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Research Article

Greenhouse Gases Emissions from Agriculture Sector in Northeastern Region of India

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Abstract

The greenhouse gas (GHG) emissions in northeastern region (NER) of India, comprising eight states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura were computed for agriculture sector, using standard emission values of carbon dioxide, methane and nitrous oxide. The emission was 10.957, 0.342, 5.746, 1.267 and 1.237 Tg of CO_2e, annually, from enteric fermentation, manure management, rice cultivation, soils and shifting cultivation, respectively, totaling 19.549 Tg CO_2e. Total annual removal through Land Use, Land Use Change and Forestry (LULUCF) was 17.341 Tg CO_2e, with net emission of only 2.208 Tg CO_2e. The state-wise annual emission from agriculture sector was; 1.075, 13.506, 0.965, 1.061, 0.350. 0.853, 0.406 and 1.331 Tg CO_2e from above states, respectively. About 56% of GHG emissions were from enteric fermentation, followed by 29.4% from rice cultivation. Assam accounted for 69.1% of GHG emissions from NER. From NER, Assam, Meghalaya and Tripura were the net emitters; while other states showed a negative balance if only agriculture sector is considered.

Keywords: Greenhouse Gas; Agriculture Sector; Northeastern Region of India

Introduction

One of the prime concerns for difficulties in emission foot printing at the urban scale is because inventories prepared for cities vary substantially from the national ones [1]. Sharma., *et al.* (2) reported the greenhouse gas emissions of anthropogenic origin by sources and removals by sinks of India for 2007 prepared under the aegis of the Indian Network for Climate Change Assessment (INCCA). Agriculture is strongly influenced by weather and climate. While farmers are often flexible in dealing with weather and year-to-year variability, there is nevertheless a high degree of adaptation to the local climate in the form of established infrastructure, local farming practice and individual experience. Climate change arising due to the increasing concentration of greenhouse gases in the atmosphere since the pre-industrial times has emerged as a serious global environmental issue and poses a threat and challenge to mankind [2,3]. Climate change can therefore be expected to impact agriculture, potentially threatening established aspects of farming systems but also providing opportunities for improvements. Quantifying GHG emissions in order to accurately assess both their contribution to total GHG emissions and the effectiveness of mitigation strategies is, however, made difficult by the level of variation, both spatially and over time [4]. Globally, agriculture accounts for about 60% of nitrous oxide (N_2O) and 50% of methane (CH_4) emission. Agricultural CH_4 and N_2O emissions increased by 17% from 1990 to 2005 [5,6]. Of global anthropogenic emissions in 2005, agriculture accounts for about 60% of N_2O and about 50% of CH_4 [5]. Emissions of GHG in the agricultural sector depend mainly on the socio-economic development, human and livestock population growth, and diet, application of adequate technologies and future climate change. Achieving increases in food production may require more use of N fertilizer, leading to possible increases in N_2O emissions, unless more efficient fertilization techniques and products can be found[7,8]. Agriculture releases to the atmosphere significant amounts of CO_2, CH_4, and N_2O [9-11]. CO_2 is released largely from microbial decay or burning of plant litter and soil organic matter [12,13]. CH_4 is produced when organic materials decompose in oxygen-deprived conditions, particularly from fermentative digestion by ruminant livestock, from stored manures, and from rice grown under flooded conditions [4]. N_2O is generated by the microbial transformation of nitrogen in soils and manures and is often enhanced where available nitrogen (N) exceeds plant requirements, especially under wet conditions [14,15]. Apart from causing global warming N_2O is also responsible for the destruction of the stratospheric ozone [16,17]. Agricultural greenhouse gas (GHG) fluxes are complex and heterogeneous, but the active management of agricultural systems offers possibilities for mitigation. We have attempted in this paper to describe the emission of GHG from the agricultural sector in the Northeastern Region (NER) of India, for livestock, rice cultivation, manure management, soils and shifting cultivation. The mitigation through, land use, land use change and forestry (LULUCF) was also computed for forest land, crop land, pastures and fuel wood use.

Study site and methodology

The NER of India, comprising 'Eight Sister' states namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura along with Sikkim (Figure 1). This region covers an area of 262,179 km2, constituting 7.9% of the country's total geographical area. It has a total population of 45.588 million; about 3.76% of the total population of the country (2011 census). The region is predominantly hilly and its economy is primarily agrarian in nature, with almost 70% of population directly dependent on agriculture and another 15% dependent on allied activities for its living. Assam has 68.0% of the population of NER. The agricultural practices in the region are broadly of two distinct types, viz., (i) settled farming practiced in the plains, valleys, foothills and terraced slopes and (ii) shifting cultivation (Jhum) practiced on the hill slopes.

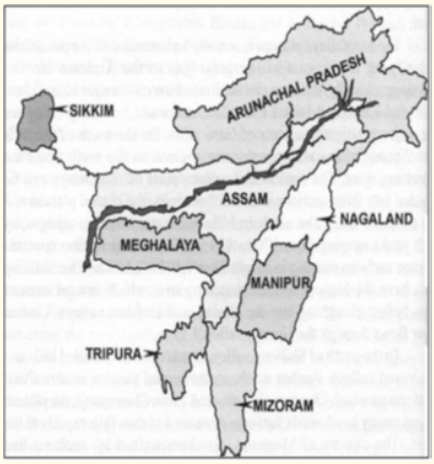

Figure 1: North-eastern region of India.

State-wise GHG emission were computed for NER.Several papers and reports have been published which have upgraded the methodologies for estimation, included country-specific emission factors and activity data [18], accounted for new sources of emissions and new gases or pollutants [19,20]. Over the years there has been a periodical refinement in the development of national GHG inventory. Recent reports [19] on estimation of methane from the animal sector broadly adopt methane emission factors (coefficients) developed by[21] and provide emission coefficients for different age groups. Singh [22] has predicted the average methane emission rate to be at 35, 27.5, 35.5, 4.2 and 3.7 kg animal^{-1}year^{-1} for cattle (crossbred), cattle (indigenous), buffalo, sheep and goat, respectively. The emission factors (mean) used for CO_2, CH_4, and N_2O, for biomass burning in tropical forests, are; 1626 g kg^{-1}, 6.6 g kg^{-1}, and 0.2 g kg^{-1}, respectively, as described by Silva., *et al*. [23]. The GWP for CH_4 (based on a 100-year time horizon) is 21, while that for N_2O, it is 310 when GWP value for CO_2 is taken as 1. We used standard rates of emission for computing GHG emission from NER. The GWP of different treatments were calculated using the following equation [24]:

$$GWP=CO_2 \text{ emission} + CH4 \text{ emission} \times 21+ N_2O \text{ emission} \times 310$$

Results and Discussion

Climate change

Climate change refers to long-term fluctuations in temperature, precipitation, wind, and other elements of the Earth's climate system. Natural processes such as solar-irradiance variations, variations in the Earth's orbital parameters, and volcanic activity can produce variations in climate [25]. The climate system can also be influenced by changes in the concentration of various gases in the atmosphere, which affect the Earth's absorption of radiation. The IPCC reported that the global average surface temperature of the Earth has increased by between 0.6 ± 0.2°C over the 20th century [10]. Although the Earth's atmosphere consists mainly of oxygen and nitrogen, neither plays a significant role in enhancing the greenhouse effect because both are essentially transparent to terrestrial radiation. The greenhouse effect is primarily a function of the concentration of water vapor, carbon dioxide, and other trace gases in the atmosphere that absorb the terrestrial radiation leaving the surface of the Earth [26]. We have clear evidence that human activities have affected concentrations, distributions and life cycles of these gases [26].

Emissions from agriculture sector in NER

Livestock Emissions

Enteric fermentation

Methane is produced as part of normal digestive processes in animals. During digestion, microbe's resident in an animal's digestive system ferment food consumed by the animal. This microbial fermentation process, referred to as enteric fermentation, produces CH_4 as a byproduct. The amount of CH_4 produced and emitted by an individual animal depends primarily upon the animal's digestive system, and the amount and type of feed it consumes. Ruminant animals are the major emitters of CH4 because of their unique digestive system27. McAllister., *et al*. [28] reported that, proteins, starch and plant cell-wall polymers consumed by the animal are hydrolyzed to amino acids and simple sugars by the bacteria, protozoa and fungi which reside in the rumen. In ruminants, the vast majority of enteric CH_4 production occurs in the reticulo-rumen.

The population of cattle, buffaloes, sheep, goats, pigs, horses etc. is, 13307, 643, 416, 5947, 4478, and 22 thousand, respectively. Assam has the highest number of livestock (17.226 million or 68.6%), followed by Tripura (1.889 million) and Meghalaya (1.762 million). Annual methane emission from livestock in NE region is 508.8 Gg or 10.946 Tg CO_2e (Table 1). Highest methane emission by livestock is in Assam, followed by Tripura, Meghalaya and Arunachal Pradesh. Maximum methane emitted is by cattle, followed by bufalo, goats and pigs with emissions of 439.1, 33.36,29.73 and 4.47 Gg, respectively. About 97.03% methane is emitted by four categories of livestock like, cattle, buffaloes, goat and sheep. It has been reported that livestock category, dairy or non-dairy cattle, nature of feed and management practices influence the methane emission by the livestock [11].

State	Cattle	Buffalo	Sheep	Goats	Pigs	Horses etc.	Others	Total	CO_2e (Tg)
Arunachal	16.60	0.165	0.100	1.460	0.356	0.072	8.854	27.606	0.579
Assam	331.35	27.500	1.770	21.600	2.000	0.132	0	384.355	8.071
Manipur	11.28	3.410	0.045	0.255	0.314	0.012	0.380	15.702	0.320
Meghalaya	27.29	1.265	0.105	1.825	0.524	0.024	0	31.034	0.652
Mizoram	1.16	0.330	0.005	0.080	0.267	0.012	0.076	1.925	0.040
Nagaland	15.51	1.925	0.020	0.890	0.698	0.012	1.254	20.309	0.426
Sikkim	4.46	0	0.015	0.460	0.035	0	0.190	5.155	0.108
Tripura	31.48	0.770	0.020	3.165	0.284	0	0	35.721	0.750
Total	439.13	35.365	2.080	29.735	4.478	0.264	10.754	521.807	10.946

Table 1. Methane emission (Gg) from livestock in Northeastern states of India.

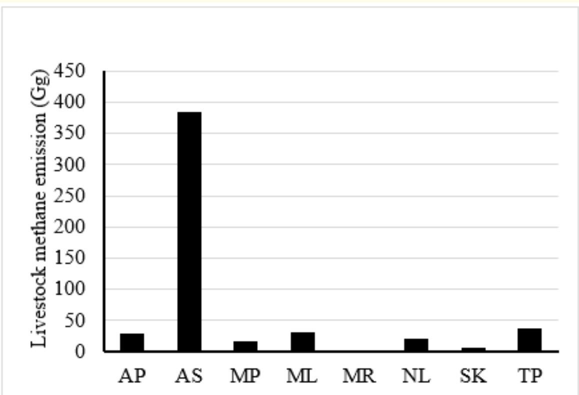

Figure 2: Methane emission from livestock in NER states.

Manure management

Livestock manure is principally composed of organic material. When this organic material decomposes in anaerobic environment, methanogenic bacteria produce methane. When manure is stored or treated as a liquid (ponds, tanks or pits), it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid (stacks or pits) or deposited on pastures and rangelands, it tends to decompose aerobically and little or no methane is produced. The management of livestock manure can produce anthropogenic CH_4 and N_2O emissions. Direct N_2O emissions are produced as part of the N cycle through the nitrification and de-nitrification of the organic N in livestock dung and urine. The second pathway is the runoff and leaching of N from manure to the groundwater below. Manure composition varies by animal diet, growth rate, and type, including the animal's digestive system, also affects the amount of CH_4. Total annual methane emission from manure management in NE region is 16.18 Gg, varying from 0.1741 Gg in Sikkim to 11.11 Gg in Assam (Table 2).

State	CH_4	N_20	CO_2e
Arunachal	0.9107	0.000387	19.24467
Assam	11.1108	0.004719	234.78969
Manipur	0.5089	0.000216	10.75386
Meghalaya	1.1365	0.000483	24.01623
Mizoram	0.2115	0.000090	4.46940
Nagaland	0. 9152	0.000389	19.33979
Sikkim	0.1741	0.000074	3.67904
Tripura	1.2184	0.000517	25.74667
Total	16.1861	0.006875	342.03935

Table 2: GHG emission from manure management (Gg).

Nitrous oxide emission

Nitrous oxide (N_2O) is a long-lived, potent GHG with 310 times the GWP per molecule of CO_2. Very large GWP makes N_2O a major contributor to climate change. Emissions of N_2O in agriculture are predominantly from soils, amended with fertilizers, manure, and compost, which release inorganic nitrogen (N) in the soil. Nitrous oxide emission through manure management in the region is 6.875 tons (Table 2). This is due to conversion of manure nitrogen into nitrous oxide during storage. The amount of N_2O released depends on the system and duration of waste management. Emissions of N_2O taking place during storage or handling of manure come under 'manure management', whereas emissions from soil application of manure are considered as 'soil emissions'. There are three potential sources of N_2O emissions related to animal production. These are (a) animals themselves, (b) animal wastes during storage and treatment, (c) dung and urine deposited by free-range grazing animals. Total GHG emission from manure management in the region was 0.342 Tg of CO_2e during 2015 (Table 2).

Soil management

Nitrous oxide is produced naturally in soils through the microbial processes of nitrification and de-nitrification. A number of agricultural activities increase mineral N availability in soils, thereby increasing the amount available for nitrification and de-nitrification, and ultimately the amount of N_2O emitted. Direct increases occur through a variety of management practices that add or lead to greater release of mineral N to the soil, including fertilization; application of managed livestock manure and other organic materials. Nitrogen (N) used in crop fertilization in the region was 37700 tons during 2010-11. Nitrous oxide emitted from soils, including fertilizer use, was 5.0729 Gg (1572.7 Gg CO_2e) (Table 3).

State	N_2O emitted (Gg)	CO_2e (Gg)
Arunachal	0.1609	49.900
Assam	3.2768	1015.832
Manipur	0.3319	102.907
Meghalaya	0.2053	63.667
Mizoram	0.1120	34.720
Nagaland	0.2192	67.955
Sikkim	0.1716	53.200
Tripura	0.5952	184.527
Total	5.0729	1572.708

Table 3. Nitrous oxide emission from soils and N fertilizer use.

Methane emission from rice cultivation

The chemical environment of reduced soil and the extremely limited O_2 supply in the soil-floodwater system has a large influence on carbon (C) and nitrogen (N) dynamics of irrigated rice systems. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the key greenhouse gases (GHG) that contribute towards the global warming. Concentrations of these gases in the atmosphere are increasing at 0.4, 3.0 and 0.22% per year, respectively [29]. More differentiated approach describing CH4 production and oxidation in rice fields was presented [30-32]. Rice is grown in NE region in about 3.5 million ha and the CH_4 emissions are to the tune of 0.273 Tg or 5.746 Tg CO_2e, annually (Table 4). Since the environment becomes anaerobic under flooded conditions, CH_4 is produced

State	Area under rice ('000 ha)	CH_4 emission (Gg)	CO_2e (Gg)
Arunachal	126	9.84	206.6
Assam	2484	194.22	4078.6
Manipur	168	13.13	275.7
Meghalaya	108	8.44	177.3
Mizoram	52	4.06	85.3
Nagaland	173	13.53	284.1
Sikkim	147	11.48	241.1
Tripura	242	18.92	397.3
Total	3500	273.62	5746.0

Table 4: Rice area and methane emission in NER states.

Through anaerobic decomposition of soil organic matter by methanogenic bacteria. As much as 60 to 90 percent of the CH4 produced is oxidized by aerobic methanotrophic bacteria in the soil (some oxygen remains at the interfaces of soil and water, and soil and root system) [33,34]. Some of the CH_4 is also leached away as dissolved CH_4 in floodwater that percolates from the field. The remaining un-oxidized CH_4 is transported from the submerged soil to the atmosphere primarily by diffusive transport through the rice plants.

GHG emissions from shifting cultivation

The burning of secondary vegetation in shifting cultivation releases CO_2 and other trace gases to the atmosphere. If the shifting cultivation system is in equilibrium, carbon dioxide released by fire will be reincorporated into the secondary vegetation biomass regrowing in the fallow areas that make up the system and will not therefore contribute to variation in the atmospheric CO_2 concentration on longer time scales, while the other trace gas emissions will represent a net addition to the atmosphere [35,36]. However, shifting cultivation systems are rarely in equilibrium thus resulting in net emission of CO_2 and other trace gases [35]. Estimates are given for carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Residue burning is not so common in the region, so the GHG emissions were not estimated.The shifting cultivation in the region is followed in 386 thousand ha of land, annually, with Manipur having a maximum area of 900 thousand ha. The GHG emitted annually were estimated to be 1101 Gg of CO_2, 4.482 Gg of methane and 0.1353 Gg of nitrous oxide (Table 5). This comes to 1.237 Tg of CO_2e. Shifting cultivation contributes about 6,32% of GHG emissions in the region.

State	Annual area ('000 ha)	CO_2	NH_4	N_2O	CO_2e
Arunachal	70	199.7	0.811	0.0245	224.326
Assam	69	196.8	0.799	0.0242	221.081
Manipur	90	256.7	1.042	0.0316	288.378
Meghalaya	53	151.2	0.613	0.0185	169.808
Mizoram	63	179.7	0.743	0.0221	202.154
Nagaland	19	54.2	0.220	0.0067	60.897
Sikkim	0	0	0	0	0
Tripura	22	62.7	0.254	0.0077	70.421
Total	386	1101.0	4.482	0.1353	1237.065

Table 5: GHG emission from shifting cultivation (Gg).

Land use land use change and forestry

Emissions from land use and land cover change are the most uncertain component of the global carbon cycle and estimates vary greatly and are difficult to compare due to differences in data sources, assumptions, and methods37. The estimates from LULUCF sector include emission by sources and or removal by sinks from changes in forest land, crop land, grassland, and settlements. Estimates indicate that GHG sequestration through LULUCF in the region was 17.341 Tg of CO_2e during 2015. This was mainly due to forest area in different states of the region, which contributed to 64,0% of the net removals, while crop land contributed 36.0%. However, in Assam, forests are responsible for only 35.5% of GHG removals and the rest sequestration was through crop land. GHG removals and emitted in the region was estimated to be -13.37, -7.50, 1.75 and 1.77 Tg of CO_2e through forests, crop land, pastures/grass lands and fuel wood use, respectively (Figure 3).

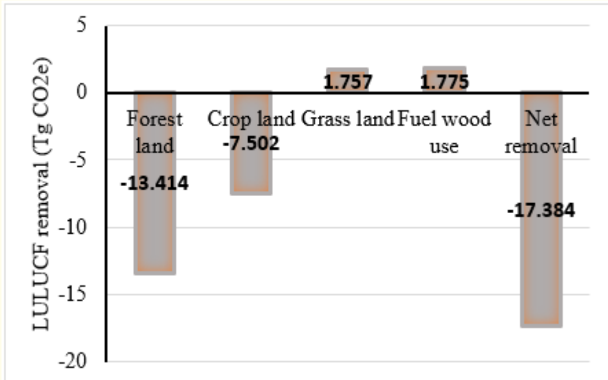

Figure 3: GHG removals/additions through LULUCF in NER states.

Total GHG emission (without LULUCF)

Total CO_2, CH_4 and N_2O emission from the agriculture sector in the region and in different states are given in table 6. The methane emission from livestock fermentation, manure management, rice cultivation and shifting cultivation was, 816.087 Gg (17.187 Tg CO_2e), nitrous oxide emission was 4.2314 Gg (1.3117 Tg CO_2e), from manure management, soils and shifting cultivation and 1.101Tg of CO_2e from shifting cultivation. There is no shifting cultivation practice in Sikkim, so the emission from this sector is zero. If net emissions are considered in the region, that is, LULUCF is taken into account (Figure 4), total GHG emissions (including LULUCF) are only 2.208 Tg of CO_2e. Interestingly, only Assam, Meghalaya and Tripura have positive net emissions from agriculture sector, while

State	Live-stock EF	Manure	Mgmt.	Rice Cult.	Soils		Shifting Cultivation		GHG emission CO_2e(Tg)
	CH_4	CH_4	N_2O	CH_4	N_2O	CO_2	CH_4	N_2O	
Arunachal	27.61	0.911	0.000387	9.84	0.1474	199.7	0.811	0.0245	1.0757
Assam	384.35	11.111	0.004719	194.22	2.9047	196.8	0.799	0.0242	13.5063
Manipur	15.70	0.509	0.000216	13.13	0.1965	256.7	1.042	0.0316	0.9654
Meghalaya	31.03	1.136	0.000483	8.44	0.1263	151.2	0.613	0.0185	1.0618
Mizoram	1.93	0.211	0.000090	4.06	0.0585	179.7	0.743	0.0221	0.3505
Nagaland	20.31	0.915	0.000389	13.53	0.2012	54.2	0.220	0.0067	0.8532
Sikkim	5.15	0.174	0.000074	11.48	0.1716	0	0	0	0.4061
Tripura	35.72	1.218	0.000517	18.92	0.2831	62.7	0.254	0.0077	1.3313
Total	521.80	16.185	0.006875	273.62	4.0893	1101.0	4.482	0.1353	19.5503

Table 6: Total GHG emissions from NE Region without LULUCF (Gg).

all other states of the region showed negative emission values. The emissions from industry, energy and waste management, have not been considered.

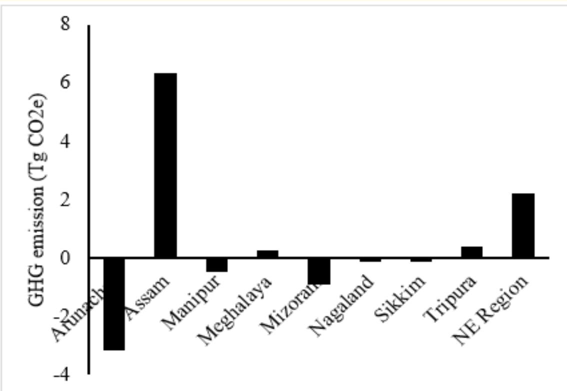

Figure 4: Net GHG emissions from agriculture (with LULUCF).

Contribution of various components in GHG emissions from agriculture sector

The relative contribution of various components such as, enteric fermentation, manure management. Rice cultivation, soils and shifting cultivation has been shown in figure 5. Enteric fermentation is by far the largest contributor to GHG emissions from agriculture sector in the region with a share of 56%, followed by rice cultivation (29.4%), soils (6.5%), shifting cultivation (6.3%) and manure management (1.8%). It shows that livestock and rice cultivation methane emissions contribute more than 85% of GHG emission in NE region. By taking appropriate measures, the GHG emission in the region can be reduced to a great extent.

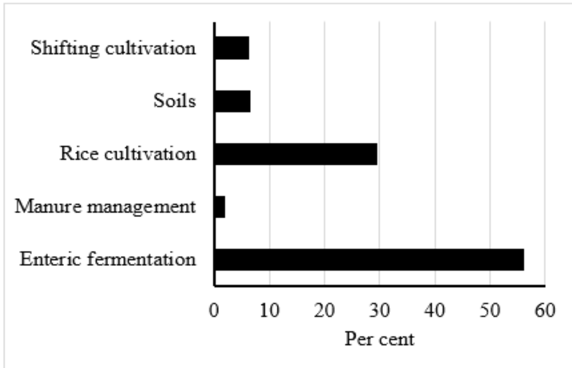

Figure 5: Percent emission of GHG from various components of agriculture sector in NE states.

Conclusions

Methane emission contribution from livestock is the highest as compared to various other subsectors from agriculture, viz. rice cultivation and open burning of crop residue. The largest biogenic sources of CH_4 are enteric fermentation from ruminant animals and rice production. Greenhouse gas emissions from the agricultural sector that are related to animal production comprise CH_4 directly emitted from domestic animals, CH_4 and N_2O emitted from manure and grazed lands, and N_2O emitted from soils. Out of a total 19.550 Tg of CO_2e GHG emission from agriculture sector, 17.384 Tg CO_2e (88.9%) is removed through LULUCF. Effort to reduce GHG emission from livestock, rice cultivation and abandoning of shifting cultivation in NER, would lead to net zero emission from agriculture sector. Mitigation of methane emitted from livestock is approached most effectively by strategies that reduce feed input per unit of product output. Application of fermented manures like biogas slurry in the place of unfermented farmyard manure can help in reducing GHG emissions. Balanced farming systems are required to be introduced for containing greenhouse gas emissions at desired level.

Bibliography

1. Sethi M. "Decoding urban India's carbon footprint: spatial-numerical mapping of thermal energy emissions". *Current Science* 108 (2015): 1617-1623.
2. Sharma., *et al*. "Greenhouse gas inventory estimates for India". *Current Science* 101 (2011): 405-415.
3. Sharma., *et al*. "Greenhouse gas emissions from India: A perspective". *Current Science* 90 (2006): 326-333.
4. Mosier AR., *et al*. "Assessing and mitigating N2O emissions from agricultural soils". *Climatic Change* 40 (1998): 7-38.
5. Smith P., *et al*. "Agriculture. In Climate Change: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Metz B, Davidson OR, Bosch PR Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, (2007).
6. Sharma UC. "GHG emissions and mitigation: impact on agriculture, water and soil resources in NW Himalayas. Paper presented in Seminar on" Sustaining Hill Agriculture in Changing Climate" 5-7 Dec., held at Agartala, Tripura, India, (2015).
7. Galloway JN. "The global nitrogen cycle". *Treatise on Geochemistry* 8 (2003): 557-583.
8. Mosier AR. "Environmental challenges associated with needed increases in global nitrogen fixation". *Nutrient Cycling in Agroecosystems* 63 (2002): 101-116.
9. Cole CV., *et al*. "Global estimates of potential mitigation of greenhouse gas emissions by agriculture'. *Nutrient Cycling in Agroecosystems* 49 (1997): 221-228.
10. IPCC. 2001. Climate change: The scientific basis. Cambridge Univ. Press, Cambridge, UK., (2001).
11. Paustian K., *et al*. "Agricultural Mitigation of Greenhouse Gases: Science and Policy Options. CAST (Council on Agricultural Science and Technology) Report, R141 2004, ISBN 1-887383-26-3, (2004).
12. Smith P. "Engineered biological sinks on land. In the Global Carbon Cycle. Integrating humans, climate, and the natural world, (ed. Field CB, Raupach MR). SCOPE 62, Island Press, Washington D.C. (2004): 479-491.
13. Janzen HH. "Carbon cycling in earth systems - a soil science perspective". *Agriculture, Ecosystems and Environment* 104 (2004): 399-417.
14. Oenema O., *et al*. "Trends in global nitrous oxide emissions from animal production systems". *Nutrient Cycling in Agroecosystems* 72 (2005): 51-65.
15. Smith KA., *et al*. "Impacts of land management on fluxes of trace greenhouse gases". *Soil Use and Manage* 20 (2004): 255-263.
16. Rodhe AL. "A comparison of the contribution of various gases to the greenhouse effect". *Science* 248 (1990): 1217-1219.
17. Li C., *et al*. "Modeling greenhouse gas emissions from rice-based production systems: Sensitivity and upscaling". *Global Biogeochemical Cycles* 18 (2004): 1-19.
18. Mitra AP. "Uncertainty Reduction in GHG Inventory Estimates inIndia: An Overview. In Climate Change and India: Uncertainty Reduction in Greenhouse Gas Inventory Estimates (ed. Mitra, A. P., Sharma, S., Bhattacharya, S., Garg, A., Devotta, S. and Sen, K.), Universities Press, Hyderabad, (2004).
19. Mitra AP and Bhattacharya S., "Climate change and greenhouse gas inventories: Projections, impacts and mitigation strategies. In Climate Change and India: Issues, Concerns and Opportunities (ed. Shukla, P. R., Sharma, Subodh K. and Ramana, P. V.), Tata McGraw-Hill, New Delhi, (2002).
20. Garg A and Shukla PR. Emission Inventory of India, Tata McGraw-Hill, New Delhi, (2002).
21. Swamy M and Ramasami T. "Methane emission from India through enteric fermentation: an estimate. In Proceedings of IGBP Symposium on Changes in Global Climate due to Natural and Human Activities (1997): 24-26.
22. Singh GP. "Livestock production and environmental protection. Proceedings of X Animal Nutritional Conference, Karnal, (2001): 211-222.

23. Silva JMN., *et al*. "Greenhouse gas emissions from shifting cultivation in the tropics, including uncertainty and sensitivity analysis". *Journal of Geophysical Research* 116 (2011): 1-21.

24. Watson., *et al*. "Climate Change 1995, impacts, adaptations and mitigation of climate change: Scientific-technical analyses, Intergovernmental Panel on Climate Change, Cambridge University Press, USA (1996).

25. US EPA. U.S. Greenhouse Gas Emissions and Sinks: 1990-2000, U.S. Environmental Protection Agency, Office of Atmospheric Programs, 2002, EPA 430-R-02-003.

26. IPCC Climate Change: The Science of Climate Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell, eds.; Cambridge University Press. Cambridge, U.K., (1996).

27. Singhal., *et al*. "Methane emission estimates from enteric fermentation in Indian livestock:Dry matter intake approach". *Current Science* 88 (2005): 119-127.

28. McAllister TA., *et al*. "Dietary, environmental and microbiological aspects of methane production in ruminants". *Canadian Journal of Animal Science* 76 (1996): 231-243.

29. Battle M., *et al*. "Atmospheric gas concentrations over the past century measured in air from fin at the south pole". *Nature* 383 (1996): 231-235.

30. Cao M., *et al*. "Modelling methane emissions from rice paddies". *Global Biogeochemical Cycles* 9 (1995): 183-195.

31. Pathak H., *et al*. "Greenhouse gas emissions from Indian rice fields: calibration and upscaling using the DNDC model". *Bio Geosciences* 2 (2005): 113-123.

32. Pathak H and Wassmann R. "Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of Technical Coefficients". *Agricultural Systems* 94 (2007): 807-825.

33. Holzapfel-Pschorn., *et al*. "Production, oxidation and emission of methane in rice paddies". *FEMS, Microbiology Letter* 31 (1985): 343-351.

34. Sass RL., *et al*. "Methane production and emission in a Texas rice field". *Global Biogeochemical Cycles* 4 (1990): 47-68.

35. Fearnside PM. "Global warming and tropical land-use change: Greenhouse gas emissions from biomass burning, decomposition and soils in forest conversion, shifting cultivation and secondary vegetation". *Climatic Change* 46 (2000): 115-158.

36. Lehsten V., *et al*. "Estimating carbon emissions from African wildfires". *Bio Geosciences* 6 (2009): 349-360.

37. Ramankutty., *et al*. "Challenges to estimating carbon emissions from tropical deforestation". *Global Change Biology* 13 (2007): 51-66.

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