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Full Length Research Paper

Greenhouse Gas Emissions from Agriculture Sector and Potential for Carbon Sequestration in Tungabhadra River Basin, India

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Abstract

Since 1997 of Kyoto Protocol to 2012 Doha has clearly placed the "Common but Differentiated Responsibilities to reduce the concentrations of Greenhouse Gases (GHGs) and climate change". Central to this reduction in GHGs emission from all the member nations. Accordingly, guidelines were developed to measure GHGs emissions at national levels by various agencies and the Intergovernmental Panel on Climate Change (IPCC). On the other hand, in the event of negative implication due to climate change, it would be a particular river basin which will bore it, and not the entire nation. Therefore, mitigation statergies shoud focus on GHGs reduction at macro level and adoption measures at micro level. However, the major issues are uncertainty at micro level and also emissions of GHGs which are contributing to global warming. To study these issues in detail we have selected the Tungabhadra River basin in southern Indiaand estimated GHGs emissions from various segments of the agriculture sector, viz., a) the cultivation of rice, b) nitrogen fertilizer applications, c) residue burning, d) enteric fermentation and manure management. Results indicate fluctuations in the emissions of methane, nitrous oxide and carbon dioxide.

Key Words: *Climate Change, IPCC Guidelines, Greenhouse Gas Emissions, Inventory*

Introduction

Energy from the sun reaches the earth and portion of it's reflected back (albido). Some of the atmospheric gases such as water vapor, carbon dioxide trap some of this outgoing energy, in other words, they act like glass panels of a greenhouse. Without this natural "greenhouse effect," temperatures in the atmosphere would be much lower than the current temperatures. However, problems may arise when the atmospheric concentration of greenhouse gases increases and increasing trend in the concentrations of Greenhouse Gases (GHGs) such as Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) from various anthropogenic activities in the atmosphere is reported by several studies. As apprehended, since the beginning of the industrial revolution, atmospheric concentrations of carbon dioxide have increased nearly 30 percent, methane concentrations have more than doubled and nitrous oxide concentrations have risen by about 15 per cent. Subsequently, the global mean surface temperature has risen by 0.4–0.8°C (Subhod Sharma et al, 2006). As a result of this warming, 20th century's 10 warmest years have occurred in the last 15 years. Of these, 1998 was the warmest year in the record. Further, negative implications of this rise in temperature such as decrease in the snow cover in the Northern Hemisphere , sea level rise of 4-8 inches over the past century, increase in the frequency of extreme rainfall events etc were reported from across the the world.

This paper attempts to estimate the Greenhouse Gases at micro level i.e. at a level of river basin. This study mainly focussed on the inventory of GHGs emissions from agriculture sector and also potential for carbon sequestration within the boundaries of the river basin in the state of Karnataka only.

Study Area

The Tungabhadra (TB) River basin is one of the major sub-basin of the Krishna river basin in peninsular India and stretches over an area of about 47,827 Sq. Km (1.45 percent of the Indian total geographical area) in the states of Karnataka (81.1 percent of the basin) and Andhra Pradesh (18.89 percent of the basin) (Figure 1). The total population of the TB basin is about 88.53 lakhs with population density of 302 persons per Sq. Km Average literacy rate is about 64 per cent in the basin. The total forest area of the basin is about

4.48 lakh Ha in which 60 per cent of the area is situated in the upper part of the basin (Western Ghat) while the rest is spread both in middle and lower parts of the basin. Calculations are based on the secondary data obtained from the line departments.

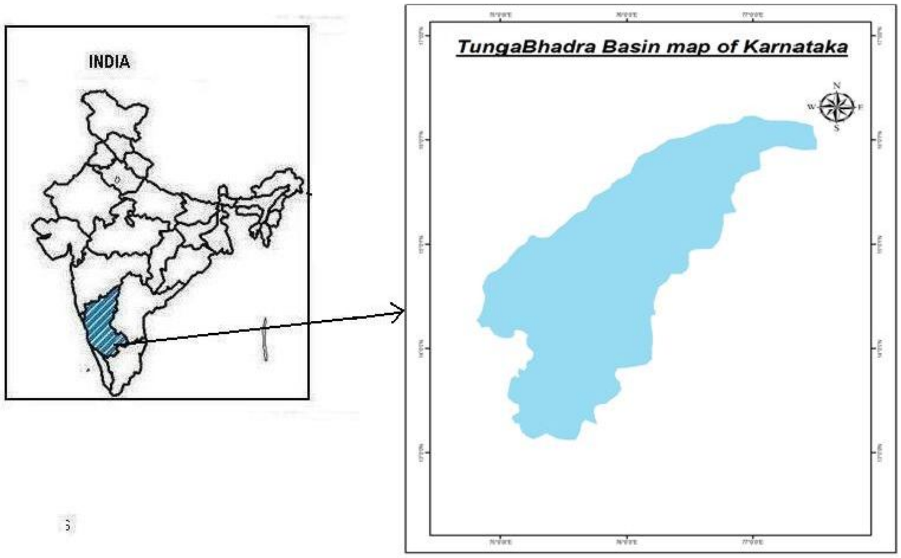

Figure 1: Location of the study area, Tungabhadra River Basin, South India

Methodology

The methodology prescribed by the IPCC (Revised 1996) for National Greenhouse Gas Inventories is used and below said equations are adopted for estimation.

Equation 1: Rice Cultivation

Methane emissions from rice fields is calculated by using the below said equation

$F_c = EF \times A \times 10^{-12}$

Where,

Fc = estimated annual emission of methane in Gg /yr;

EF = methane emission factor integrated over integrated cropping season, in g/ m^2;

A = annual harvested area in m^2/yr.

Equation 2: Domestic Livestock

Methane emissions from enteric fermentation and manure management are calculated by applying an emissions factor to the number of animals of each livestock type in the basin to produce a total. Emission factors are considered from the developing country (India) perspectives.

Nitrous oxide emissions from Animal Waste Management Systems (AWMS) are calculated by the following equations.

1. $Nex_{(AWMS)} = \sum_{(T)} [N_{(T)} \times Nex_{(T)} \times AWMS_{(T)}]$

Where,

$Nex_{(AWMS)}$ = N excretion per Animal Waste Management System (kg/yr)

$N_{(T)}$ = number of animals of type T

$Nex_{(T)}$ = N excretion of animals of type T in the country (kgN/animal /yr)

$AWMS_{(T)}$ = fraction of $Nex_{(T)}$ that is managed in one of the different distinguished animal waste management systems for animals of type T

T = type of animal category

2. $N_2O_{(AWMS)} = \sum [Nex_{(AWMS)} \times EF_{3(AWMS)}]$

Where,

$N_2O_{(AWMS)}$ = N_2O emissions from all Animal Waste Management Systems in the country (kgN/yr)

$Nex_{(AWMS)}$ = N excretion per Animal Waste Management System (kg/yr)

$EF_{3(AWMS)}$ = N_2O emissions factor for an AWMS (kg N_2O -N/kg of $Nex_{(AWMS)}$)

Equation 3: Agricultural Soils

Estimation of nitrous oxide emissions from synthetic fertilizers applied for cultivation is calculated by below equation

$T\ N_2O = (A \times B) \times 10^{-6}$

Where,

$T\ N_2O$ = Total Nitrous Oxide emissions from the synthetic fertilizers used in Gg

A = Total synthetic fertilizers applied (in Kg N/Yr)

B = Emissions factors for direct emissions (in Kg N_2O- N/Kg N)

Results and Discussion

Scenario of Land Use and Land Cover Change in the Tungabhadra River Basin

Observation and analysis of statistical data from 1960 to 2011 along with field observation and discussions indicate that land use changes in the basin over a period . According to Indian land-use classification, geographical area is classified under nine fold system. Forest area in the basin has increased from 13.4 percent to 15.8 percent due to programmes such as afforestation, social forestry . Land available for non cultivation is decreased from 11.2 percent to 10.2 percent because of land conversion for other built up areas such as residential, commercial and road network etc., Other uncultivable land excluding fallow land has also come down drastically to 8.6 percent from 13.2 percent due to decrease in grazing land and cultivable waste. Fallow land is slightly slowly increased from 10.3 percent to 11.0 percent but current fallows has decreased drastically due to insufficient supply of water through canals (tail end issues), and lack of rainfall. Cropping land or area increases 10 percent over a period due to extension of irrigation area through unauthorized and also leveling of upland into irrigable land.

GHGs Emissions from Agriculture Sector

Emissions from agriculture sector are accounted from all the four sectors, viz, flood irrigation of rice, application of nitrogen fertilizers, field burning of agricultural residues and animal husbandry. Upland rice fields, which are not flooded do not produce significant quantities of CH_4. The measurements at various locations of the world show that there are large temporal variations of CH_4 fluxes and that the flux differs markedly with soil type and texture, application of organic matter and mineral fertilizer. The wide variations in CH_4 fluxes also indicate that the flux is critically depend upon several factors including climate, characteristics of soils and paddy, and agricultural practices, particularly the water regime. The parameters that affect methane emissions vary widely both spatially and temporally. Multiple year data sets near the same location and under similar conditions can lead to substantial differences in seasonal methane emission levels, making it difficult to establish a single number as the methane emission level from a field, let alone at a regional or country level.

Methane Emissions from Cultivation of Flooded Rice

The Tungabhadra river basin has a huge command area and most of the area is dominated by the flooded rice cultivation and other water intensive crops. Because of the availability of water, soil texture and climate system influence to cultivate flooded rice. Methane emissions from flooded rice is estimated and shown in below table 1.

Table 1: Estimation of methane from flooded rice in Tungabhadra River Basin in Gg

Year	Water Manage ment Regime	Paddy harvested area in Ha	Paddy Harvested Area (m^2*10^{-9}) A	Scaling Factor for Methane Emission B	Correction factor for Organic Amendment C	Seasonally Integrated Emission factor for Contineously	CH_4 Emissions in Gg E=(A*B*C *D)
1995-96	Flooded Rice	446288	4.463	1	1	10	44.63
2000-01		504374	5.044	1	1	10	50.44
2004-05		437394	4.374	1	1	10	43.74
2010-11		584384	5.843	1	1	10	58.43

Data Source: Department of Economics and Statistics, Bangalore and District at Glance

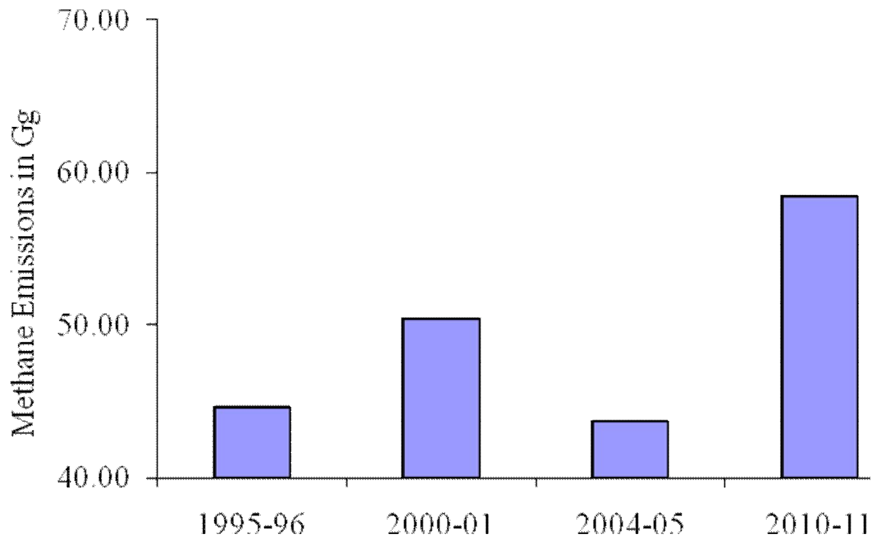

Figure 2: Methane emissions since 1995 to 2011 in Gg

As can be seen from the figure 2, the emissions of methane from rice fields fluctuating and emissions are directly proportional to the area sown under the wet paddy system. The paddy area is increasing every year and also observed decreasing trend in the year 2004-05 due to bad monsoon and lack of availability of water. Later, the area under flooded rice shown increasing, similarly methane emissions have also recorded high (58.43 Gg) particularly in the year 2010-11. Methane is one of the major element of GHG and contributing factor to global warming. Thus, the focus on reduction in emissions is quite essential and also the practice of aerobic rice cultivation is better than the anaerobic system.

Apart from flooded rice cultivation, burning of agricultural residues has emitted GHGs such as methane and nitrous oxide. In addition, residue burning will also emit carbon monoxide and sulphur oxide.

Methane and Nitrous Oxide Emissions from Agricultural Residue Burning

Large quantities of agricultural residues are produced from farming systems world- wide. Burning of crop residues in the field is a common agricultural practice in developing countries to avoid the pest diseases, maintain the yield and also minimize excess plant materials. During the process emits a large amount of smoke with short duration and destabilizes the condition of local atmosphere.

A GHG especially nitrous oxide emits during the burning of agricultural waste. The residue left over after the harvest of crops such as sugar cane and maize will undergo in the burning process. These practices are common in developing country perspectives and still farmers practicing it. Because burning is an effortless process to remove waste from the agricultural field. Similar methods have been adopted in the Tungabhadra river basin to take out the left out waste after the harvest of sugar cane and maize. The total emissions of nitrous oxide and methane have shown in table 2.

Table 2: Nitrous oxide and methane emissions from agricultural residue burning in Gg

Variables/Year	1995-96	2000-01	2004-05	2010-11
CH_4	1.18	1.45	1.18	1.34
CO	24.75	30.44	24.84	28.23
N_2O	0.04	0.05	0.04	0.04
NO_x	1.41	1.73	1.41	1.60

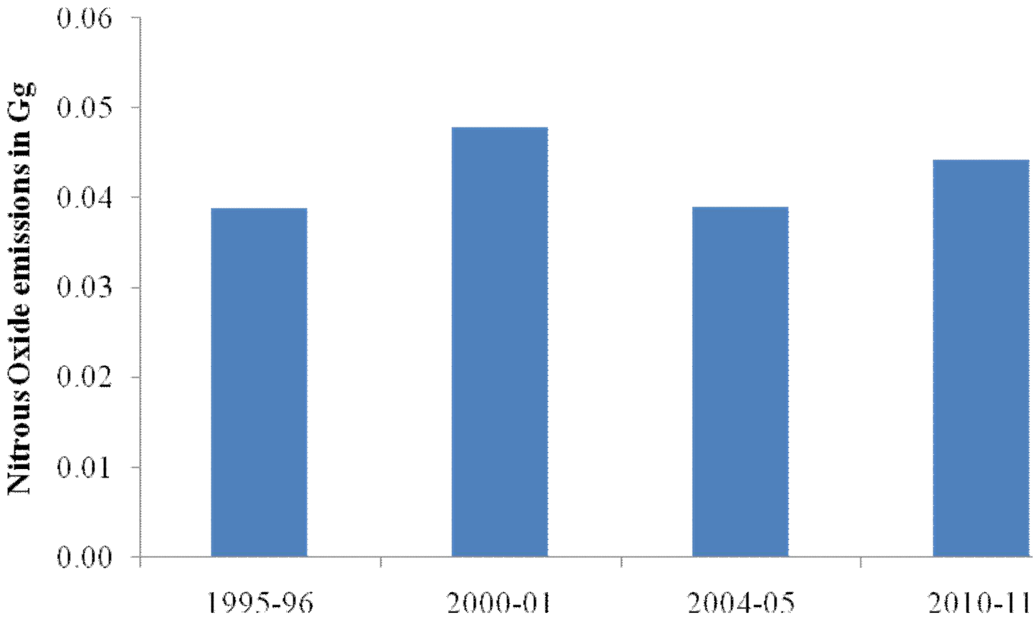

Figure 3: Nitrous oxide emission from burning of agricultural residues in Gg

The emission of nitrous oxide directly depends on the production of maize and sugar cane crops. Because, the fraction of material after the harvest which is burning will emits the nitrous oxide. The figure 3 shows the variations in the emissions due to differences in the production across the years. In the year 2000-01 shows highest emission of nitrous oxide (0.05 Gg) due to higher production in sugar cane and maize in the Tungabhadra river basin. Open burning is a traditional and easy way to remove the waste which will be leading to environmental degradation. In addition pollute atmosphere and soil quality while destroying the soil organisms. Therefore, conserving the maize straw will reduce the load and also practice of the decomposition treatment in the farm field itself will minimize the GHG emissions which are loaded in the atmosphere (Mendoza et.al, 1999). Moreover, sugar cane consumes large amount of fertilizer especially nitrogen which is a substitute of GHG concentrations in the atmosphere. Nitrogen consumption is huge particularly in the river basin because of multiple cropping pattern and also large number of area sown.

Nitrous Oxide Emissions from Applications of Synthetic Fertilizers

Nitrogenous fertilizers play an import role in increasing crop yields. Use of nitrogenous fertilizer, however, increases nitrous oxide emissions from soil and water through nitrification and denitrification processes. Another contributing agent to the level of nitrous oxide emissions is leguminous crops that add nitrogen to the soil. The consumption of nitrogen fertilizer has kept on increasing (table 3) in the Tungabhadra River basin and simultaneously nitrous oxides emissions showing an increasing trend in the basin (table 4).

Table 3: The quantity of nitrogen fertilizer consumption (in tones) and percentage growth in Tungabhadra River basin

Year	Nitrogen fertilizer consumption in Tonnes	Percentage growth
1995-96	131567.0	
2000-01	135945.6	3.22
2004-05	160440.6	15.27
2010-11	288067.0	44.30

Data Source: Department of Economics and Statistics, Bangalore and District at Glance

Frequent use of fertilizers in the basin is affecting soil quality. Nearly, 20 per cent of the command area under the Tungabhadra project is facing a alkaline and salinity issues. The fertilizer consumption in the Tungabhadra basin has increased to 2.8 lakh tonnes per annum (in 2011) (nearly 25 percent of state consumption) in which nitrogen is about 48.4 per cent because nitrogen is cost effective and quick nutrient supplier. Phosphorous and potash consumption was 32.6 per cent and 19.0 per cent respectively. Similarly, potash usage is also showing an increasing trend. Especially farmers from downstream of the basin use more fertilizers rather than the upstream farmers and it is directly entering the river and polluting the river course. The nitrous oxides emissions from fertilizer is accounted and shown in table 4.

Table 4: Estimation of nitrous oxide from application of nitrogen fertilizer in the Tungabhadra River basin in Gg

Year	Type of N input to soil	Amount of N input (kg N/yr)	Emission factor for Direct Emissions EF1 (kg N_2O-N/kg N)	C Direct Soil Emissions (Gg N_2O-N/yr)
		A	B	$C=(A*B)*10^{-6}$
1995-96	Synthetic fertilizer	131567000	0.0125	1.64
2000-01		135945560	0.0125	1.70
2004-05		160440560	0.0125	2.01
2010-11		288067000	0.0125	3.60

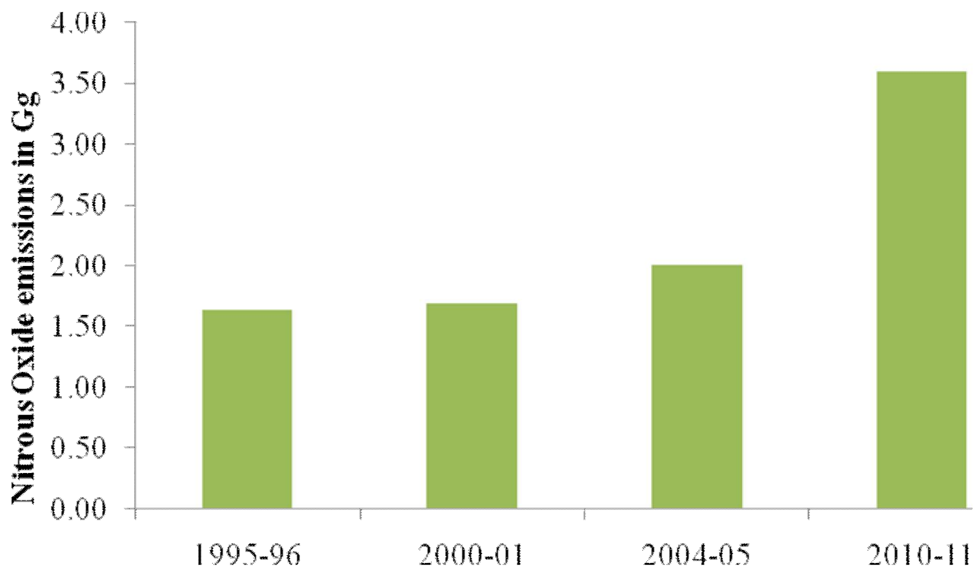

Figure 4: Nitrous oxide emissions due to application of synthetic fertilizer from 1995 to 2011 in Gg

Fertilizer application is effective in increasing the crop yield but at the same time it degrades the quality of fragile soil and convert into inactive. According to studies by International Fertilizer Industry Association (IFA) half of the nitrogen applied will remain in the soil and it leaches into the air, water and soil and pollute the environment[1]. As can be seen in figure 4 the nitrous oxide emissions have kept on increasing and it is proportional to the applications of nitrogen to the crops to obtain more yields. In the recent year 2010-11 recorded highest emissions 3.6 Gg because of reduction in applications of organic manure, violation of cropping pattern and also loss of soil quality due to repeating the cultivation of same crops. Moreover, traditional cropping pattern in the basin is vanishing and moving towards modern agriculture methods. Most of the farmers intention is to obtain more yields rather than conserving the quality of the soil. Thus, the mechanization system in the agriculture has increased to the level of 60 percent in the basin. Therefore, the number livestock has been decreasing and ratio of application of organic manure coming down and also observed that some part of the basin stopped completely.

GHG Emissions from Animal Husbandry

Livestock management is an important subsidiary activity in the farming sector as it provides draft power, supplementary nutrition/income as well as organic manure. The majority of the farming families required the livestock and it depends on the agricultural land owned and manpower available to look after. Contribution of GHGs such as methane and nitrous oxide from livestock through the process of enteric fermentation and manure management. The number of livestocks in the Tungabhadra River basin is showing decreasing trend (table 5) due to mechanization and influence of modern agriculture techniques.

[1] http://www.arcadiabio.com/nitrogen

Table 5: The type and number of livestock (in thousand numbers) in the Tungabhadra River basin

Year/livestock	Cattle	Buffaloes	Sheep	Goats	Pigs	Dogs	Other Livestok	Total Livestock	Total Poultry
1995	1512	828	926	495	23	352	1	4006	6868
2000	1727	781	943	582	51	241	3	3591	3776
2005	1742	925	1176	631	30	400	2	4775	9029
2011	1591	752	1242	700	40	258	1	4332	5657

Enteric Fermentation

Methane from enteric fermentation is produced in herbivores as a by-product of the digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the blood-stream. Both ruminant animals (e.g., cattle, buffalo, sheep and goats) and some non-ruminant animals (e.g., pigs, horses) produce methane, although ruminants are the largest source. The amount of CH_4 released depends upon the type, age and weight of the animal and the quantity and quality of the feed consumed. The methane emissions from enteric fermentation are estimated and shown in table 6.

Table 6: Methane emissions (in Gg) from domestic livestock across the years in Tungabhadra River basin

Year/Livestock	1995-96	2000-01	2004-05	2010-11
Cattle	40.8	46.6	47.0	42.97
Buffalo	49.7	46.9	55.5	45.11
Sheep	4.8	4.9	6.1	6.47
Goats	2.6	3.0	3.3	3.66
Swine	0.2	0.4	0.2	0.28
Poultry	0.2	0.1	0.2	0.13
Total	98.2	101.9	112.4	98.62

In the Tungabhadra River basin methane emissions shows higher from the buffaloes followed by cattle (table 6) because buffaloes consume more feed than cows. Significant emissions are recorded from ruminant animals and least emissions are observed by nonruminant animals. The supply of quality feed will certainly reduce the emissions through enteric fermentation.

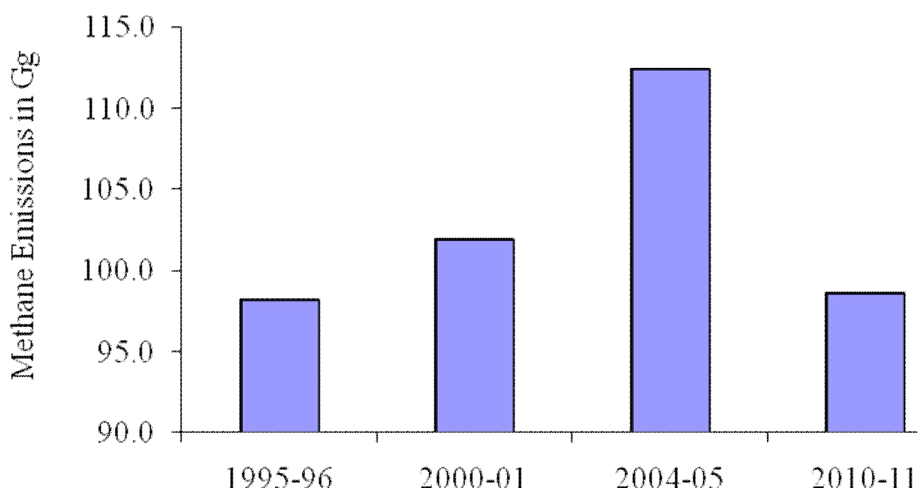

Figure 5: Methane emissions (in Gg) from enteric fermentation from 1995 to 2011

The figure 5 shows increase in methane emissions from 98.2 Gg to 112.4 Gg from 1995 to 2005 then started decreasing (98.62 Gg) due to decline in livestock population. Mechanization in farming is the primary cause of livestock population and also cost involved in management of cows and buffaloes. Besides, modern era is impressed by modern agriculture system. Thus, farmers interest is shading towards rearing livestock as a result, livestock population showing a decreasing trend. Apart from enteric fermentation, manure management also contributes GHG emissions.

Manure Management

During anaerobic decomposition of manure, methane is emitted. The amount of methane produced from manure depends on, the number of animals, the amount of feed consumed, and the digestibility of the feed, animal type, the condition of the digestive tract, and the quality of the feed consumed. Liquid manure management systems, such as ponds, lagoons, and holding tanks lead to anaerobic conditions, which can emit up to 80 per cent of manure based methane emissions, while solid manure emits little or no methane and environmental conditions (temperature and moisture). In addition nitrous oxide emitted during manure storage, handling and application through nitrification or denitrification. Indirect sources of nitrous oxide include volatilisation and subsequent atmospheric deposition of ammonia (NH_3) and nitrogen oxides (NO_X). The nitrous oxide from Tungabhadra river basin were calculated and shown in figure 6.

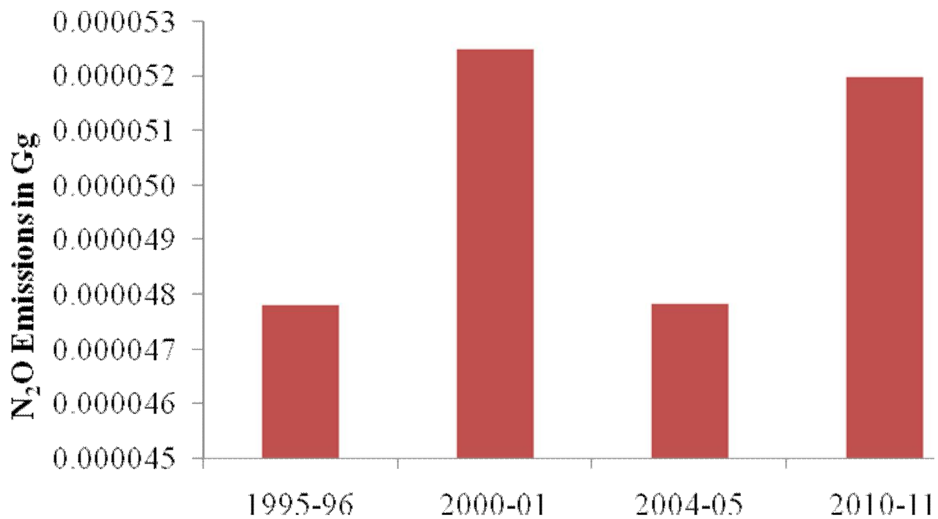

Figure 6: Nitrous oxide emissions (in Gg) from domestic livestock during manure management process in Tungabhadra River basin

A Nitrous oxide emission in the year 2000 was higher (0.000053 Gg) because number of cattle and poultry were high compared to other years. In the year 2004-05 emissions decreased drastically and then shown an increasing trend in 2010-11. According to the data and observation the number of livestock is declining because of a decrease in grazing land, migration of people and increased mechanization in the agricultural sector.

Summary of Agricultural Emissions

Animal husbandry through the process of enteric fermentation and manure management emitted larger quantity of GHGs nearly 55 percent in agriculture sector in each year then followed by rice cultivation of about 25 percent. Besides, agricultural soils through nitrification and denitrification of nitrogen fertilizers emitted of about 15 percent in the basin. Field burning of agricultural residues accounts minimum and their emissions is insignificant compared to others in agriculture sector (table 7). Better management of livestock through providing quality feed and high energy fodder will certainly contribute minimum. Aerobic rice cultivation and also application Systematic Rice Intensification (SRI) methods while cultivating rice will leads minimize the methane emission loads in the atmosphere. Traditional cultivation methods and also usage of organic manure instead of synthetic fertilizer reduce the nitrous oxide emissions. Meantime it will stabilize the soil quality to obtain maximum yield.

Table 7: Carbon dioxide (equi.) emissions (in Gg) from agriculture sector from 1995 to 2011 in Tungabhadra River basin.

	1995		2000		2005		2011	
Year/Process	in Gg	in %	in Gg	in %	in Gg	in %	in Gg	in %
Rice Cultivation	937.2	26.70	1059.19	28.1	918.13	23.32	1227.03	27.54
Feild Burning of Agricultural Residues	36.81	1.05	45.27	1.2	36.93	0.94	41.98612	0.94
Agricultural Soils	509.82	14.52	526.79	14.0	621.71	15.79	1116	25.04
EF and MM	2026.56	57.73	2139.27	56.7	2359.73	59.94	2070.976	46.48
Total	3510.39		3770.52		3936.5		4455.992	

Note: conversion factor 1 CH_4 = 21 CO_2
1 N_20 = 310 CO_2

Potential for Carbon Sequestration

Tungabhadra basin has 2,848 kms (including distributary length also) of canal length, which can grow plantations/vegetations all along the sides of canal (each side 2 line, totally 4 line along the canal) it captures 6.2 lakhs tonnes carbon per year and it may earn Rs.2492.5 lakhs per year and the total estimated cost for canal side plantation is Rs.17.8 lakhs (one time cost). One tonne of captured carbon yields almost 10 US$, thus a total of 5.33 lakh Ha of waste land available in the basin if converted into plantation (one ha 100 plants or one acre 40 plants) or green cover can captures 14.5 Million tonnes per year and may earn 1,459.4 lakh US$ per year (Rs.58,379.9 lakhs). The total estimated cost of the plantation would be Rs.1,664.9 lakh (one time investment). Total road (national, state, district and rural) length is 70,149.75 km in the basin, thus each side of the road (one line each side) can be converted into plantation, which may captures 7.67 Million tonnes of carbon per year and can earn 767.43 lakh US$ per year (Rs.30,697.5 lakhs). The total estimated costs of road side plantation could be approximately Rs.438.43 lakh (one time investment).

Conclusion

The agriculture sector is one among the major contributor of GHG after the energy sector in the world. The end results of this study shown that animal husbandry (domestic livestock) contribute nearly 55 percent of GHGs through enteric fermentation and manure management from agriculture sector followed by rice cultivation 25 percent. Agriculture is the primary sector which provides basic needs such as food and employment for the people. Cultivation of crops is essential for food production at the same time focus on the mitigations of GHGs emission is needed. Producing maximum yield will benefit the nation undoubtedly but concentrations on reducing the applications of nitrogen fertilizer is required because it contributes nearly 15 percent in the Tungabhadra River basin. Crop rotation, practice of organic manure and scientific knowledge in cultivation etc., will minimize the future environmental damages. Mechanization in agriculture and also decrease in grazing and public land provides insufficient fodder for domestic livestock. Moreover, the interest of the farmers on livestock rearing is decreasing to the level of 30 percent and youth's involvement in agriculture going down (40-50 percent) particularly in the Tungabhadra River basin. Besides, financial assistance from the government for livestock management is declining and fertilizer companies are promoting the farmers to apply more synthetic fertilizers to obtain better yield. Thus, applications of nitrogen fertilizers have increased and concentrations in the use of organic manure destabilized. Therefore, better scientific knowledge of cultivation and management is essential for the farmers to mitigate the further GHG emissions and global warming.

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