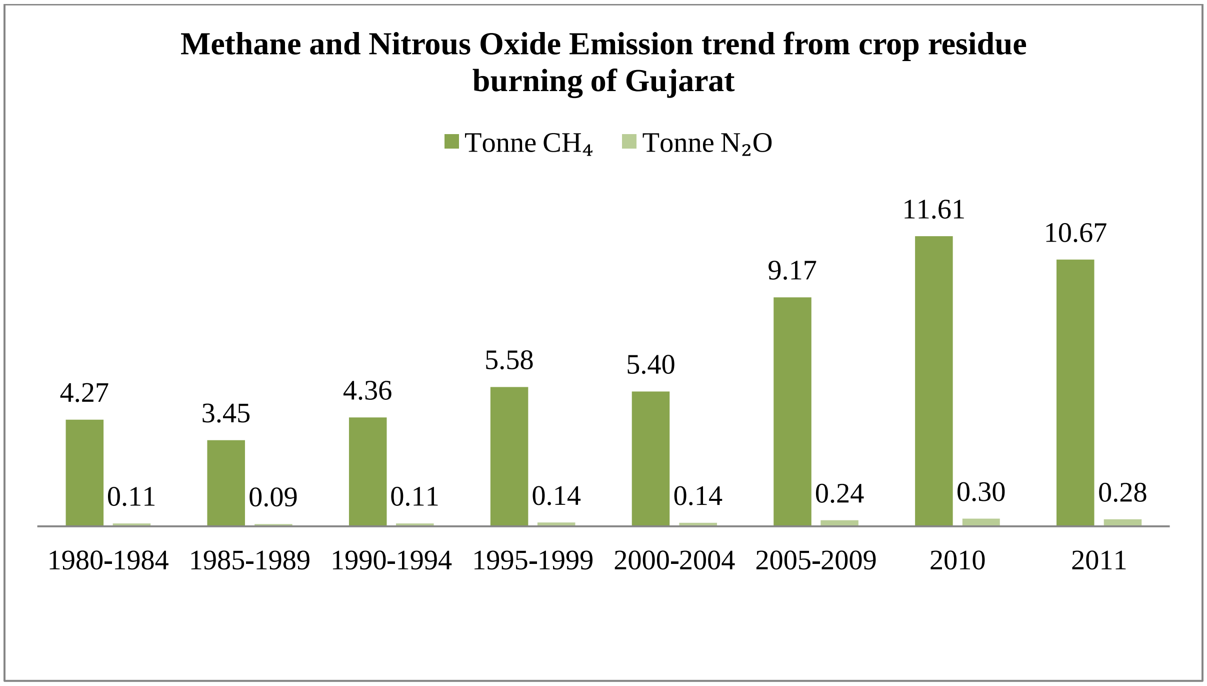

Figure 1: Methane and Nitrous Oxide Emission trend from crop residue burning of Gujarat-1980 to 2011

The above graph shows the methane and nitrous oxide emissions from the crop residue burning for the period of 1980 to 2011. It has been observed that the cotton, groundnut and wheat are the major contributors to the methane and nitrous oxide emissions from the crop residue burning in the state of Gujarat. It can be seen that Crop residue burning majorly contributes to the methane emission compared to the nitrous oxide emissions.

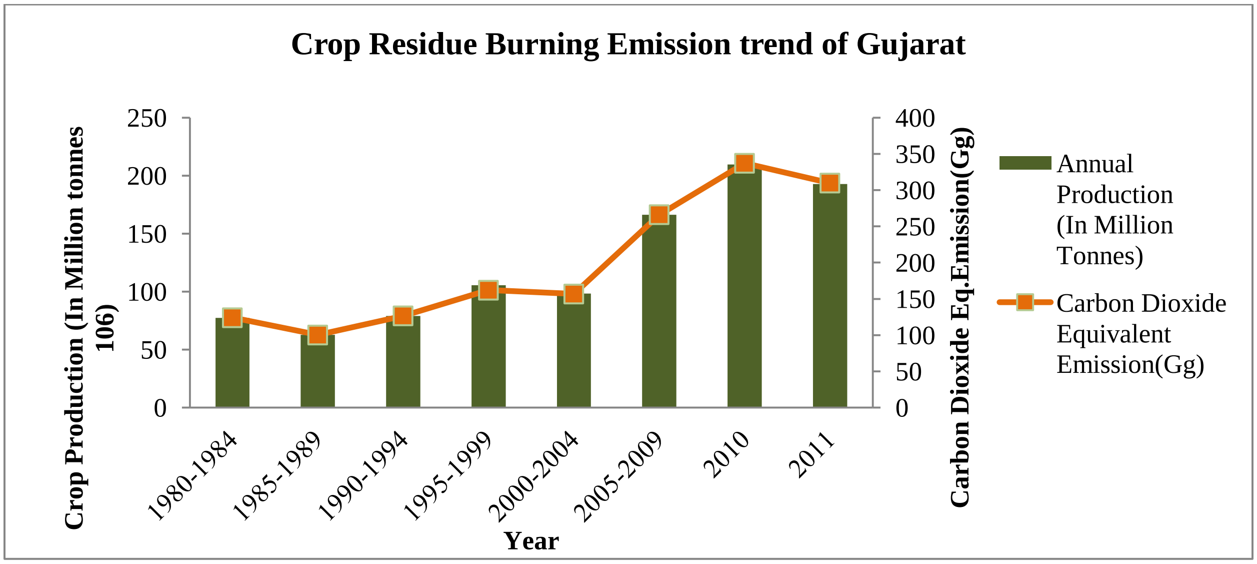

Figure 2: CO_2 Eq. Emission trend of crop residue burning-1980 to 2011

The CO_2 Equivalent emissions from burning of crop residue in the state of Gujarat in terms of Gg/year are 124, 100.1, 126.6, 162, 156.7, 266.2, 337.1 and 309.8 for the years 1980-84, 1985-89, 1990-94, 1995-99, 2000-04, 2005-09, 2010 and 2011, respectively. From the above graph we can observe that the CO_2 Equivalent Emissions are directly proportional to the crop production. If the crop production increases, the amount of crop residues increases and thus the emission of methane and nitrous oxide increases.

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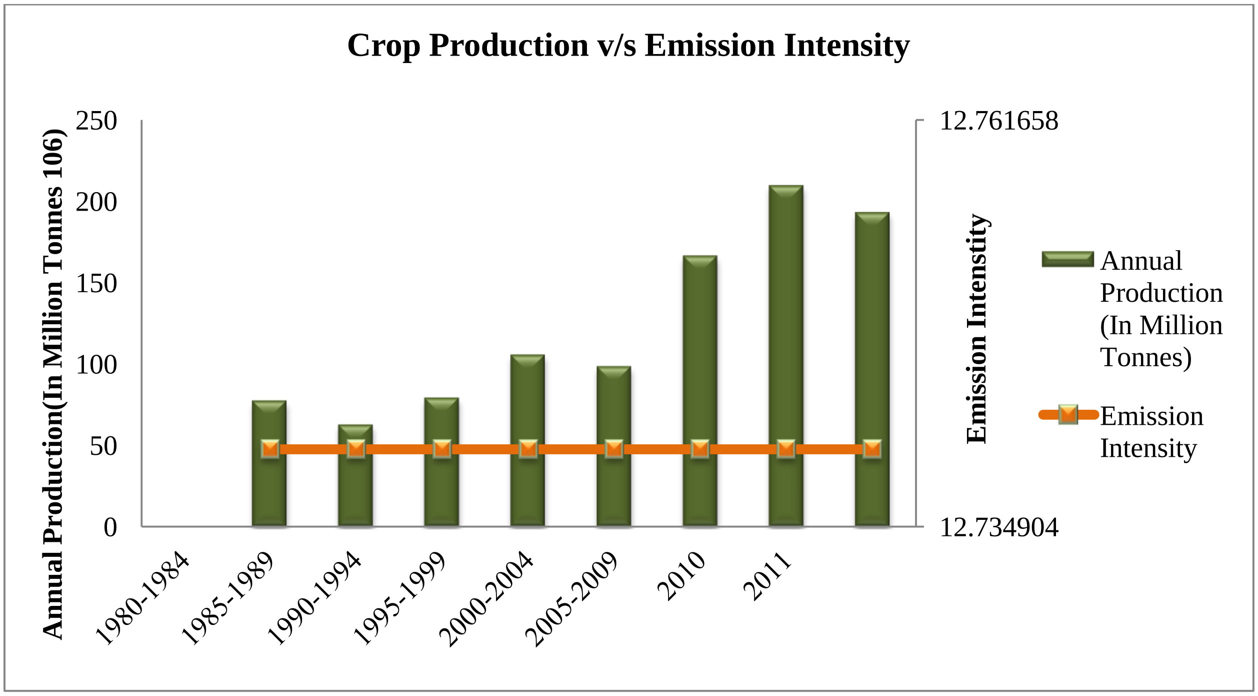

Figure 3: Emission intensity trend of crop residue burning-1980 to 2011

The above graph represents the Annual crop production where it can be clearly seen that it was increased, but the emission intensity remained same with 12.74 $\times 10^{-3}$.

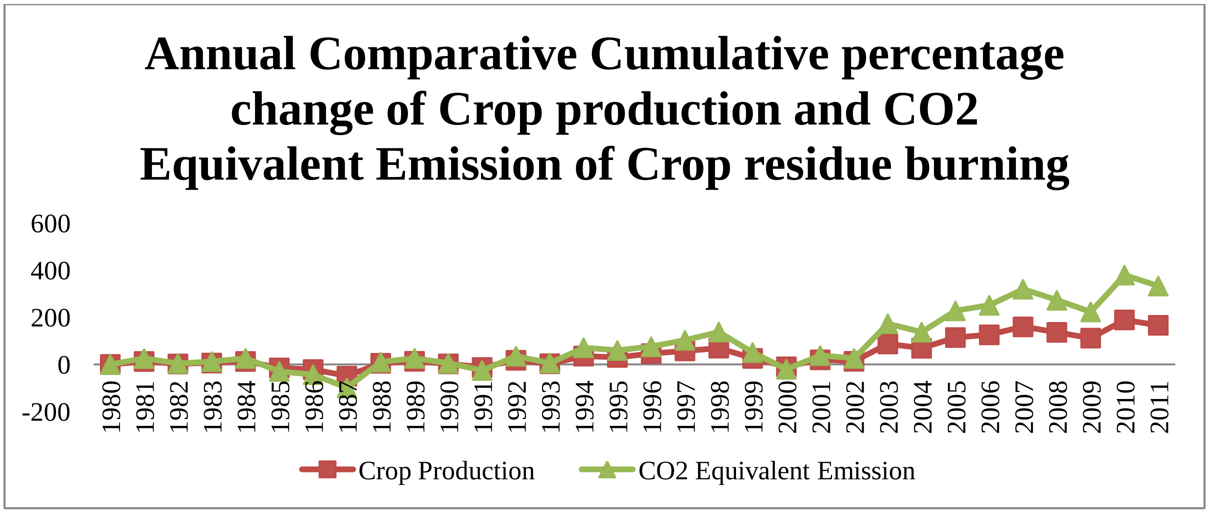

Figure 4 Annual Comparative Cumulative percentage change of Crop production and CO_2 Equivalent Emission of Crop residue burning

From the above graph we can observe that, during the years 1980 to 1984, the crop production and crop residue burning emission is directly proportional to each other. The case was same for the years 1988 to 1993. But during the years 1985 to 1987 and 1994 to 2011, with the fluctuation in the crop production, the emission trend fluctuated in the same manner with the more CO_2 Equivalent emission. There was a 97% increase in the CO_2 equivalent emission from the crop residue burning in the state of Gujarat (1980-2011).

CONCLUSION

Global climate change has emerged as a threat to sustainability. In the absence of adaptation and mitigation strategies, climate change can seriously damage agriculture. The impact of vulnerability is not only decided by the extend of climate change, but also by the robustness of the development process in the economy. The quality of development would provide an insurance against the impacts of climate change and increase adaptive capacity. And for the development propose the inventory of emission report have to be very accurate, district and sectoral level can be useful to focus the actions aimed at mitigation by the local administrators and economic agents and thereby reduce the cost of mitigation and simultaneously enhance the mitigation potential.

From this study it is very obvious that Greenhouse Gas emissions in the atmosphere show a varriable trend not only over the years, but also across various sectors, sub sectors, categories and sub-categories. It also varies between the population, area and the production. This study was conducted on the three main Greenhouse gases viz. Methane (CH_4), Nitrous oxide (N_2O) and Carbon dioxide (CO_2) from Crop residue burning for the years 1980 to 2012.

From this study, the net CO_2 equivalent emissions from the Agriculture sector crop residue burning shows variations, depending on the changes in the activity data. On the other hand, emission intensity, which is a very sensitive, and at the same time, more reliable parameter for appraising the performance of the agriculture sector has also been calculated. However, the emission intensity of a crop residue burning, remains the same during the years. The emission intensity of the Crop residue burning is highest with the $12.74*10^{-3}$ Gg/Production, though the emission of crop residue burning is very less compared to the other sources. But the emission-intensity of the source is very high, thus the crop residue burning emission should be taken as a serious threat to the climate as it can alter the weather in short-term and also on a long term basis.

As discussed before that the crop residue burning is the major threatening source from the agriculture sector, the Gujarat's contribution from the crop residue burning emission to the national level stands as a second highest contributor by 4.68% in the year 2005. Crop residue burning has lead to 10.67 Gg Methane emissions and 0.28 Gg Nitrous oxide emissions in the year 2011. The residue can be put to various productive usages such as incorporated in the fields, bio-energy, etc., and this is possible only if residue is collected and managed properly. Awareness must be created amongst the farming communities about the negative impacts of crop residue burning and importance of crop residue incorporation in soil for maintaining sustainable agricultural productivity.

Rather burning the crop residue it can be used in the fuel, fodder, industrial and construction material and as well as to fertile the soil. The balance use of crop residue is the important part .The Abellon Clean Energy Ltd. Have established a pellet plant. Framers collect residues (including cotton stalks, cumin waste, castor bean husks, mustard stalks and bagasse) and take them to the pellet plant, and convert it into the boiler fuel to replace lignite and sometimes black coal.

All emission calculations in this report have been carried out mainly using Tier I approach; as higher quality of data was not available. An attempt can be made in future to carry out calculation using higher Tier and country specific emission factors. As reporting of GHG inventory of sources is a continuous process; the challenge lies in reporting a more refined inventory every time, which is transparent, comprehensive, comparable and accurate as well.

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