GHG Platform INDIA

National Level Greenhouse Gas Estimates for the Agriculture, Forestry and Other Land Use Sector (AFOLU)

2005-2013

VASUDHA FOUNDATION
Green ways for a good earth!

CEEW Council on Energy, Environment and Water | CIMMYT | CSTEP | ICLEI Local Governments for Sustainability | SHAKTI Sustainable Energy Foundation | Vasudha Foundation | WRI India

Credits and Acknowledgments

Vasudha Foundation would like to acknowledge GHG Platform India for recognizing the need for year on year independent emission estimates for India. We would also like to thank Shakti Sustainable Energy Foundation for the generous grant support.

We would also like to thank all our platform partners Council on Energy, Environment and Water (CEEW), Center for Study of Science, Technology and Policy (CSTEP), ICLEI Local Governments for Sustainability- South Asia, and World Resources Institute for their continuous support to the Platform.

This study would not have been possible without the constant support provided by Dr. Tek Sapkota, CIMMYT and Dr. Sudha Padmanabha, Fair Climate Network. Dr. Tek and Dr. Sudha have been engaged with the platform to provide technical inputs for carrying out the estimations from AFOLU sector as well as providing quality assurance of the estimates.

In addition to the experts mentioned above who have provided methodological advice and quality assurance, we would also like to acknowledge the help provided by National Remote Sensing Centre Hyderabad. We would especially like to thank Dr. C. Sudhakar Reddy in helping us correctly interpret the land use change matrix that the Platform was able to procure and Dr. P.G. Diwakar and Dr. K. Sreenivas Rao who provided us with the land use change matrix for 2006-2013.

Last, but not the least, we express our gratitude to WRI India for a comprehensive review of this study.

Abbreviations

AFOLU	Agriculture, Forest and Other Land Use
AGB	Above Ground Biomass
AWMS	Animal Waste Management System
BGB	Below Ground Biomass
BUR	Biennial Update Report
CH_4	Methane
CO_2	Carbon Dioxide
EF	Emission Factor
FSI	Forest Survey of India
GHG	Green House Gas
GoI	Government of India
INCCA	Indian Network on Climate Change Assessment
IPCC	Intergovernmental Panel on Climate Change
MoA	Ministry of Agriculture
MOEFCC	Ministry of Environment, Forest and Climate Change
N_2O	Nitrous Dioxide
NATCOM	National Communication to the UNFCCC
NRSC	National Remote Sensing Centre
QA/QC	Quality Assurance/Quality Control
SOC	Soil Organic Carbon

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Document Information

Version	Date	Description
2.0	28th September 2017	*This document contains information on assumptions and the methodology followed to estimate emission from the AFOLU sector at national level from 2005-13.*
2.1	13th November 2017	*Structural and editorial changes made.* *This document contains information on assumptions and the methodology followed to estimate emission from the AFOLU sector at national level from 2005-13.* *This document is undergoing a peer review process, however, any changes that may be made further will not have an impact on the figures and estimates. Once the review process is completed, the final document will be uploaded and the same shall be updated in this section.*

Executive Summary

AFOLU (Agriculture, Forest and Other Land Use) sector is the third largest emitter of GHGs in India. The AFOLU sector contributed almost 172 million tCO_2e (~7% of the economywide emissions) to the emissions of India in 2013. The major contributing key source categories of emissions from AFOLU sector are livestock and rice cultivation. Land use, as a whole, is a net sink, primarily due to CO_2 removals by forests in India. Table 1 Overview of Emissions from AFOLU sector in 2005 and 2013 gives details of emissions from this sector in the year 2005 and 2013.

Table 1 Overview of Emissions from AFOLU sector in 2005 and 2013[1]

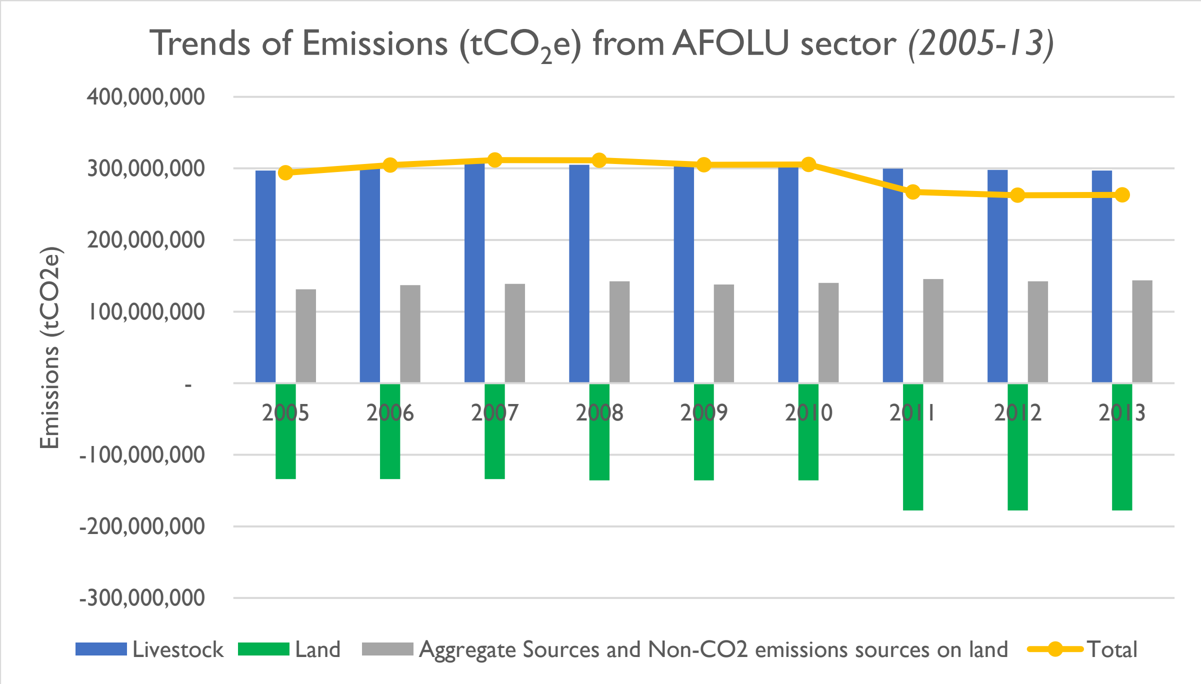
IPCC Code	Sector/ Sub-sector	Emissions in 2005 (in million tCO_2e) AR2 GWP	Emissions in 2013 (in million tCO_2e) AR2 GWP	Percentage change in Emissions	Emissions in 2005 (in million tCO_2e) AR5 GWP	Emissions in 2013 (in million tCO_2e) AR5 GWP	Percentage change in Emissions
3	AFOLU	201.72	172.30	-14.58%	294.09	263.15	-10.52%
3A	Livestock	222.87	223.13	0.11%	296.92	297.19	0.09%
3A1	Enteric Fermentation	201.60	201.91	0.15%	268.80	269.22	0.15%
3A2	Manure Management	21.27	21.21	-0.26%	28.11	27.97	-0.49%
3B	Land	-134.03	-177.73	32.61%	-134.03	-177.73	32.61%
3B1	Forest Land	-145.62	-188.83	29.68%	-145.62	-188.83	29.68%
3B2	Cropland	2.30	2.47	7.20%	2.30	2.47	7.20%
3B3	Grassland	0.63	0.71	11.90%	0.63	0.71	11.90%
3B4	Wetland	N.E.	N.E.	-	N.E.	N.E.	-
3B5	Settlements	0.45	0.49	10.47%	0.45	0.49	10.47%
3B6	Other Land	8.21	7.43	-9.45%	8.21	7.43	-9.45%
3C	Aggregate Sources and non-CO_2 emissions sources on land	112.88	126.91	12.42%	131.20	143.69	9.52%
3C1a	Emissions from Biomass burning in forests	0.32	0.32	1.50%	0.40	0.40	1.50%

[1] Please refer to AFOLU sector file, worksheet 'Summary"

IPCC Code	Sector/ Sub-sector	Emissions in 2005 (in million tCO_2e) AR2 GWP	Emissions in 2013 (in million tCO_2e) AR2 GWP	Percentage change in Emissions	Emissions in 2005 (in million tCO_2e) AR5 GWP	Emissions in 2013 (in million tCO_2e) AR5 GWP	Percentage change in Emissions
3C1b	Emissions from biomass burning in croplands	5.00	6.32	26.24%	5.99	7.57	26.26%
3C1c	Emissions from Biomass burning in Grasslands	N.E.	N.E.	-	N.E.	N.E.	-
3C1d	Emissions from Biomass burning in Other Land	N.E.	N.E.	-	N.E.	N.E.	-
3C2	Liming	N.E.	N.E.	-	N.E.	N.E.	-
3C3	Urea Fertilization	N.E.	N.E.	-	N.E.	N.E.	-
3C4	Direct N_2O emissions from managed soils	29.95	40.27	34.45%	25.60	34.42	34.45%
3C5	Indirect N_2O emissions from managed soil	7.59	10.21	34.45%	6.49	8.73	34.45%
3C6	Indirect N_2O emissions from manure management	N.E.	N.E.	-	N.E.	N.E.	-
3C7	Rice Cultivation	70.02	69.79	-0.32%	92.71	92.57	-0.15%
3D	Other	N.E.	N.E.	-	N.E.	N.E.	-
Note: N.E. – Not Estimated							

In general, during the period of estimation, the GHG emissions from this sector have decreased, primarily due to increased removals of CO_2 from the forests.

The major trends exhibited by this sector are being captured in the graph below.



The major emitting source categories in the AFOLU sector (without Land Use, Land Use Change & Forestry, LULUCF sector) are enteric fermentation contributing to almost 58% emissions followed by rice cultivation with 20% contribution in the year 2013. The other sub-sectors are very small contributors to the emissions from AFOLU. The major developments that are to be reported for calculating the GHG emissions from the AFOLU sector in this phase of the project are as follows:

- For land use emissions, the activity data is being sourced from state level changes and being added up to the national level for all categories, except forests. To the extent possible, India specific emission factors have been used for these calculations
- For forests, a combination of bottom up and top down approaches has been used to calculate removals of GHGs.
- For calculating biomass burning from forests, India specific activity data, along with emission factors have been used.

Introduction

The GHG estimates for the AFOLU sector being presented in this document are a part of a collaborative effort by GHG Platform India to build year on year estimates that are available in the public domain and can hopefully lead to greater discussion and debate on climate change policies and practises in India. The platform comprises notable civil society groups in the climate and energy space in India, who also have a prominent role in the platform and the emissions estimations. These institutions are Council on Energy, Environment and Water (CEEW), Center for Study of Science, Technology and Policy (CSTEP), ICLEI Local Governments for Sustainability- South Asia, Shakti Sustainable Energy Foundation, Vasudha Foundation and World Resources Institute India. The platform seeks to add value to various ongoing GHG estimation efforts by helping address existing data gaps and data accessibility issues, extending beyond the scope of national inventories, and by increasing the volume of analytics and policy dialogue on India's Greenhouse Gas emissions sources, profile, and related policies.

The greenhouse gases (GHG) accounted for this sector are namely Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) with total carbon dioxide equivalent (CO_2e) using global warming potential (GWP) and global temperature potential (GTP) from Intergovernmental Panel on Climate Change (IPCC) Assessment Reports (AR2 and AR5).

The key sources of GHG emissions from this sector for which emission estimation has been done are:

- 3A. Livestock
  - 3A1. Enteric Fermentation
  - 3A2. Manure Management
- 3B. Emissions from Land through various uses that land is put to by human interventions from
  - 3B1. Forest Land
  - 3B2. Cropland
  - 3B3. Grassland
  - 3B5. Settlements
  - 3B6. Other Lands
- 3C. Aggregate sources and non-CO_2 emissions sources on land
  - 3C1a. Emissions from biomass burning in forests
  - 3C1b. Emissions from biomass burning in croplands
  - 3C4. Direct N_2O emissions from managed soils
  - 3C5. Indirect N_2O emissions from managed soils
  - 3C7. Rice Cultivation

The sources of GHG emissions for which calculations have not been done are the following:

  - 3B4. Wetlands
  - 3C1c. Emissions from biomass burning in Grassland
  - 3C1d. Emissions from biomass burning in Other Land
  - 3C2. Liming
  - 3C3. Urea Fertilisation
  - 3C6. Indirect N_2O emissions from Manure Management

Key highlights:

- Emission estimates are being provided for the period CY 2005-2013.

- Activity data for the agriculture sector is available for the fiscal year i.e. April-March. For the purpose of this study, this data has been converted into calendar year by allocating 1/4th of the emissions of the previous fiscal year and 3/4th of the emissions of the current fiscal year for the total emissions for the current calendar year.
- For measuring emissions from land, data for the fiscal year has been assumed to be the same as the calendar year. This is because emissions from land do not appear to have any seasonal variations that would require us to identify differences, if any, between fiscal year and calendar year in the Indian context.

The base year for these emission estimates is 2005. From the perspective of data availability and India's NDC, which chooses 2005 as the base year for its pledges, the year 2005 is of historical and administrative importance and hence, has been considered as the base year for these calculations.

The GHG estimates are primarily based upon the following activity data:

- India's Livestock Census for 2002, 2007 and 2012. Data for intermediate years of the estimation from 2005 to 2013 are extrapolated or interpolated as required;
- Crop production data available publicly from the website of the Department of Agriculture and Cooperation for period of estimation i.e. 2005 to 2013;
- Forest sector data available from State of India's Forests reports produced biennially by the Forest Survey of India, Dehradun. This report uses State of Forests Reports from 2005 to 2015;
- Data available on land other than forests for the period 2006-07 to 2011-12 from the National Remote Sensing Centre, Hyderabad.

Institutional Arrangement and Capacity

Institutional arrangements for this exercise are shown in the diagram given below in Figure 2. Vasudha Foundation, New Delhi is involved in preparation of emission estimates from the AFOLU sector.

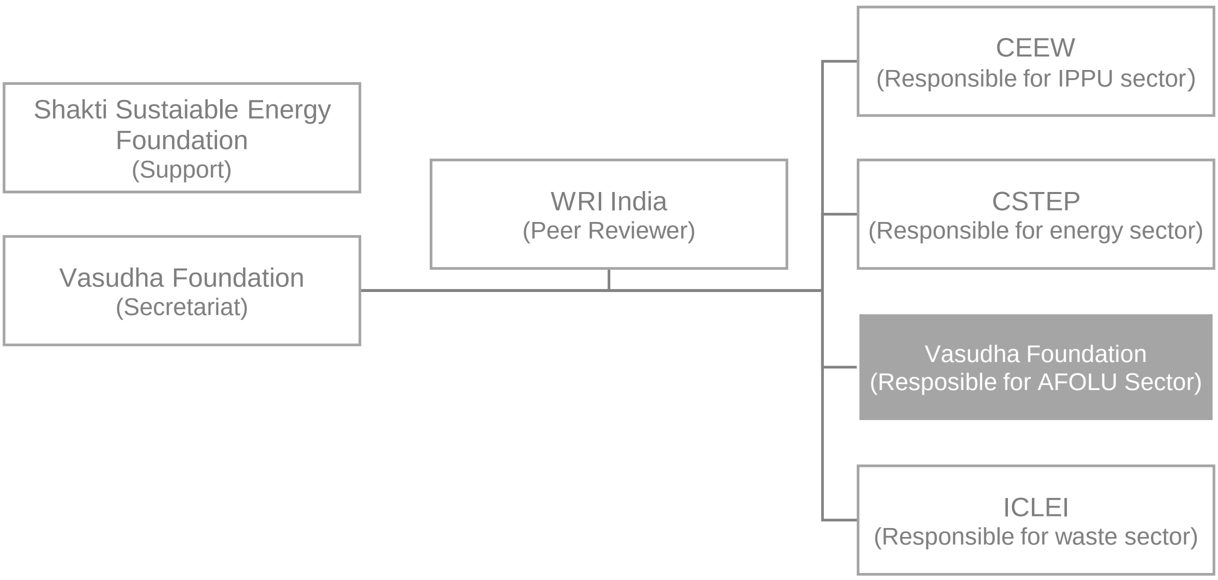


Figure 1 Institutional Arrangement of GHG Platform India

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Technical competence of staff

This work has primarily been done by Raman Mehta and Samiksha Dhingra. Raman is an environment and climate change professional with very wide experience of working on environment, forests, wildlife, and climate change. Samiksha has a master's in Climate Science and Policy from TERI university and has been working on issues of climate change and energy for the past 3 years. In addition, Srinivas Krishnaswamy, CEO, Vasudha Foundation has also provided his guidance, experience and insights from time-to-time to this work.
In addition, Dr. Tek Sapkota, CIMMYT and Dr. Sudha Padmanabha, Fair Climate Network. have been engaged in this exercise to provide technical inputs for carrying out the estimations from AFOLU sector as well as providing quality assurance of the estimates. Dr. Tek has contributed to India's first NATCOM on GHG and was invited to the elite panel of reviewers of the IPCC database and methodologies on GHGs by WMO/UNEP. Dr. Sudha has a good knowledge of CDM projects, GIS and LULUCF sector.

Reviewers' Profile:

Chirag Gajjar

Chirag Gajjar is senior manager and leads mitigation for WRI's climate program in India. He leads research and project management execution for WRI India. He is the focal point for carbon pricing and science-based targets work in India. He also focuses on GHG measurement and management for businesses, and engaging with policy makers on long-term decarbonization strategies. He has been instrumental in supporting various Indian businesses to adopt internal price on carbon. He is the project leader for WRI India on GHG Platform India project. chirag.gajjar@wri.org

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Subrata Chakrabarty works with WRI's climate program in India. He primarily works on GHG Platform – India (SEEG India Projects) which aims at creating credible and accurate national and state - level GHG inventories based on IPCC methods. His role includes reviewing the GHG estimation reports for various sectors such as energy, waste, IPPU, AFOLU. In addition, he leads the capacity building activities under India GHG Program – a flagship initiative by WRI India, disseminating regional, sectoral and global best practices to create a culture of inventorization and benchmarking of GHG emissions in India. He also supports the team with the need-based work related to Science Based Targets and Internal Carbon Pricing. subrata.chakrabarty@wri.org

GHG Estimation Preparation, Data Collection, Process, and Storage

These estimates were prepared in consultation with and under the guidance of the technical experts that were engaged separately for the agriculture and land sector. The emission estimation methods broadly conform to the methodologies that appear to have been followed by the official inventories for 2007 and 2010 in context with the 2006 IPCC revised guidelines for national GHG inventories. In addition to the peer review process, estimates for AFOLU sector have been reviewed by the external experts engaged by Vasudha for advising and providing guidance for the exercise. The activity data used for emission estimation has been validated through linear trend analysis. Quality assurance and verification was done by checking for variance, if any with official GHG inventories for the years they are available. The data has been archived using excel and available for open access on www.ghgplatform-india.org

In this exercise, species specific estimation methods were used for enteric fermentation and manure management. For calculating emissions from land, IPCC's stock exchange method was used where land stratification was identified and differences of land use and carbon pools were calculated, details of which can be found in the consecutive chapters. For estimating emissions from other aggregate non-CO_2 emission sources on land, standard methods described in 2006 IPCC guidelines on national GHG inventories (hereafter referred as 2006 IPCC guidelines) were followed.

Planning and methodology improvement:

Underlying activity data for these calculations has been sourced from official sources considered true and authentic, unless such data was not available in the public domain. In cases where data are not available in public domain, assumptions were made in consultation with the experts associated with this exercise as well as on the basis of official publications. These publications throw light on the sorts of assumptions that may have been made for official inventories published by the Government of India. Further, country specific emissions factors have been used for all calculations, where such information was available and in the public domain. In case it was found to be impossible to use country specific emission factors, IPCC default emission factors were used for the calculations. Further, all sectoral and sub-sectoral calculations have been compared with official emissions inventories published by the Government of India for the years for which such information is available in the public domain and found to have been within an acceptable level of variance. There are several gaps of data that have become apparent in the process of doing these calculations, on which we hope to be able to engage with the government constructively in a process that would not only result in improving our own estimations, but also contribute in achieving higher levels of accuracy and lower levels of uncertainty of the official GHG emissions estimations.

Data Sources:

Activity data for various sub-sectors within agriculture has been captured or derived in the following manner:

Table 2 Overview of activity data for AFOLU sector

IPCC ID	**CATEGORIES**	**PRINCIPAL DATA SOURCE**	**PRINCIPAL COLLECTION MECHANISM**
3A1	Enteric Fermentation	Livestock Census of India for 2007 and 2012	• Activity Data derived from Livestock Census of India from Ministry of Agriculture
3A2	Manure Management	Livestock Census of India for 2007 and 2012	• Activity Data derived from Livestock Census of India from Ministry of Agriculture
3B1	Forest Land	Forest Survey of India, Dehradun	• Forest Survey of India, Dehradun

3B2	Cropland	National Remote Sensing Centre, Hyderabad	• National Remote Sensing Centre[2], Hyderabad
3B3	Grassland	National Remote Sensing Centre, Hyderabad	• National Remote Sensing Centre[3], Hyderabad
3B5	Settlements	National Remote Sensing Centre, Hyderabad	• National Remote Sensing Centre[4], Hyderabad
3B6	Other land	National Remote Sensing Centre, Hyderabad	• National Remote Sensing Centre[5], Hyderabad
3C1a	Biomass Burning in Forest Land	Forest Survey of India, Dehradun	• Forest Survey of India, Dehradun
3C1b	Biomass Burning in Cropland	Quantity of residue generated derived as a ratio of production. Quantity of residues burnt derived based on scientific studies	• Activity Data derived from Ministry of Agriculture • Residue to crop ratio derived from Bandyopadhyay et. al. 2001 • Ratio of burning of rice straw derived from Gadde et. al. 2009 • Ratio of burning of other crop residues derived from Jain et. al. 2014 • Combustion factors of different residues taken from Turn et. al. (1997), Streets et. al. 2003, and Jain et. al. 2014
3C4	Direct N_2O emissions from managed soils	Fertilizer consumption data	• Activity Data derived from Fertiliser Association of India (Soft copy is available on request).
3C5	Indirect N_2O emissions from managed soils	Fertilizer consumption data	• Activity Data derived from Fertiliser Association of India (Soft copy is available on request).
3C7	Rice Cultivation	Directorate of Economics and Statistics, Department of Agriculture, Cooperation and	• Activity Data derived from Ministry of Agriculture

[2] Land Use Change Matrix available on request from National Remote Sensing Centre, Hyderabad
[3] Land Use Change Matrix available on request from National Remote Sensing Centre, Hyderabad
[4] Land Use Change Matrix available on request from National Remote Sensing Centre, Hyderabad
[5] Land Use Change Matrix available on request from National Remote Sensing Centre, Hyderabad

		Farmer's Welfare, Government of India	

All sub-categories falling under IPCC Codes 3A i.e. Livestock, have been accounted for in these calculations. All sub-categories under IPCC codes 3B Land have been accounted for in this exercise, except for 3B4 i.e. wetlands. All the sub-categories falling under the code 3C Aggregate Sources and Non-CO_2 Emission Sources on Land have not been accounted due to lack of data availability. These are as follows:
3C1c Biomass Burning in Grassland
3C1d Biomass Burning in All Other Land
3C2 Liming
3C3 Urea Fertilization
3C6 Indirect N_2O Emissions from Manure Management
3D Other

Brief description of key source categories

The key sources of emissions for the period 2005-13 are enteric fermentation and rice cultivation, which together account for around half of the emissions from AFOLU sector. The methodologies used for calculating emissions for these two subsectors are consistent with Tier II of the 2006 IPCC guidelines. Emissions from Land other than forests are a source of emissions, but the Forests of India are a net sink.

Uncertainty Evaluation

As far as uncertainties of the GHG emission estimates calculated by the platform for the Agriculture Sector are concerned, they mainly arise due to uncertainties in calculating the GHG emissions for enteric fermentation and rice cultivation. This is primarily due to the following reasons:

- There are uncertainties around gross energy intake of livestock of different categories across regions as well as economic status of the people that are engaged in economic activities that involve rearing of livestock in India. Thus, assumptions have had to be made that may not be reflective of the actual situation on the ground. Further, authentic data for manure management is also not available and assumptions have had to be made based on expert research studies.
- Data for different water management regimes for rice cultivation in India are not documented. Hence, assumptions have been made based on studies done by experts that are now a bit dated and may not be totally accurate.
- Authentic data for agricultural residues and their uses are unavailable. Hence assumptions have had to be made for emissions arising out of this subsector based on certain expert research studies.

As far as uncertainties of the GHG emission estimates described by the platform for Land are concerned, they arise out of uncertainties of the data and its availability in the public domain, as well as methodological uncertainties that have been highlighted by the IPCC itself.

Uncertainty from this sector also arises due to assumptions made in calculating biomass/SOC carbon stock factor (2006 IPCC Guidelines[6]).

General Assessment of Completeness

Every attempt has been made to have as complete an assessment of the GHG emissions within the AFOLU sector, as possible. However, emissions estimations for the following sub-sectors within AFOLU could not be calculated:

3B4. Wetlands
3C1c. Emissions from biomass burning in Grassland
3C1d. Emissions from biomass burning in Other Land
3C2. Liming
3C3. Urea Fertilisation
3C6. Indirect N_2O emissions from Manure Management

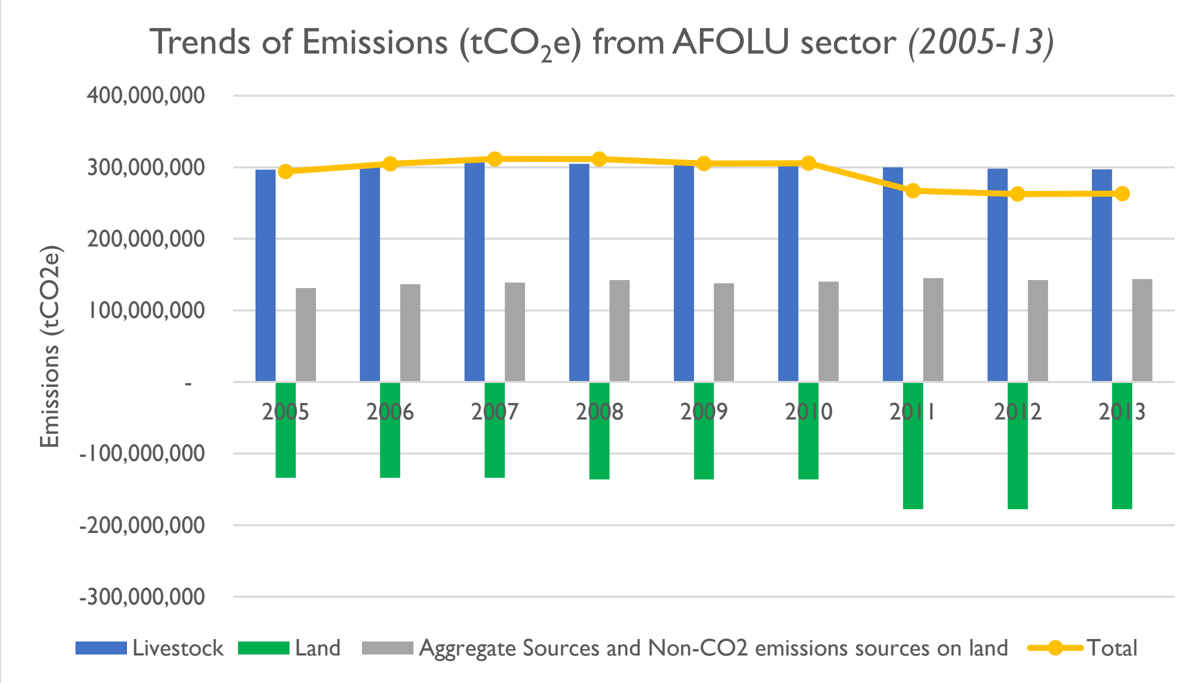
Calculations for these sectors could not be carried out due to either lack of availability of the underlying activity data, such as in the case of wetlands or biomass burning in other lands, or due to there being very negligible incidence of such activities in the country, such as liming. For biomass burning in cropland, methodology is adopted from NATCOM II. Similarly, biomass burnt data has been derived by apportioning burnt area based on NATCOM II. biomass burning in forest land However, we will continue to engage on searching for data where there is a deficiency of such data in the public domain but existence within official departments or institutions, as well as explore possibilities for carrying out primary data gathering, if support for such primary data gathering is forthcoming in future.

Trends in Emissions

The graph below shows that the total emissions from AFOLU sector followed a linear trend from 2005-13. There was a marginal decrease of approximately 38 Million tonnes CO_2e in total emissions from 2010 (208 Million tCO_2e) to 2011 (170 Million tCO_2e). This decrease can be attributed to increase in absorption of GHGs from India's forests.

Figure 2 Trends of Emissions from AFOLU Sector

[6] http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html



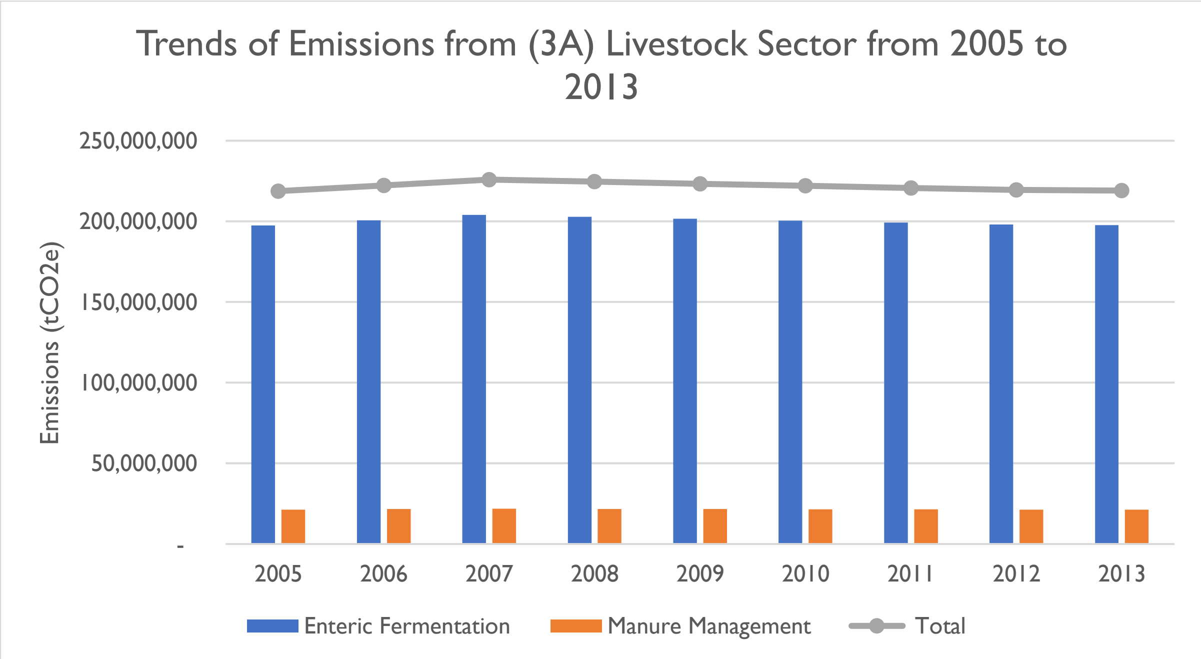
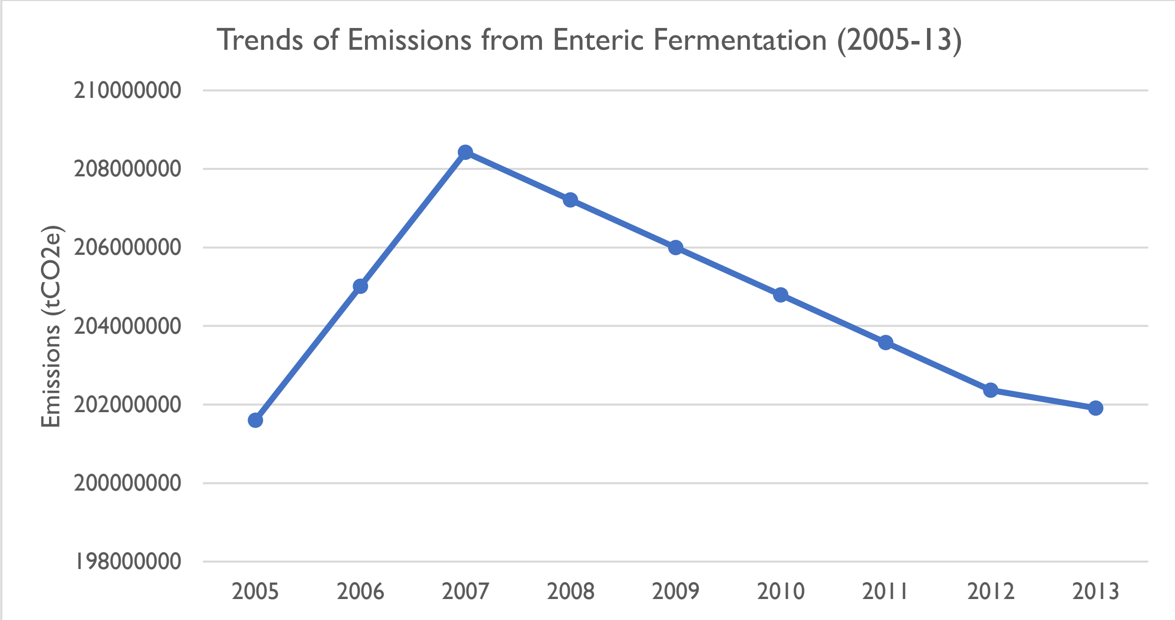


Figure 3 Trends of Emissions from Livestock Sector

Emissions from the livestock sector i.e. enteric fermentation and manure management contribute a major share in the AFOLU sector. The emissions from this sector increased from 2005 to 2007. Since 2007, emissions have been declining due decrease in livestock population from 2007 onwards. The population rose from 507 million in 2005 to 529 million in 2007 and declined to 505 million in 2013. The compound annual growth rate of population during the livestock census years (2007 and 2012) was -0.68%. The growth rate (CAGR) of emissions from this sector was 0.02% from 2005 to 2013.



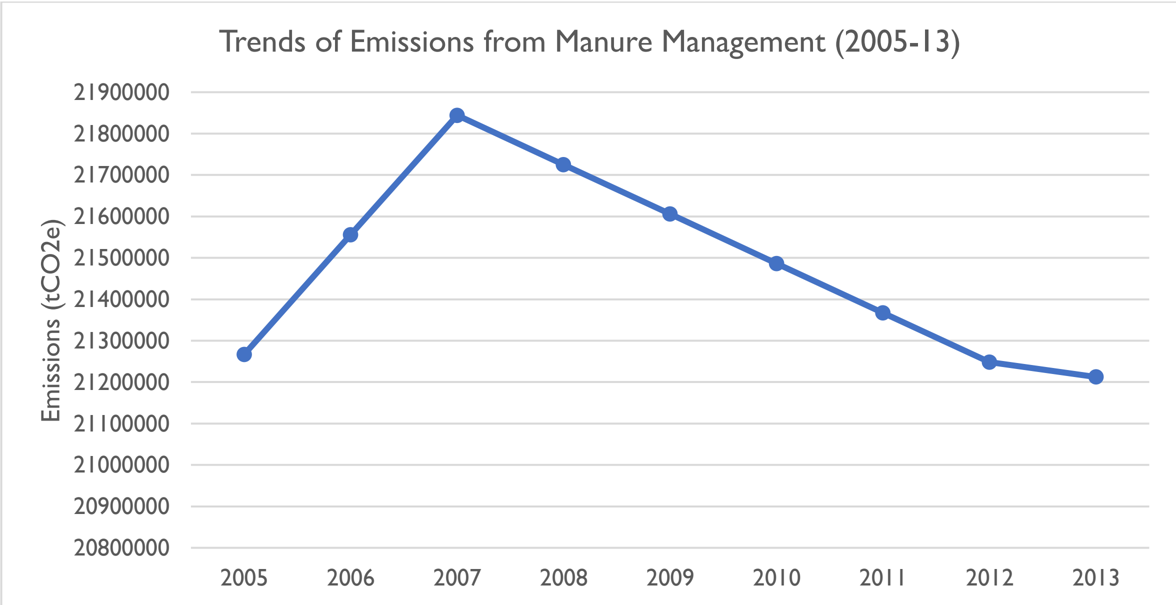


Figure 4 Trends of emissions from Enteric Fermentation and Manure Management

Category-wise trends in emissions

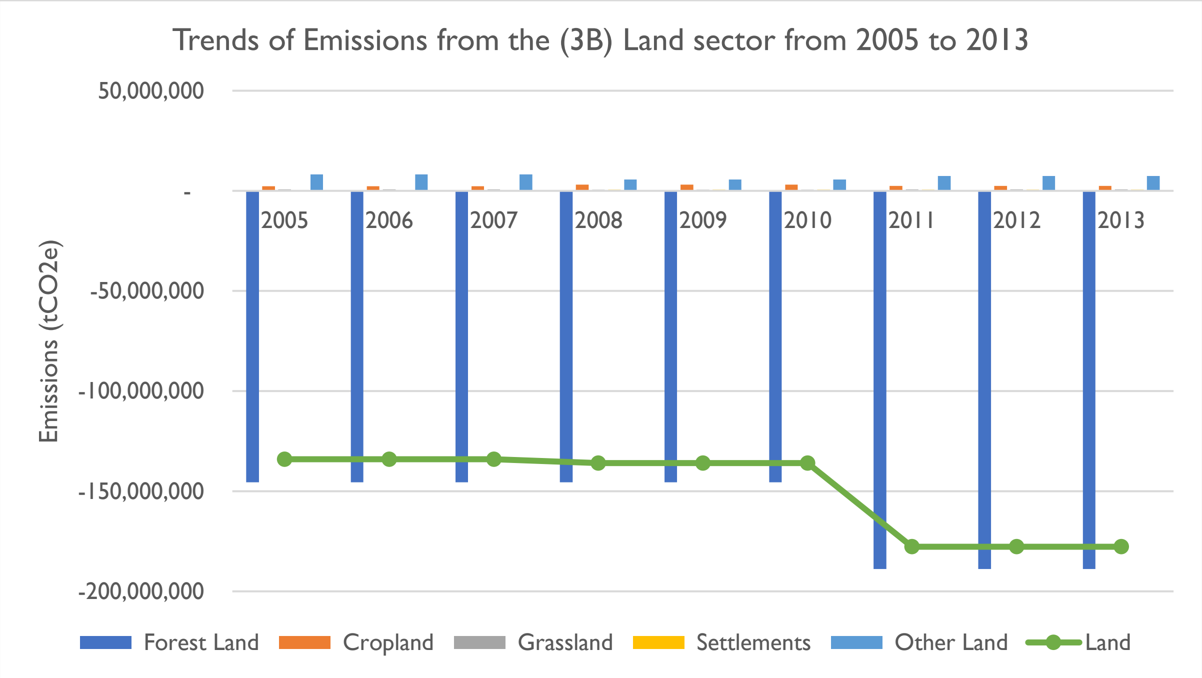


Figure 5 Trends of Emissions from Land Sector

As seen in the graph above, removals from LULUCF sector followed a linear trend from 2005 to 2011 and then increased from thereafter. This increment in emissions from -134 Million tCO2e to -177.73 Million tCO2e from 2005 to 2011 can be attributed to increase in carbon stock in forest land from 39.71 Million tC (in 2005) to 51.50 Million tC (in 2011).

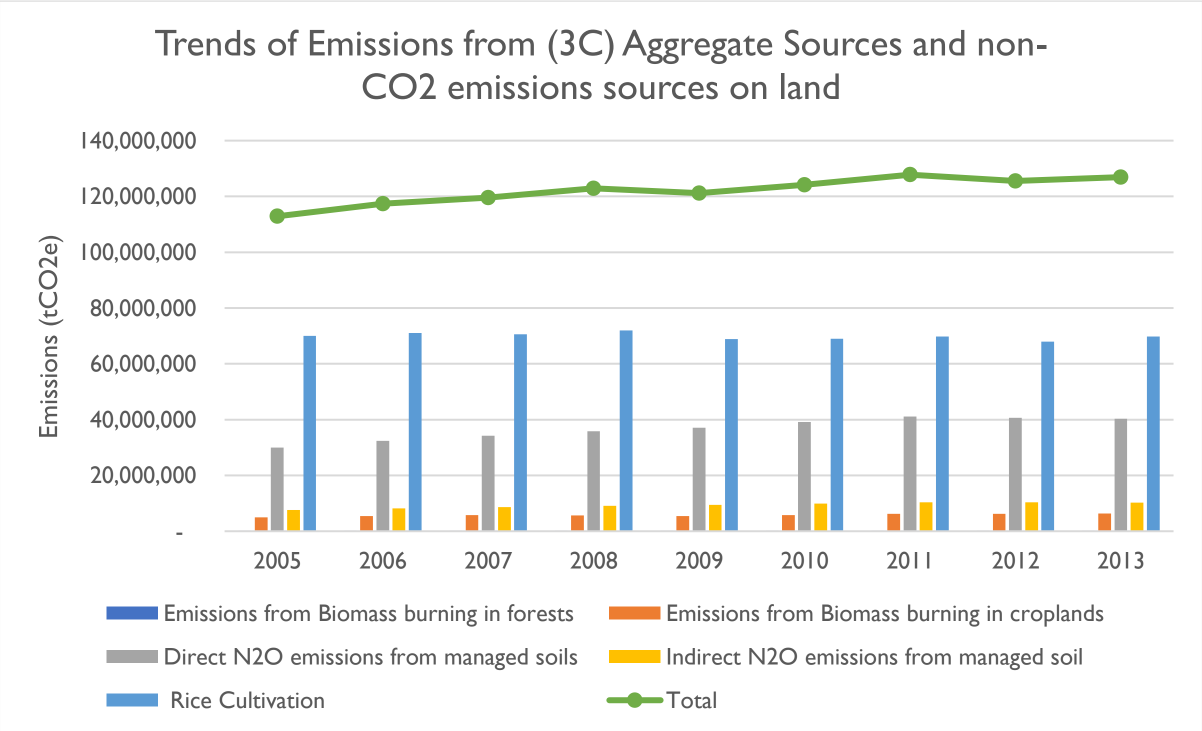


Figure 6 Trends of emissions from Aggregate sources and non-CO_2 emissions sources on land

Emissions from the category (3C) aggregate sources and non-carbon dioxide emission sources on land have increased over the years. It observed a net growth of 13% and compound growth of 1.37%. Rice cultivation emissions contribute majorly (~55%) in this category followed by direct nitrous oxide emissions from managed soils (~40%).

Given below are sub-sectoral trends from the AFOLU sector:

3B1 Forest Land

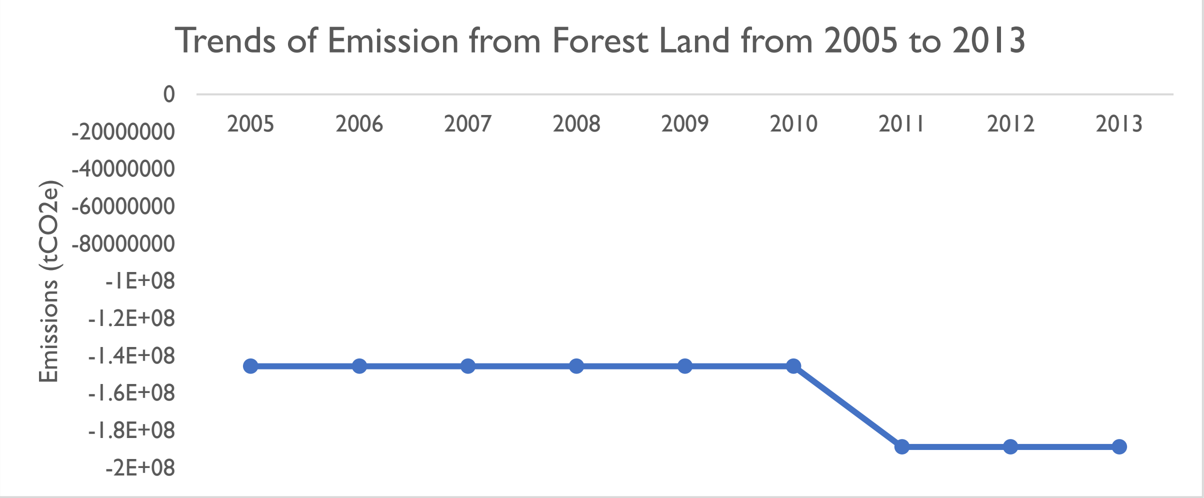


Figure 7 Trends of emissions from Forest Land

As per FSI[7], there was a 1.4% change in carbon stock in forest land during 2011 and 2012 which lead to an increase in absorption of greenhouse gases from the atmosphere. Therefore, there was an increase (~3% CAGR) in absorption of carbon dioxide from Indian forests from 2005 to 2013.

3B2 Cropland

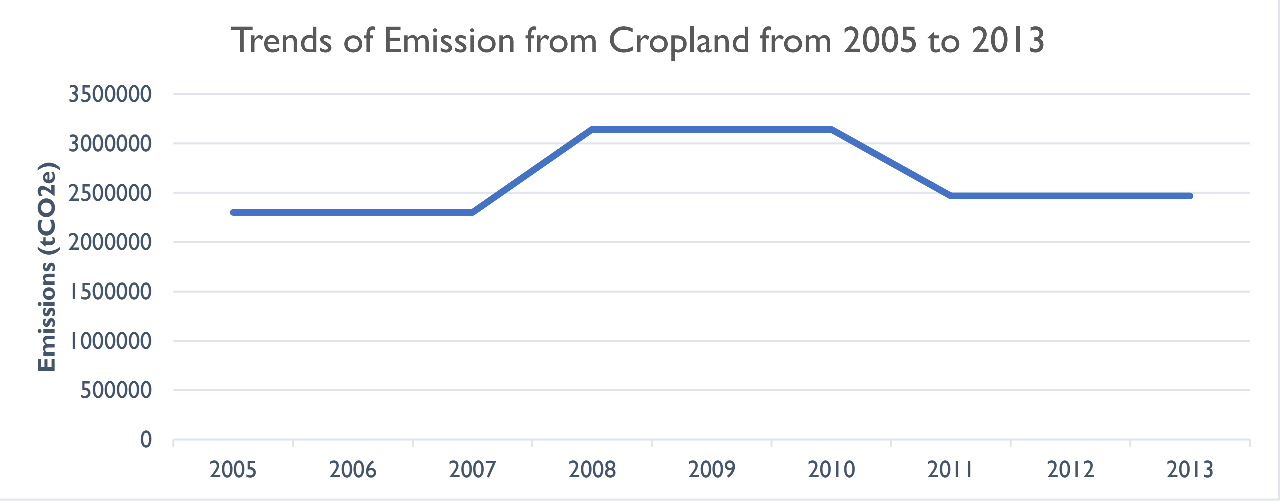


Figure 8 Trends of emissions from Cropland

Cropland sector in India acts as a carbon source. As per the Land Use change matrix obtained from NRSC, Hyderabad[8], the land use change from the categories cropland remaining cropland, and land converted to cropland increased from 2008-11. This further led to an

[7] http://fsi.nic.in/isfr-2015/isfr-2015-growing-stock.pdf
[8] NRSC Change Matrix is provided in a hard copy on request.

increase in emissions from these categories from 2008-11. However, from the year 2011, emissions have decreased. The compound annual growth rate from this sector is 0.87% and the net growth is 7.20%.

3B3 Grasslands

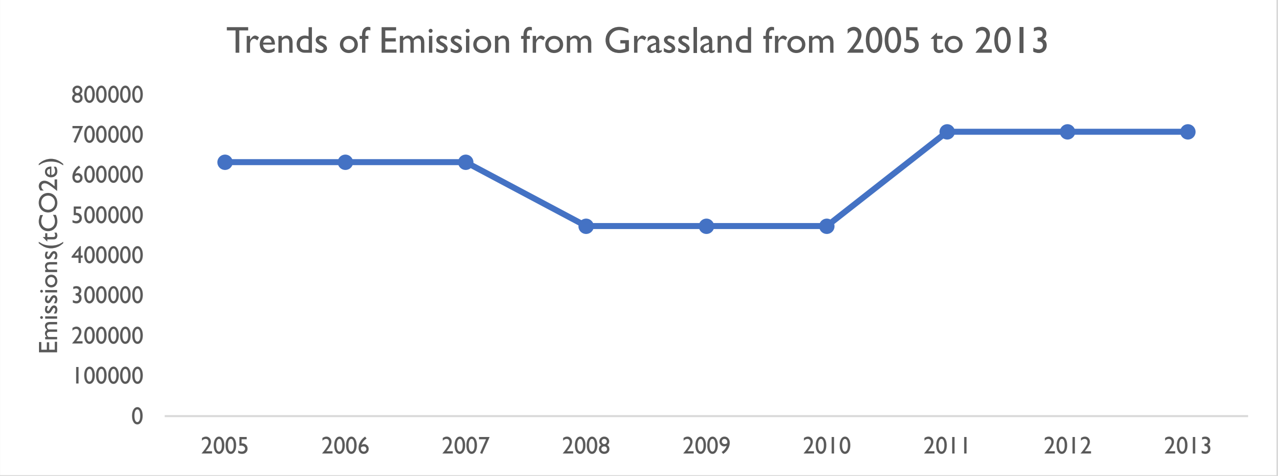


Figure 9 Trends of emissions from Grassland

Contrary to croplands, the land use change from categories Grasslands remaining grasslands and Land converted to Grasslands declined during the intermediate years 2008 to 2011. Therefore, emissions from grassland showed a decrease in emission trend from 2011-13. However, overall (from 2005 to 2013) emissions from this sector have increased at a compound rate of 1.41%.

3B5 Settlements

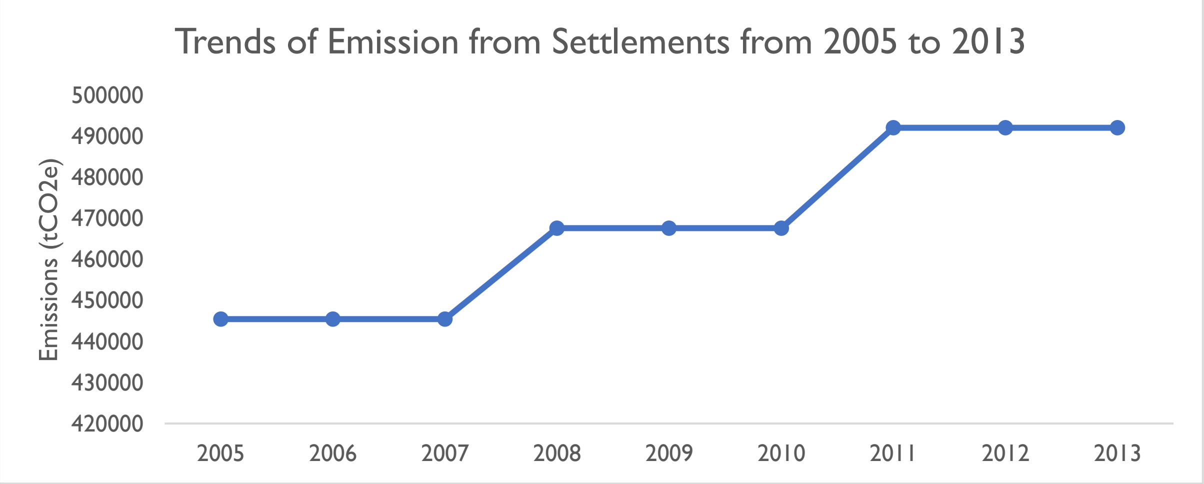


Figure 10 Trends of Emissions from Settlements

Emissions from the category Settlements show an increase of 1.25% when compounded annually from 2005 to 2013 due to increase in land area falling under categories Settlement Remaining Settlements and Land converted to Settlements.

3B6 Other Lands

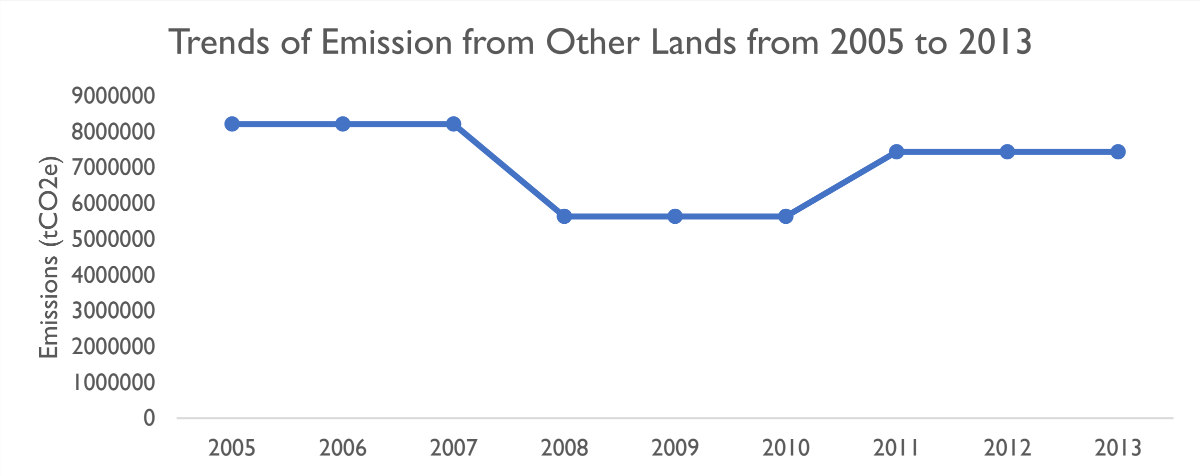


Figure 11 Trends of emissions from Other Land

Emissions from Other Land remaining Other Land and Land converted to Other Land have decreased over the years. However, there was a much steep fall from 2007 to 2008. The emissions have decreased at a compound rate of 1.23%.

3C1 Biomass Burning in Forest Land

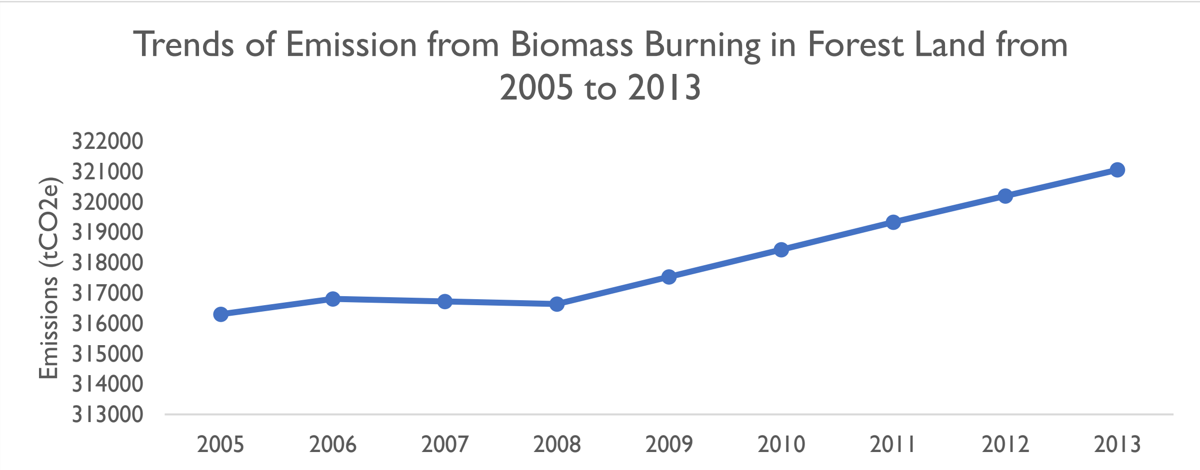


Figure 12 Trends of emissions from biomass burning in forest land

Carbon dioxide emissions due to biomass burning in forests land have been increasing due to increase in the burnt area. The emissions from this sub-sector grew at a compound rate of 1.54%. The overall contribution of this sub-sector in the AFOLU sector is also negligible.

3C2 Biomass Burning in Croplands

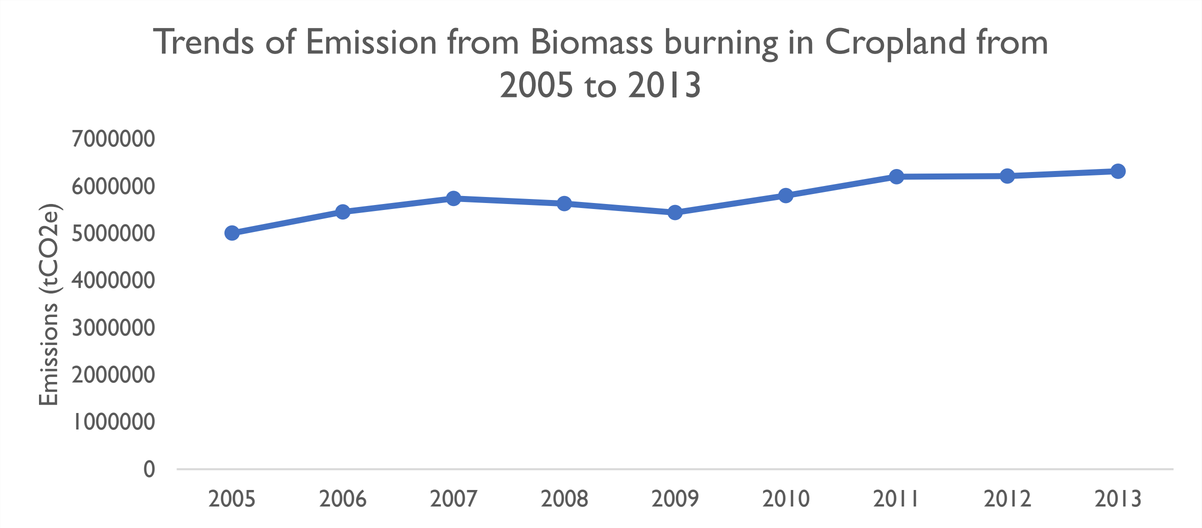


Figure 13 Trends of emission from biomass burning in cropland

Emissions from residue burning category showed a steady rise from 2005 to 2007 and then declined slightly till the year 2009. Thereafter, the emissions showed a gain in momentum with a slight dip in the year 2012. The rise and fall in trends from burning of crop residues is due to the change in amount of crop burnt which can be further attributed to the constant variation in crop production in India from 2005 to 2013. Emissions from this sector grew at a compound rate of ~3%.

3C3 & 3C4 Direct and Indirect N_2O Emissions from Managed Soils

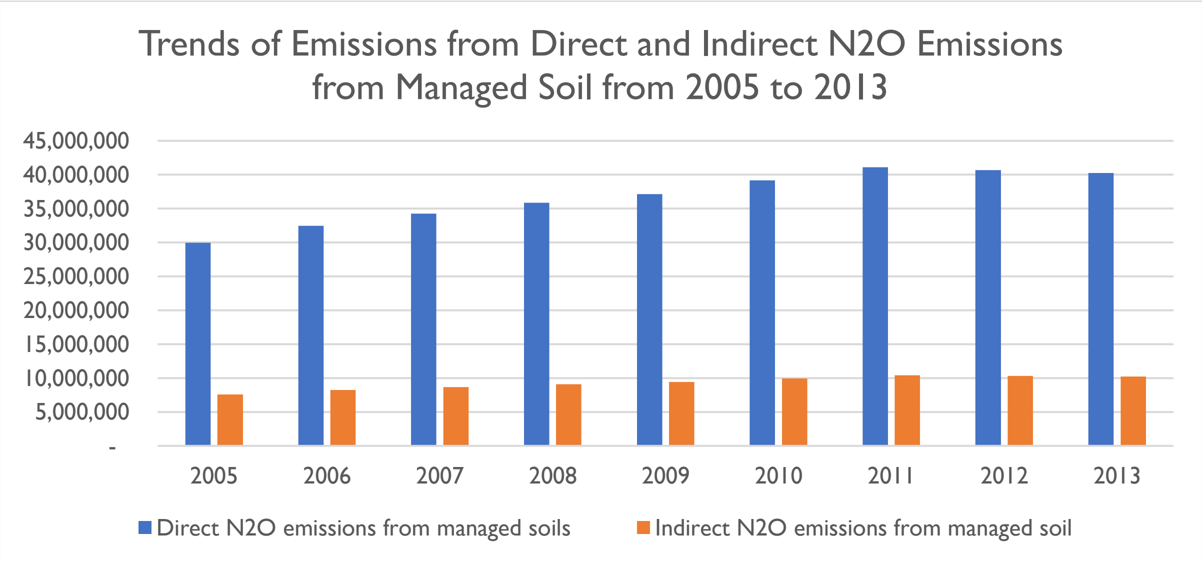


Figure 14 Trends of emissions from direct and indirect N_2O emissions from managed soil

Direct and Indirect emissions arising due to use of fertilisers showed a constant increase due to an increment in the quantity of fertilisers used from 2005 to 2013. The consumption of fertilizers increased at 2.73% compounded annually for these years and the emissions grew at 3.77% rate.

3C5 Rice Cultivation

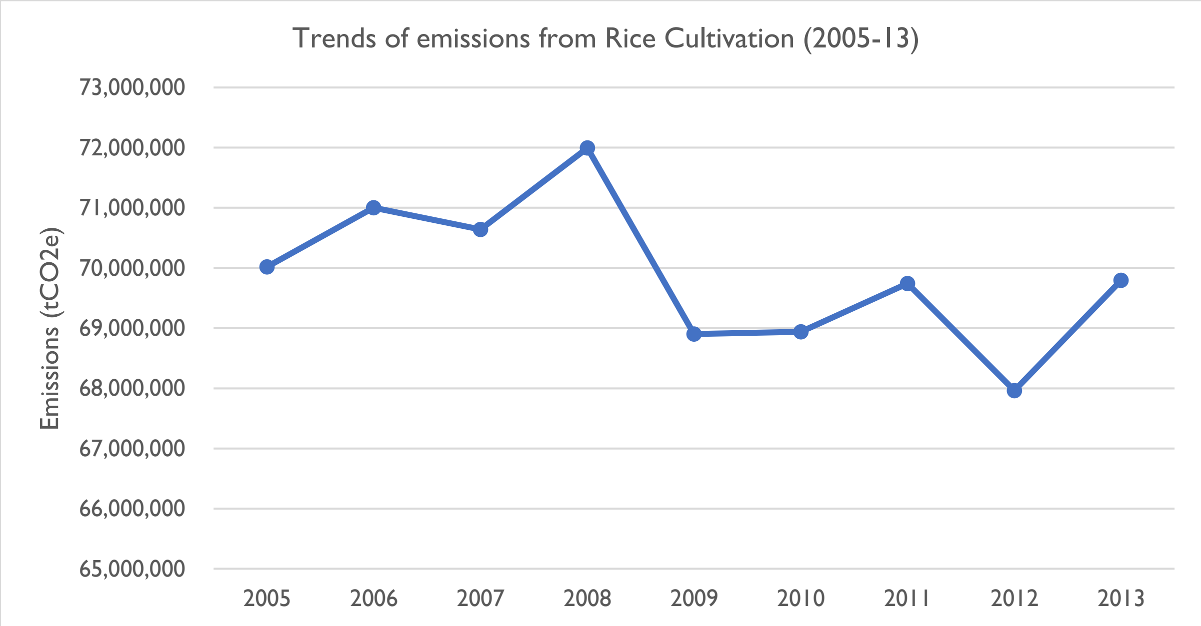


Figure 15 Trends of emission from rice cultivation

Emissions from rice cultivation category follow a non-linear trend due to a constant change in annual rice sown area from 2005 to 2013.

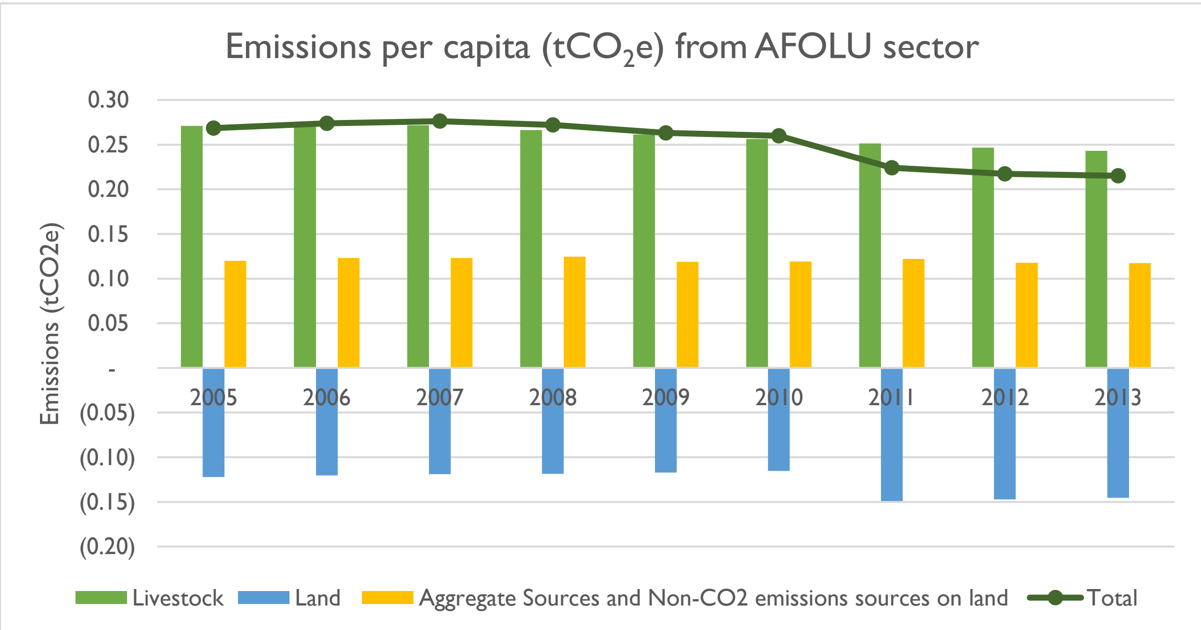


Figure 16 Trends of emission per capita population from AFOLU sector

The per capita emissions are decreasing at compound rate of 3% annually for AFOLU sector between 2005 and 2013. This is due to increase in removals from Indian forests and also increase in population of India.

The emissions intensity (emissions per unit of GDP) of India from AFOLU sector is also showing a downward trend at a compound rate of 8.79% due to fall in emissions from this sector and rise in GDP (using GDP values from World Bank Database[9]).

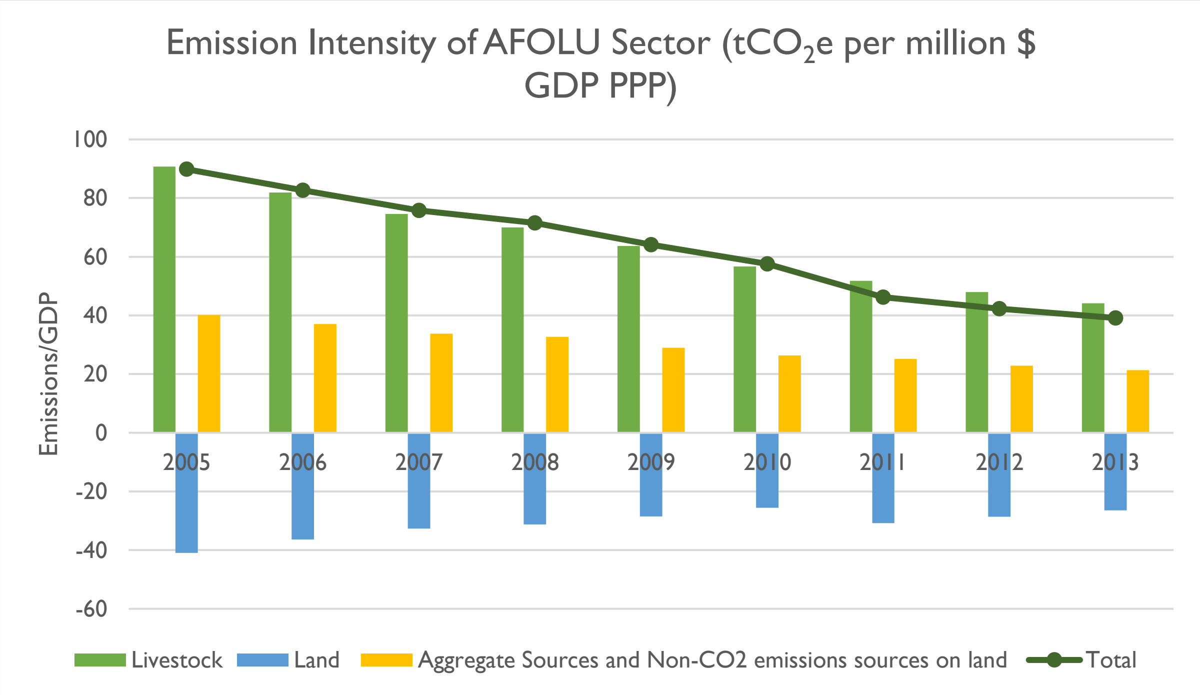


Figure 17 Trends of emissions intensity of AFOLU sector (GDP values from World Bank Database)

Detailed Emission Estimates for AFOLU

Overview of the sector

Emission estimates for AFOLU sector have been provided as under for the base year (2005) and the reporting year (2013):

Table 3 Overview of Emission Estimates from different gases.

IPCC Code	Sector/ Sub-sector	Total Emissions from 2005 to 2013 (in million tonnes)			
		CO_2	CH_4	N_2O	CO_2e
3	AFOLU	1,342.99	126.87	1.40	1,789.59
3A	Livestock		95.04	0.02	2,034.22
3A1	Enteric Fermentation		87.49		1,840.91
3A2	Manure Management		7.55	0.02	193.31
3B	Land	-1,343.00			-1,343.00
3B1	Forest Land	-1,440.21			-1,440.21
3B2	Cropland	23.73			23.73
3B3	Grassland	5.44			5.44
3B5	Settlements	4.22			4.22
3B6	Other Land	63.83			63.83
3C	Aggregate Sources and non-CO_2 emissions sources on land		31.83	1.39	1,098.37
3C1a	Emissions from Biomass burning in forests		0.12	0.00	2.86

[9] http://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GDP.PCAP.PP.KD&country=IND

3C1b	Emissions from biomass burning in croplands		1.77	0.05	51.79
3C4	Direct N_2O emissions from managed soils			1.07	330.84
3C5	Indirect N_2O emissions from managed soil			0.27	83.88
3C7	Rice Cultivation		29.95		628.99

Between 2005 and 2013, there has been a decrease of approximately 1.95% compounded annually in the CO_2 equivalent emissions from this sector for India. This is primarily due to increase of carbon dioxide removals from the atmosphere by the forests. Once the forests are taken out of the equation, the sources within AFOLU sector show an increase of around 4.01% in the CO_2 equivalent emissions. This is negligible if looked at in the context of year on year emissions growth in this sector.

Boundary of GHG Estimates

This assessment provides GHG emission estimates for all states and union territories of India. India's GDP in 2013 was US$ 1,856.72. billion[10] at current values. The largest sectoral contribution to India's GDP was from the services sector (50.6%[11]), while the contribution of Industry and agriculture was 30.8%[12] and 18.6%[13] respectively.

Overview of Source Categories and Methodology

The key sources of GHG emissions from this sector for which emission estimation has been done are given below. The sources of the activity data are also being mentioned along with listed sources of GHG emissions. Country specific emissions factors have been used wherever possible, failing which, IPCC default emission factors have been used:

3A. Livestock

- 3A1. Enteric Fermentation. Activity Data taken from the Livestock Census of India[14]. Methane Emission factors used are the same as those used for India NATCOMM – II[15]. The overall approach followed was Tier – II approach.
- 3A2. Manure Management. Activity Data taken from the Livestock Census of India. Methane Emission factors used for cattle's and buffaloes are the same as those used for India NATCOMM – II. Methane and Nitrous Oxide emission factors for other categories (i.e. Sheep, Goat, Donkeys, Camels, etc.) have been derived from 2006 IPCC guidelines. The overall approach followed was Tier – I/II approach.

3B. Emissions from Land

- 3B1. Forest Land. Activity data taken from Forest Survey of India. Emission factors derived from Forest Survey of India's carbon stock estimates and land covered under various categories of forest cover in different states. The overall approach followed was Tier – II approach.

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[10] World Development Indicators, https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=IN
[11] World Development Indicators, https://data.worldbank.org/indicator/NV.SRV.TETC.ZS?locations=IN
[12] World Development Indicators, https://data.worldbank.org/indicator/NV.IND.TOTL.ZS?locations=IN
[13] World Development Indicators, https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=IN
[14] http://dahd-archive.nic.in/dahd/statistics/livestock-census.aspx
[15] http://unfccc.int/resource/docs/natc/indnc2.pdf

- 3B2. Cropland. Activity data taken from National Remote Sensing Centre. Emission factors taken from expert studies that are listed in the bibliography of this document. The overall approach followed was Tier – II approach.
- 3B3. Grassland. Activity data taken from National Remote Sensing Centre. Emission factors taken from expert studies that are listed in the bibliography of this document. The overall approach followed was Tier – II approach.
- 3B5. Settlements. Activity data taken from National Remote Sensing Centre. Emission factors taken from expert studies that are listed in the bibliography of this document. The overall approach followed was Tier – II approach.
- 3B6. Other Lands. Activity data taken from National Remote Sensing Centre. Emission factors taken from expert studies that are listed in the bibliography of this document. The overall approach followed was Tier – II approach.

3C. Aggregate sources and non-CO_2 emissions sources on land

- 3C1a. Emissions from biomass burning in forests. Activity data taken from FSI and emission factors derived from the data and assumptions available in India NATCOMM – II. The overall approach used was a Tier – II approach.
- 3C1b. Emissions from biomass burning in croplands. Activity data and emission factors have been taken from expert studies that are listed in the bibliography of this document. The overall approach used was a Tier – I approach.
- 3C4. Direct N_2O emissions from managed soils. Activity data derived from national data of fertiliser consumption. Emission factors taken from expert studies that are listed in the bibliography of this document. The overall approach used was a Tier – II approach.
- 3C5. Indirect N_2O emissions from managed soils. Activity data derived from national data of fertiliser consumption. Emission factors taken from expert studies that are listed in the bibliography of this document. The overall approach used was a Tier – II approach.
- 3C7. Rice Cultivation. Activity data derived from Ministry of Agriculture. Emission factors based on expert analysis and publications listed in the bibliography of this document. The overall approach used was a Tier – II approach.

3A1. Estimation of Emissions from Enteric Fermentation

Category Description

Enteric fermentation resulting in emissions of CH_4 arises out of the process of ingesting and digesting of food eaten by herbivores, primarily bovines and ovine. However, other animals such as camels, horses and mules etc. also emit small amounts of CH_4. Emissions under this source have been calculated as per the following livestock categories:

Table 4 Overview of source categories of Enteric Fermentation

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
3.	**AFOLU**			
3A	**Livestock**			
3A1	**Enteric Fermentation**			
3A1a	Cattle			
3A1ai	Dairy cows (Indigenous and Cross Bred)	Secondary	High	Livestock Census of India for 2007 and 2012
3A1aii	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	Secondary	High	
3A1b	Buffalo (dairy and non-dairy)	Secondary	High	
3A1c	Sheep	Secondary	High	
3A1d	Goats	Secondary	High	

3A1e	Camels	Secondary	High	
3A1f	Horses and ponies	Secondary	High	
3A1g	Donkeys	Secondary	High	
3A1h	Pigs`	Secondary	High	

Methodology

The methodological details for estimation of GHG emissions for enteric fermentation are as under:

Table 5 Methodology details of emission estimation from enteric fermentation

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH_4	
		METHOD APPLIED	EMISSION FACTOR
3.	**AFOLU**		
3A	**Livestock**		
3A1	**Enteric Fermentation**		
3A1a	Cattle	T2	CS
3A1ai	Dairy cows (Indigenous and Cross Bred)	T2	CS
3A1aii	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	T2	CS
3A1b	Buffalo (dairy and non-dairy)	T2	CS
3A1c	Sheep	T2	CS
3A1d	Goats	T2	CS
3A1e	Camels	T1	D
3A1f	Horses and ponies	T1	D
3A1g	Donkeys	T1	D
3A1h	Pigs	T1	D

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Steps followed:

Step 1:

As a first step, the average annual population of animals was taken from the Census of Livestock, which is conducted every five years. Categorization was done as per available categories in the census viz. dairy and non-dairy for cattle (indigenous cows, crossbred cows and buffaloes). In this analysis, mules and asses are not added in the total livestock population as there are no emissions from the same. The details regarding categorisation are given in the table below:

Table 6 Categorization of livestock for derivation of methane emission factors

Category	Sub category
a) Mature dairy cows (Mature cows that have calved at least once and used principally for milk production)	▪ "Cross-bred" dairy cows ▪ "Indigenous cows" (non-descript or desi) dairy cows. ▪ "Buffaloes"
b) Non-dairy cattle	▪ Young cattle (cross bred cows, indigenous cows and buffaloes):

	a) Below 1 year[16] b) 1-3 years[17] ▪ Others (cross bred cows, indigenous cows and buffaloes): a) Male (Breeding, Working and Others) b) Female (Non-dairy adults)
c) Goats	▪ Mature (1 year and above) ▪ Young (less than 1 year)
d) Sheep	▪ Mature (1 year and above) ▪ Young (less than 1 year)
e) Camels	▪ No classification
f) Horses and ponies	▪ No classification
g) Pigs	▪ No classification

Livestock populations for the intermediate years between the livestock census years was calculated from the annual increment of population between the two census years (For e.g. 2002 and 2007). Given below is an example of the formula used:

Annual Increment Ratio = (Population in Year 2007 - Population in 2002)/No. of Years

Population in year 2003 = Population in year 2002 + Annual Increment Ratio

Population in year 2004 = Population in year 2003 + Annual Increment Ration

Livestock population from the succeeding year i.e. 2013 has been derived from the CAGR computed between 2007 and 2012 for the various categories of livestock populations. Formula used for calculating the future population:

CAGR = {(Ending Value/Beginning Value) ^ (1/No. of Years)}-1

Step 2:
Assumptions for the livestock whose emissions were being estimated using a Tier II approach were also made on their body weight. These assumptions were made based on Swamy and Bhattacharya 2006 and Swamy et al 2004. The assumptions made regarding the body weight of the various categories of the animals was as follows:

Table 7 Average body weight of livestock

Category of Livestock		Assumed Average Bodyweight (In Kgs)
Indigenous cattle	Dairy	175
	Non-dairy:	
	Mature males	200
	Mature females	175
	Young stock	

[16] Based on NATCOM II, emission factors are available for cattle population categories of crossbred, buffalo, and indigenous cattle for age group below 1 year. However, census data category provides data for under 1 year. Therefore, the emission factor for population below one year has been applied to the category titled under one year.

[17] Based on NATCOM II, emission factors are available for cattle population categories of crossbred, buffalo, and indigenous cattle for age group 1 to 3 years. However, census data category provides data for 1 to 2.5 years. Therefore, the emission factor for population between 1 to 3-year has been applied to the category titled 1 to 2.5 years.

	Below I year	40
	I to 3 years	140
Crossbred cattle	Dairy	275
	Non-dairy:	
	Mature males	300
	Mature females	275
	Young stock	
	Below I year	60
	I to 3 years	180
Buffalo	Dairy	275
	Non-dairy:	
	Mature males	300
	Mature females	275
	Young stock	
	Below I year	70
	I to 3 years	180
Sheep	0-3 months	9.53
	3-6 months	12.1
	6-9 months	15.9
	9-12 months	19.1
	Adult	26.7
Goats	0-3 months	9.3
	3-6 months	11
	6-9 months	16.5
	9-12 months	19.5
	Adult	32.2

The next set of assumptions were made regarding Methane Conversion Factors for each livestock category. These factors were:

Table 8 Methane Conversion Factor for Livestock based on Swamy and Bhattacharya (2006)[18]

Category of Livestock		Methane Conversion Factor (%)
Indigenous cattle, crossbred cattle and buffaloes	Dairy	6.00
	Below I year	5.50
	1-3 years	5.50
	Non-dairy	
	Male (working, breeding)	6.00
	Male (others and/or not working)	6.00
	Female	6.00
Sheep		6.00
Goats		5.00

Notably, these were also the assumptions made for calculating emissions from livestock in NATCOM II 2012[19]. Thus, the emission factors that have been used in this estimation are the same as the ones used in NATCOMM II 2012 for bovines. For other categories, the emission factors are taken from 2006 IPCC guidelines.

[18] http://www.iisc.ernet.in/currsci/nov252006/1340.pdf
[19] http://unfccc.int/resource/docs/natc/indnc2.pdf

Based on these sets of assumptions, IPCC equation 10.21 (Refer Annex I for sample calculation) was used for calculation of emissions:

$$EF = \frac{\left[GE \cdot \frac{Y_m}{100} \cdot 365\right]}{55.65}$$

Where,
EF = Emission factor (Kg methane / animal / year),
GE = Gross energy intake (MJ[20] / animal / year),
Y_m = Methane conversion rate which is the fraction of gross energy feed converted to methane

The table mentioned below provides emission factors for each sub-group:

Table 9: Emission factor of each sub-group in terms of kilograms of methane per animal per year

Category	Sub-category	Age group	Methane emission factor (kgCH$_4$/head/year)	Source
Indigenous Cattle	Dairy cattle	Indigenous	28.00	NATCOM II, 2012
	Non-dairy cattle (indigenous)	0-1 year	9.00	NATCOM II, 2012
		1-3 year	23.00	NATCOM II, 2012
		Adult	32.00	NATCOM II, 2012
Cross-bred cattle	Dairy cattle	Cross-bred	43.00	NATCOM II, 2012
	Non-dairy cattle (cross-bred)	0-1 year	11.00	NATCOM II, 2012
		1-3 year	26.00	NATCOM II, 2012
		Adult	33.00	NATCOM II, 2012
Buffalo	Dairy buffalo		50.00	NATCOM II, 2012
	Non-dairy buffalo	0-1 year	8.00	NATCOM II, 2012
		1-3 year	22.00	NATCOM II, 2012
		Adult	44.00	NATCOM II, 2012
Sheep			5.00	IPCC 2006
Goat			5.00	IPCC 2006
Horses & Ponies			18.00	IPCC 2006
Donkeys			10.00	IPCC 2006
Camels			46.00	IPCC 2006
Pigs			1.00	IPCC 2006
Poultry			0.00	IPCC 2006

Step 3:
Emissions from process of enteric fermentation are calculated by multiplying the selected emissions factors with the associated animal population (IPCC equation 10.19, Refer Annex I for sample calculation) and summed using IPCC equation 10.20 (Refer Annex I for sample calculation) given below:

$$Emissions = EF_{(T)} \cdot \left(\frac{N_{(T)}}{10^6}\right)$$

[20] Assumed to be 18.45

Where,

$Emissions$	= methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}
$EF_{(T)}$	= emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}
$N_{(T)}$	= the number of head of livestock species/category T in the country
T	= species/category of livestock

$$Total\ CH_{4_{Enteric}} = \sum_i E_i$$

Where,

$Total\ CH_{4_{Enteric}}$	= total methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}
E_i	= Emissions for the i^{th} livestock categories and subcategories

Uncertainties

The uncertainties regarding calculations of emissions under this category depends on factors including body weight of the animals as well as their feed intake. Further, feed intake of livestock varies from region to region and thus could cause variations in emissions from enteric fermentation.

Table 9 Uncertainties in emission estimation from Enteric Fermentation

IPCC ID	GHG Source & Sink Categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO_2	CH_4	N_2O
3A1	Enteric Fermentation	Estimation	There are significant variations in body weight and size of livestock across India, along with variations of feed intake that are not fully captured.	Not Ascertained		

Source Category Specific QA/QC

The data that have been used for this estimation are from Livestock Census of India for 2007 and 2012[21]. All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified

[21] http://dahd.nic.in/documents/statistics/livestock-census

with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The emissions estimates of Phase I have been extended for the estimation done for this round and remain unchanged from before.

Verification

3A1. Enteric Fermentation			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
INCCA (2007)	21,20,95,800	20,81,89,100	-1.84%
BUR (2010)	22,70,33,520	20,47,91,149	-9.80%

All the necessary and required data from Livestock Census of India for 2007 and 2012[22] have been used. The calculations are consistent with the requirements of best practise as per 2006 IPCC guidelines. In case of verification with INCCA, the minor variation of 1.84% arise mainly due to rounding off calculations. There is a need in the BUR report to provide greater details of data or of the assumptions that have been made used while in making their calculations that has been used while estimating emissions. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

Planned Improvements

As and when data that captures the diversity of livestock, for both body weight and feed intake, in India becomes available, it will be utilised for more precise emission estimations from this source.

3A2. Estimation of Emissions from Manure Management

Category Description

Emissions from animal manure arise from the process of its decomposition. In general, emissions are reduced if the manure can decompose aerobically, it produces little or no emissions, while anaerobic decomposition results in relatively higher emissions.

Table 10 Overview of source categories of Manure Management

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
3.	**AFOLU**			
3A	**Livestock**			
3A2	Manure Management			
3A2a	Cattle	Secondary	Medium	Livestock Census of India for 2007 and 2012
3A2ai	Dairy cows (Indigenous and Cross Bred)	Secondary	Medium	
3A2aii	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	Secondary	Medium	
3A2b	Buffalo (dairy and non-dairy)	Secondary	Medium	

[22] http://dahd.nic.in/documents/statistics/livestock-census

3A2c	Sheep	Secondary	Medium	
3A2d	Goats	Secondary	Medium	
3A2e	Camels	Secondary	Medium	
3A2f	Horses and ponies	Secondary	Medium	
3A2g	Donkeys	Secondary	Medium	
3A2h	Pigs	Secondary	Medium	
3A2i	Poultry	Secondary	Medium	

Methodology

The methodological details for estimation of GHG emissions are as under:

Table 11 Methodological details for emission estimation from Manure Management

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH_4		N_2O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
3.	**AFOLU**				
3A	**Livestock**				
3A2	**Manure Management**				
3A2a	Cattle	T1	CS	T1	D
3A2ai	Dairy cows (Indigenous and Cross Bred)	T1	CS	T1	D
3A2aii	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	T1	CS	T1	D
3A2b	Buffalo (dairy and non-dairy)	T1	CS	T1	D
3A2c	Sheep	T1	CS	T1	D
3A2d	Goats	T1	CS	T1	D
3A2e	Camels	T1	D	T1	D
3A2f	Horses and ponies	T1	CS	T1	D
3A2g	Donkeys	T1	CS	T1	D
3A2h	Pigs	T1	CS	T1	D
3A2i	Poultry	T1	D	T1	D

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Steps followed:

Methane emissions from Manure Management:

Step 1:
The average annual population of animals was taken from the Census of Livestock, which is conducted every five years. Categorization was done as per available categories in the census viz. dairy and non-dairy for cattle (indigenous cows, crossbred cows and buffaloes). Livestock populations for the intermediate years between the livestock census years was calculated from the annual increment of population between the two census years (For e.g. 2002 and 2007). Given below is an example of the formula used:

Annual Increment Ratio = (Population in Year 2007 - Population in 2002)/No. of Years

Population in year 2003 = Population in year 2002 + Annual Increment Ratio

Population in year 2004 = Population in year 2003 + Annual Increment Ratio

Livestock population for the succeeding year i.e. 2013 has been derived from the CAGR computed between 2007 and 2012 for the various categories of livestock populations. Formula used for calculating the future population:

CAGR = {(Ending Value/Beginning Value) ^ (1/No. of Years)}-1

Step 2:
Country specific emission factors are sourced from NATCOM II for cattle and buffalo. For the other categories, emission factors are sourced from 2006 IPCC guidelines.

The CH_4 emission factors for various categories of animals, for this category were as follows:

Table 12 Methane emission factors for emission estimation from manure management as per NATCOM II[23] and IPCC 2006

Category	**Sub-Category**	**Age Group**	**Manure Management (kg CH_4/head/year)**	**Source**
Indigenous Cattle	Dairy Cattle	Indigenous	3.50	NATCOM II, 2012
	Non-dairy Cattle	0–1 year	1.20	NATCOM II, 2012
		1–3 years	2.80	NATCOM II, 2012
		Adult	2.90	NATCOM II, 2012
Crossbred Cattle	Dairy Cattle	Cross-bred	3.80	NATCOM II, 2012
	Non-Dairy Cattle (cross-bred)	0–1 year	1.10	NATCOM II, 2012
		1–2 ½ years	2.30	NATCOM II, 2012
		Adult	2.50	NATCOM II, 2012
Buffalo	Dairy Buffalo	Buffalo	4.40	NATCOM II, 2012
	Non-Dairy Buffalo	0–1 year	1.80	NATCOM II, 2012
		1–2 ½ years	3.40	NATCOM II, 2012
		Adult	4.00	NATCOM II, 2012
Sheep			0.20	IPCC 2006
Goat			0.22	IPCC 2006
Horses and Ponies			2.19	IPCC 2006
Donkeys			0.90	IPCC 2006
Camels			2.56	IPCC 2006
Pigs			4.00	IPCC 2006
Poultry			0.00	IPCC 2006

Step 3:
Emissions from the process of manure management are calculated by multiplying the selected emissions factors with the associated animal population (IPCC equation 10.22, Refer Annex 1 for Sample Calculation) as given below:

[23] http://unfccc.int/resource/docs/natc/indnc2.pdf

$$CH_{4_{Manure}} = \sum_{(T)} \frac{(EF_{(T)} \cdot N_{(T)})}{10^6}$$

Where,

$CH_{4_{Manure}}$	= methane emissions from Manure Management, Gg CH_4 yr^{-1}
$EF_{(T)}$	= emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}
$N_{(T)}$	= the number of head of livestock species/category T in the country
T	= species/category of livestock

Step 4: Emissions from all livestock categories are added to get total methane emissions from manure management.

Nitrous Oxide emissions from Manure Management:

Step 1:
Estimate population for various livestock categories. Procedure followed for this step is same as that followed for methane emissions from manure management (Refer the above section).

Step 2:
For calculating nitrogen excretion, IPCC values[24] were used for estimating nitrogen excretion, per animal. The values adopted were:

Dairy cattle	- 60 kg N/ animal/ year
Non-dairy cattle	- 40 kg N/ animal/ year
Pigs	- 16 kg N/ animal/ year
Poultry	- 0.6 kg N/ animal/ year

Step 3:
The following nitrogen emission factors were used as per 2006 IPCC Guidelines:

Table 13 Nitrogen emission factor for emission estimation from manure management

Category of Livestock	Nitrogen emissions per animal (kgN_2O/head/year)
Dairy cattle	0.0006
Non-dairy cattle	0.0004
Pigs	0.0074
Poultry	0.0025

Step 4:
Total emissions were determined by multiplying the number of animals in each category with emission factor. Nitrogen emissions from manure management are calculated using the below mentioned equation in step 5. However, under this exercise, emission factor was obtained from India's second national communications to the UNFCCC.

N_2O emissions were calculated in the following manner:

[24] IPCC 2006 Guidelines, Chapter 10, Table 10.19, summarized from IPCC 1996 Guidelines, Chapter 4, Table B1, http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch4ref8.pdf

IPCC equation 10.25[25] (Refer Annex I for sample calculations) that was used was the following:

$$N_2O_{animals} = N_2O_{AWMS} = \sum \left[N_T \cdot N_{ex(T)} \cdot AWMS_T \cdot EF_{3(AWMS)} \right] \cdot \frac{44}{28}$$

where,

$N_2O_{animals}$	= N_2O emissions from animal production in a country (kg N/ yr)
N_2O_{AWMS}	= N_2O emissions from Animal Waste Management System in the country (kg N/ yr);
N_T	= number of animals of type T in the country
$N_{ex(T)}$	= N excretion of animals of type T in the country (kg N/animal/yr)
$AWMS_T$	= fraction of $N_{ex(T)}$ that is managed in one of the different distinguished animal waste management systems for animals of type T in the country
$EF_{3(AWMS)}$	= N_2O emission factor for an AWMS (kg N_2O -N/ kg of N_{ex} in AWMS)
T	= type of animal category
44/28	= conversion of (N_2O-N) emissions to N_2O emissions

As per the 2006 IPCC guidelines, cattle (dairy and non-dairy), pigs and poultry are the only livestock that account for the Nitrous oxide emissions and other animals like sheep, goat camels, which do not account for manure management under wet system, are eliminated from the category of animals producing N_2O from AWMS.

Step 5:

Emissions from all categories are aggregated and total emission expressed as Gg N_2O/ year.

Emissions (Gg/ Year) = EF (kg/ head/ year) x population/ 10^6 kg/ Gg.

Uncertainties

Table 14 Uncertainties of emission estimation from manure management

IPCC ID	GHG Source & Sink Categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO_2	CH_4	N_2O
3A2	Manure Management	Estimation	Precise data on manure yields and their end uses is not fully known under Indian conditions.	Not ascertained		

Uncertainty in emission estimation from manure management arise due to activity data and emission factors. Activity data on manure yields and their end uses is not fully known in Indian context, and therefore, a quantitative measure of uncertainty cannot be made. Similarly, country specific emission factors are available only for bovines. There is uncertainty associated with the same as there is limited research available on country specific emission factors. For ovine and other animals, IPCC default emission factors have been used, and there is an underlying uncertainty of 50%.

[25] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf - page 10.53

Source Category Specific QA/QC

The data that have been used for this estimation are from Livestock Census of India for 2007 and 2012[26] which have also been used for official inventories. All the parameters, units and conversion factors have been labelled properly. Assumptions (refer to methodology section of manure management) made for calculations have been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house, and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The emission estimates for this category have not been recalculated in this phase as the activity data and emission factors used are the same as used in Phase I of the platform. Only the time series is extended in phase II.

Cross-Verification

3A2. Manure Management			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
INCCA (2007)	24,36,700	2,13,41,511	775.84%
BUR (2010)	27,68,110	2,14,86,644	676.22%

All the necessary and required data from Livestock Census of India for 2007 and 2012[27] have been used. The calculations are consistent with the requirements of best practise as per 2006 IPCC guidelines. However, the huge variation from the INCCA report can be attributed to the fact that it does not provide detailed population data, i.e., category-wise population details are not provided. Further, category wise emissions are also not provided for manure management, instead emissions are reported for the total livestock categories. Furthermore, INCCA report lacks clarity/ transparency on specific Methane emission factors used for Manure Management.

[26] http://dahd.nic.in/documents/statistics/livestock-census
[27] http://dahd.nic.in/documents/statistics/livestock-census

There is a need in the BUR report to provide greater details of data or of the assumptions that have been made used while in making their calculations that has been used while estimating emissions. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

Planned Improvements

As and when data that captures the manure yields in the Indian subcontinent become available, as well as more precise information on manure management systems is also made available, these estimates can become more precise.

3B. Estimation of Emissions from Land

3B1. Forest Land

Category Description

This section provides details of estimating emissions from Forestland due to changes in biomass, dead organic matter and soil organic matter on Forest Land and Land converted to Forest Land. As mentioned above, the net removals from this sub-category in the year 2013 was 188 million tCO_2e. Share of removals from forest land in AFOLU sector is approximately 35% in 2013.

For this study, Land Use Matrix for forest land remaining forest land and land converted to forest land has been derived from the biennially updated 'State of Forest Report (SFR)' from Forest Survey of India.

For the State of Forest Report, FSI maps forest cover through satellite data with a LISS III sensor. In India, all lands that occupy an area more than one hectare and have a canopy density of more than 10% irrespective of the ownership and legal status are called Forest Cover. FSI does not make any distinction whether the forest is natural or man-made, government or private, recorded or not recorded.

For stratification of the activity data, FSI uses two variables namely forest types and canopy density. It also includes bamboo, orchards, palms etc. Given below are details of activity data used in the sub-category:

Table 15 Overview of source categories of Forest Land

IPCC ID	GHG source & sink categories	Type	Quality	Source
3B	**Land**			
3B1	Forest Land[28]	Secondary Data	High	Forest Survey of India

Methodology

Steps followed:

[28] The estimates given in this report only refer to the overall areas under forests and the carbon stock contained within them. Data at the national level is not available for forest land remaining forest land and land other than forest land converted to forest land

Step 1:
Area under Forest Land Remaining Forest Land and Land converted to Forest Land is estimated. Table below provides details of the tier approach and types of emission factors used for forest land:

Table 16 Overview of emission factors used for forest land

IPCC ID	GHG source & sink categories	CO_2	
		Method Applied	**Emission Factor**
3B1	Forest Land	T2	CS

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Step 2:
For GHG estimation from forest land in India, the *Stock-Difference Method* is applied along with country specific estimates of activity data and emission factors, in-line with section 4.2.1.1 – choice of method, Volume 4, Chapter 4, 2006 IPCC Guidelines. As per IPCC equation 2.5, Volume 4, Chapter 2, 2006 IPCC Guidelines[29], it can be used where carbon stocks in relevant pools are measured at two points in time to assess carbon stock changes, as represented in equation given below (Refer Annex I for sample calculations):

$$\Delta C = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$

where,
ΔC is Annual Carbon stock change in pool (tonnes C yr^{-1})
C_{t_2} is Carbon stock in the pool at time t_2
C_{t_1} is Carbon stock in the pool at time t_1

Emission factors for the source categories i.e. dead organic matter, litter and soil organic carbon have been derived from Forest Survey of India's Report on Carbon Stock in India. FSI's Carbon Stock Report, 2011[30] gives the biomass factor under five different pools for the forests in year 2009. The five pools mentioned in this report are Above Ground Biomass, Below Ground Biomass, Deadwood, Litter and Soil Organic Carbon Emission factors for the years in consideration has been derived using the national level estimates provided in SFR 2013 and 2015 for biomass in Indian Forest and by further applying it to the biomass values from Carbon Stock Report, 2011.

Carbon stock for each year in consideration is estimated by multiplying the biomass factor under different pools with the area under forestland categories for that year.

Step 3:
In cases where forest land remains as forest land, carbon removal from the atmosphere due to biomass growth and loss due to disturbance and biomass removals (both fuel wood and timber) are considered. The annual carbon stock changes for each land category is calculated as a sum of changes in all carbon pools of above-ground biomass, below-ground biomass,

[29] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf
[30] http://fsi.nic.in/details.php?pgID=sb_15

deadwood, litter, soils and harvested wood products. A top down approach has been used for estimating emissions from forest land. Since, SFR reports carbon stock change in fiscal year, the platform reports emission estimates in fiscal year (assumed to be same as calendar year for LULUCF sector).

Uncertainties

The activity data for the area under forests at the state level is from Forest Survey of India reports. The state level data has been aggregated to arrive at the national total for forestry. The forest cover assessment is based on satellite imagery. Internationally, the accuracy of classification of remote sensing data more than 85% is considered to be satisfactory. FSI prepared an error matrix for assessing the accuracy of classification based on remote sensing data by comparing agreement and disagreement between remote sensing derived classification with the reference data (ground truth) on a class by class basis at randomly selected locations. FSI has assessed the accuracy to be greater than 90% for all the years of survey considered for the inventory (FSI, 2011, 2013 and 2015).

The emission factors for forest land i.e. the carbon stock estimation for above ground biomass, below ground biomass, SOC, dead wood and litter is from the FSI report. FSI have reported an accuracy for carbon stock estimation as 88% and the standard error percentage of the estimation of growing stock at national level arising from National Forest Inventory at about 2%. The standard error percentage of estimates of carbon content of dead wood, woody litter, shrubs, climbers, herbs and grasses at national level arising from special biomass study is about 30% due to regional variation. But the contribution of these pools is very low to the total forest carbon pool (Ref: Carbon stock in India's Forests, Chapter 3, FSI[31]) and hence not considered significant.

Table 17 Uncertainties of emission estimation from forest land

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO_2	CH_4	N_2O
3B1	Forest Land	Estimation	Lack of data on underlying assumptions for carbon stock calculations such as stand age, species composition, etc.	Not ascertained		

Source Category specific QA/QC

The data that have been used for this estimation are from Forest Survey of India[32]. All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks

[31] http://fsi.nic.in/carbon_stock/chapter-3.pdf
[32] http://fsi.nic.in/

physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The emissions estimates of Phase I have been extended for the estimation done for this round and remain unchanged from before.

Cross-Verification

3B1. Forest Land			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
INCCA (2007)	-6,78,00,000	-14,56,19,048	-114.78%
BUR (2010)	-20,38,29,600	-14,56,19,048	28.56%

All the necessary and required data from Forest Survey of India[33] have been used. The calculations are consistent with the requirements of best practise as per 2006 IPCC guidelines. The variation in calculation with the INCCA report is because the INCCA report uses Forest cover mapping and Forest area mapping for the activity data. For carbon stock calculation, the report analysis the strata layer using GIS mapping. Details of the different strata and the amount of carbon stock associated is not available in the INCCA report. Our analysis uses FSI reports on carbon stock and forest area, therefore, the variation in results. There is a need in the BUR report to provide greater details of data or of the assumptions that have been made used while in making their calculations that has been used while estimating emissions. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

Planned improvements

For the estimation of GHG emissions/removals from land, we will be looking at generating change matrices for selected states to validate the change matrices that we have been able to obtain from official sources. In addition, we will continue to scan relevant literature for improvements in tools and methodologies, as well as more precise data in the future.

3B2. Cropland

Category Description

[33] http://fsi.nic.in/

This section provides details of estimating emissions from Cropland. Cropland includes arable and tillable land, rice fields and agroforestry systems where the vegetation structure falls below thresholds used for Forest Land (Volume 4, Chapter 5, 2006 IPCC guidelines).

The net emissions from this category in the year 2013 was 24.6 million tCO_2e and in the base year 2005 it was 23 million tCO_2e showing a negligible growth of less than one percent (compounded annually). Share of emissions from croplands in LULUCF sector is very small, contributing to approximately 1% of emissions.

For this category, Land Use Change Matrix has been derived from National Remote Sensing Centre (NRSC), Hyderabad. NRSC is a national organization hosted under Indian Space Research Organization (ISRO). Given below are details of activity data used in the sub-category:

Table 18 Overview of source categories of Cropland

IPCC ID	GHG source & sink categories	Type	Quality	Source
3B	**Land**			
3B2	Cropland	Secondary Data	High	National Remote Sensing Centre (available on request)
3B2a	Cropland Remaining Cropland	Secondary Data	High	
3B2bi	Forestland converted to Cropland	Secondary Data	High	
3B2bii	Grassland converted to Cropland	Secondary Data	High	
3B2biv	Settlements converted to Cropland	Secondary Data	High	
3B2bv	Other Land converted to Cropland	Secondary Data	High	

Methodology

Amount of carbon stored in and emitted or removed from permanent cropland depends on crop type, management practices and soil & climate variable. Annual crops (cereals, vegetable) are harvested each year, so there is no long-term storage of carbon in biomass and hence, not accounted. GHGs from Cropland are estimated from perennial woody vegetation in orchards, vineyards and agroforestry systems and soil. Carbon stored in biomass, depends on species type and cultivar, density, growth rates, harvesting and pruning practices (Volume 4, Chapter 5, 2006 IPCC guidelines).

Steps followed

Emission estimation for Cropland is done by categorizing land in two categories viz., Cropland Remaining Cropland and Land Converted to Cropland. This study uses 2006 IPCC Guidelines to estimate emissions from these categories. The steps followed in the estimation process for both the categories remain same with the only difference arising in choice/estimation of emission factors:

Step 1:
In this study, GHG emissions from change in perennial woody vegetation and soils is estimated using the *Stock Difference Method* from the following categories:
(a) Cropland remaining cropland
(b) Cropland Plantations Remaining Cropland Plantations
(c) Forestland converted to Cropland
(d) Grassland converted to Cropland (not observed by NRSC)
(e) Settlements converted to Cropland (not observed by NRSC)
(f) Other lands converted to Cropland

(g) Forest Land converted to Agriculture Plantations (not observed by NRSC)
(h) Cropland converted to Agriculture Plantations (not observed by NRSC)
(i) Settlements converted to Agriculture Plantations (not observed by NRSC)
(j) Other Land converted to Agricultural Plantations

IPCC category (3B2biii) Wetlands converted to Cropland is not considered in this assessment primarily due to lack of data.

Given below are details of the methodology approach used for emission estimation from cropland:

Table 19 Overview of emission factors used for cropland

IPCC ID	GHG source & sink categories	CO_2 Method Applied	CO_2 Emission Factor
3B2	Cropland	T2	CS
3B2a	Cropland Remaining Cropland	T2	CS
3B2bi	Forestland converted to Cropland	T2	CS
3B2bii	Grassland converted to Cropland	T2	CS
3B2biv	Settlements converted to Cropland	T2	CS
3B2bv	Other Land converted to Cropland	T2	CS

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Step 2:
For activity data, Land Use Change Matrix as prepared by NRSC is used for Croplands. The change matrix provided gives changes in the land use pattern for the years (a) 2006-08, (b) 2008-11 and (c) 2011-13. Since, the data is not available for the years 2005 and2013 land use pattern for these years has been assumed same as for the years 2006 and 2012 respectively. This is because these changes in land use tend to be almost the same when looked at year-on-year basis.

Step 3:
Emission factor estimation has been done specifically for this study. FSI creates a detailed assessment of trees outside the forests (TOF), which includes tree cover comprising of small patches of trees (<0.1 ha) in plantations and woodlots, scattered trees and farms, homesteads and urban areas as well as trees along linear features such as roads, canals and cropland bunds. FSI also provides the growing stock of the trees outside the forest land, which includes all land categories other than forest and includes cropland.

The approach adopted for estimating carbon stock changes in cropland is as follows:

Step 4:
Change in Biomass Carbon stock in Croplands: Carbon stock change in cropland remaining cropland is estimated by taking the tree biomass carbon stock at two periods in time (2004 and 2013). Biomass of trees outside forests is available for the years 2004, 2007, 2009, 2011 and 2013. The rate of change in biomass stocks are measured in terms of carbon estimated (Refer Table 20 below). The growing biomass stock of trees outside forests is declining at a rate of 0.014 tC/ha/yr among the successive measurements for the period 2004 to 2013. This rate has been used for estimating carbon stock change in cropland, grassland and settlements since the TOF remains the same in all the categories.

Table 20 Biomass carbon stock in Croplands

Category	2004[a]	2013[b]
Growing Stock in TOF (million cum)	1616.25	1573.34
Total stock in above ground biomass[34] (Mt)	1811.44	1736.35
Total stock in below ground biomass[35] (Mt)	489.09	476.11
Total biomass (Mt)	2300.53	2239.46
Total biomass Carbon[36] (MtC)	1150.26	1119.46
Rate of Change of Biomass Carbon (MtC/yr)	-3.39	
Rate of Change of Biomass Carbon (tC/ha/yr)	-0.014	

Source: a – State of Forest Report 2005, b – State of Forest Report 2015

Step 5:

Change in Soil Organic Carbon content in Croplands: Land is typically converted to Cropland from native lands, managed Forest Land and Grassland, but occasionally conversions can occur from Wetlands and seldom Settlements. Regardless of soil type (i.e., mineral or organic), the conversion of land to Cropland will, in most cases, result in a loss of soil C for some years following conversion (*5.3.3, Chapter 5, Volume 4, 2006 IPCC Guidelines*).

For Cropland Remaining Cropland, the rate of change of SOC has been derived from multiple studies that have been listed in the bibliography accompanying this document.

SOC reference values for Forestland has been used from M Kaul et al 2009 and SOC values for Cropland and Other Land has been derived from K. Sreenivas et al 2016.

Further, the total change in soil C stocks for Land Converted to Cropland is estimated using Equation 2.25 (Refer Annex I for sample calculations) given below:

$$\Delta C_{mineral} = \frac{\left(SOC_0 - SOC_{(0-T)}\right)}{D}$$

$$SOC = \sum_{C,S,I} SOC_{REF_{C,S,I}} \cdot F_{LU_{C,S,I}} \cdot F_{MG_{C,S,I}} \cdot F_{I_{C,S,I}} \cdot A_{C,S,I}$$

where,

$\Delta C_{mineral}$ = annual change in carbon stocks in mineral soils, tonnes C yr^{-1}

SOC_0 = soil organic carbon stock in the last year of an inventory time, tonnes C

$SOC_{(0-T)}$ = soil organic carbon stock at the beginning of the inventory time, tonnes C

SOC_0 and $SOC_{(0-T)}$ are calculated using the SOC equation in the box where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T)

D = Time Dependence, 20 years

C = represents the climate zones, S the soil types, and I the set of management systems that are present in a country.

SOC_{REF} = the reference carbon stock, tonnes C ha-1

[34] Above Ground Biomass = Growing Stock x density (0.7116) x Biomass Expansion Factor (1.575) ** (**Source: http://www.envfor.nic.in/mef/Technical_Paper.pdf)

[35] Based on IPCC Guidelines; Below Ground Biomass – Root Shoot Ratio is 0.27

[36] Carbon Fraction is 0.5

F_{LU} = stock change factor for land-use systems or sub-system for a particular land-use, dimensionless

F_{MG} = stock change factor for management regime, dimensionless

F_I = stock change factor for input of organic matter, dimensionless

A = land area of the stratum being estimated, ha. All land in the stratum should have common biophysical conditions (i.e., climate and soil type) and management history over the inventory time to be treated together for analytical purposes

Since, there is no land conversion from Grassland and Settlements to Cropland, no calculations have been performed for the same.

Step 6:

The total change in carbon stocks is calculated by adding up all values of the sub-categories estimates.

Uncertainties

NRSC has conducted accuracy assessment of the remote sensing land use and land classification. Stratified random points generated through image software was used to assess the accuracy of classification. The number sample points for each stratum was selected based on the proportion of the area. However, a minimum of 20 sample points was considered for each class to estimate the accuracy of the classified output. Ground truth data, legacy maps, and multi-temporal FCC have formed the basis for assessment and generation of Kappa co-efficient. For quality check, it was submitted to the QAS team. Refinement of crop classification areas obtained based on classification map at the end of the year was used.

The classification outputs were subjected to post classification accuracy assessment. The error matrix of accuracy assessment for different states was done. The overall classification accuracy is found to be 88.82% with a range of 83.05% to 95.31% in different states.[37]

For subsequent years, the planimetric accuracy was stated, wherein it is less than one pixel in plain areas and less than 2 pixels in hilly terrains[38]. During 2013-14 it was <1 pixel in plains.

The standing stock or biomass stock outside forest area is which includes cropland is taken from the State of Forest Report (FSI). There are no estimates of precision levels.

SOC reference values for Forestland from M Kaul et al 2009 has not estimated uncertainty. In fact, the research paper has reported uncertainties in input variables due to very large spatial heterogeneity that affect net Carbon flux from land use change.

The SOC of land use was from the study conducted by Srinivas *et al* 2016 from NRSA, wherein the SOC was spatially mapping at 250 m resolution and an estimate of their pool size in India was undertaken using many remote sensing derived data layers and data mining approach. The SOC densities were estimated for 1198 soil samples located across India using a stratified random sampling that integrated land use, soil, topography and agroecological regions. Using

[37] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0607.pdf (refer section 3.5)
[38] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0809.pdf (refer section 2.2), http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/1112.pdf (refer section 2.21), http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/1314.pdf (refer section 3.1)

Random forests (RF) based spatial prediction procedure with climatic, land cover, rock type, soil type, multi-year NDVI, irrigation status as independent input variables, models for predicting carbon density at 250 m spatial resolution were developed. For modelling with RF algorithm, about 898 soil profile observations (75% observations) were used, while the rest of 300 (25% of total observations) were used for validation. The Root Mean Square Error (RMSE) statistic was used to measure the degree of agreement between the predicted and observed values. The relationship between observed and predicted values was characterized by Mean Squared Deviations (MSD) parameter which was 3.19.

Activity data in the public domain is available but cannot be verified independently due to lack of open access to remote sensing data that is used by governmental agencies.

Table 21 Uncertainty in emission estimates from cropland

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO_2	CH_4	N_2O
3B2	Cropland	Estimation	Lack of access to finer resolution data to map land use changes. Lack of availability of region specific carbon stock data based on topography and climatic regions.	Not ascertained		

Source Category specific QA/QC

The data that have been used for this estimation are from National Remote Sensing Centre. All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The emissions estimates of Phase I have been extended for the estimation done for this round and remain unchanged from before.

Cross-Verification

3B2. Cropland			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
INCCA (2007)	-20,75,20,000	23,01,407	101.11%
BUR (2010)	-11,07,57,170	31,42,534	102.84%

All the available data sources from National Remote Sensing Centre have been used. The calculations are consistent with the requirements of best practise as per 2006 IPCC guidelines. In case of INCCA report, the variation is mainly because INCCA report does not estimate emissions from the category 'Land converted to Cropland'. It only estimates emissions from 'Cropland remaining Cropland'. Hence, the variation from GHG Platform India results as both the categories have been considered for emission estimation. Furthermore, rate of change of biomass and carbon stock is not available in detail in the INCCA report. There is a need in the BUR report to provide greater details of data or of the assumptions that have been made used while in making their calculations that has been used while estimating emissions. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

Planned improvements

For the estimation of GHG emissions/removals from land, we will be looking at generating change matrices for selected states to validate the change matrices that we have been able to obtain from official sources. In addition, we will continue to scan relevant literature for improvements in tools and methodologies, as well as more precise data in the future.

3B3. Grassland

Category Description

This section provides details of estimating emissions from Grassland. Grasslands are generally distinguished from "forest" as ecosystems having a tree canopy cover of less than a certain threshold, which varies from region to region. Below-ground carbon dominates in grassland and is mainly contained in roots and soil organic matter (Volume 4, Chapter 6, 2006 IPCC guidelines).

In India, grasslands include many categories other than forest land and cropland. These lands are largely used for livestock grazing. The net emissions from this category in the year 2013 was 0.63 million tCO_2e and in the base year 2005 it was 0.7 million tCO_2e showing an increment of 1.26% (compounded annually). Share of emissions from grasslands in LULUCF sector is very small.

For this category, Land Use Change Matrix for grassland has been derived from National Remote Sensing Centre (NRSC), Hyderabad. NRSC is a national organization hosted under Indian Space Research Organization (ISRO). Given below are details of activity data used in the sub-category:

Table 22 Overview of source categories of Grassland

IPCC ID	GHG source & sink categories	Type	Quality	Source
3B	**Land**			

3B3	Grassland	Secondary Data	High	National Remote Sensing Centre (available on request)
3B3a	Grassland Remaining Grassland	Secondary Data	High	National Remote Sensing Centre (available on request)
3b3bi	Forest Land converted to Grassland	Secondary Data	High	National Remote Sensing Centre (available on request)
3b3bii	Cropland converted to Grassland	Secondary Data	High	National Remote Sensing Centre (available on request)
3b3biii	Settlements converted to Grassland	Secondary Data	High	National Remote Sensing Centre (available on request)
3b3bv	Other Land converted to Grassland	Secondary Data	High	National Remote Sensing Centre (available on request)

Methodology

Inter-annual climatic variability is a crucial factor for consideration when estimating emissions from grasslands. Substantial changes in standing biomass can occur from year to year that is associated with differences in annual rainfall. Inter-annual rainfall variability may also affect management decisions such as irrigation or fertilizer application (Volume 4, Chapter 5, 2006 IPCC Guidelines) and thereby affecting emission estimates.

Emission estimation for Grassland is done by categorizing land in two categories viz., Grassland Remaining Grassland and Land Converted to Grassland. This study uses 2006 IPCC Guidelines to estimate emissions from these categories. The steps followed in the estimation process for both the categories remain same with the only difference arising in choice/estimation of emission factors:

Steps followed:
Step 1:
In this study, GHG emissions from grasslands is estimated using the *Stock Difference Method* from the following categories:
(a) Grassland remaining Grassland
(b) Forest Land converted to Grassland
(c) Cropland converted to Grassland
(d) Settlements converted to Grassland
(e) Other Land converted to Grassland

Given below are details of the methodology used for grasslands:

Table 23 Overview of emission factors used for grasslands

IPCC ID	**GHG source & sink categories**	**CO_2**	
		Method Applied	**Emission Factor**
3B3	Grassland	T2	CS
3B3a	Grassland Remaining Grassland	T2	CS
3b3bi	Forest Land converted to Grassland	T2	CS
3b3bii	Cropland converted to Grassland	T2	CS
3b3biii	Settlements converted to Grassland	T2	CS
3b3bv	Other Land converted to Grassland	T2	CS

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Step 2:
For activity data, Land Use Change Matrix as prepared by NRSC is used for Grasslands. The change matrix provided gives changes in the land use pattern for the years (a) 2006-08, (b) 2008-11 and (c) 2011-13. Since, the data is not available for the years 2005 and 2013 land use pattern for these years has been considered to be same as for the years 2006 and 2012 respectively. This is because these changes in land use tend to be almost the same when looked at year on year.

Step 3:
Emission factor estimation has been done specifically for this study. FSI creates a detailed assessment of trees outside the forests (TOF), which includes tree cover comprising of small patches of trees (<0.1 ha) in plantations and woodlots, scattered trees and farms, homesteads and urban areas as well as trees along linear features such as roads, canals and cropland bunds. FSI also provides the growing stock of the trees outside the forest land, which includes all land categories other than forest and includes cropland.

Step 4:
The approach adopted for estimating carbon stock changes in grassland is as follows:

Change in Biomass Carbon stock in Grassland: Carbon stock change in grassland remaining grassland is estimated by taking the tree biomass carbon stock at two periods in time (2004 and 2013). Biomass of trees outside forests is available for the years 2004, 2007, 2009, 2011 and 2013. The rate of change in biomass stocks are measured in terms of carbon estimated (Refer Table below). The growing biomass stock of trees outside forests is declining at a rate of 0.014 tC/ha/yr among the successive measurements for the period 2004 to 2013. This rate has been used for estimating carbon stock change in cropland, grassland and settlements since the TOF remains the same in all the categories.

Table 24 Biomass Carbon Stock in Grassland

Category	2004[a]	2013[b]
Growing Stock in TOF (million cum)	1616.25	1573.34
Total stock in above ground biomass[39] (Mt)	1811.44	1736.35
Total stock in below ground biomass[40] (Mt)	489.09	476.11
Total biomass (Mt)	2300.53	2239.46
Total biomass Carbon[41] (MtC)	1150.26	1119.46
Rate of Change of Biomass Carbon (MtC/yr)	-3.39	
Rate of Change of Biomass Carbon (tC/ha/yr)	-0.014	

Source: a – State of Forest Report 2005, b – State of Forest Report 2015

Step 5:
The annual change in organic C stocks in mineral soils is estimated using the equation given below of the IPCC methodology (Equation 2.25, (Refer Annex I for sample calculations)):

$$\Delta C_{mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

[39] Above Ground Biomass = Growing Stock x density (0.7116) x Biomass Expansion Factor (1.575)** (**Source: http://www.envfor.nic.in/mef/Technical_Paper.pdf)
[40] Based on IPCC 2006 Guidelines; Below Ground Biomass – Root Shoot Ratio is 0.27
[41] Carbon Fraction is 0.5

$$SOC = \sum_{C,S,I} SOC_{REF_{C,S,I}} \cdot F_{LU_{C,S,I}} \cdot F_{MG_{C,S,I}} \cdot F_{I_{C,S,I}} \cdot A_{C,S,I}$$

where,

$\Delta C_{mineral}$ = annual change in carbon stocks in mineral soils, tonnes C yr^{-1}

SOC_0 = soil organic carbon stock in the last year of an inventory time, tonnes C

$SOC_{(0-T)}$ = soil organic carbon stock at the beginning of the inventory time, tonnes C

SOC_0 and $SOC_{(0-T)}$ are calculated using the SOC equation in the box where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T)

D = Time Dependence, yr

C = represents the climate zones, S the soil types, and I the set of management systems that are present in a country.

SOC_{REF} = the reference carbon stock, tonnes C ha-1

F_{LU} = stock change factor for land-use systems or sub-system for a land-use, dimensionless

F_{MG} = stock change factor for management regime, dimensionless

F_I = stock change factor for input of organic matter, dimensionless

A = land area of the stratum being estimated, ha. All land in the stratum should have common biophysical conditions (i.e., climate and soil type) and management history over the inventory time to be treated together for analytical purposes

Due to lack of data during two points of time, the rate of change in SOC for grassland was determined from the country-specific reference soil organic C stocks from K. Sreenivas et al. 2016 and default stock change factors (F_{LU}, F_{MG}, F_I) as given by the 2006 IPCC guidelines. Annual rates of stock change were calculated as the difference in stocks (over time) divided by the time dependence (D) of the stock change factors (with a default value of 20 years). The reference SOC is as determined by FSI for native forests. Based on the Tier I approach, for F_{LU}, F_{MG} and F_I, a default value of 1, 0.97 and 1 was considered respectively for the rate of change which is for moderately degraded grasslands (2006 IPCC Guidelines). The annual SOC change for lands converted to grassland was estimated as the difference on the SOC values from other lands to native vegetation.

Since, there is no land conversion from Forest Land, Cropland and Settlements to Grassland, no calculations have been performed for the same.

The total change in carbon stocks is calculated by adding up all values of the sub-categories estimates.

Uncertainties

NRSC has conducted accuracy assessment of the remote sensing land use and land classification. Stratified random points generated through image software was used to assess the accuracy of classification. The number sample points for each stratum was selected based on the proportion of the area. However, a minimum of 20 sample points was considered for each class to estimate the accuracy of the classified output. Ground truth data, legacy maps, and multi-temporal FCC have formed the basis for assessment and generation of Kappa co-efficient. For quality check, it was submitted to the QAS team. Refinement of crop classification areas obtained based on classification map at the end of the year was used.

The classification outputs were subjected to post classification accuracy assessment. The error matrix of accuracy assessment for different states was done. The overall classification accuracy is found to be 88.82% with a range of 83.05% to 95.31% in different states[42]

For subsequent years, the planimetric accuracy was stated, wherein it is less than one pixel in plain areas and less than 2 pixels in hilly terrains[43]. During 2013-14 it was <1 pixel in plains.

The standing stock or biomass stock outside forest area is which includes cropland is taken from the State of Forest Report (FSI). There are no estimates of precision levels.

SOC reference values for Forestland from M Kaul et al 2009 has not estimated uncertainty. In fact, the research paper has reported uncertainties in input variables due to very large spatial heterogeneity that affect net C flux from land use change.

The SOC of land use was from the study conducted by Srinivas *et al* from NRSA, wherein the SOC was spatially mapping at 250 m resolution and an estimate of their pool size in India was undertaken using many remote sensing derived data layers and data mining approach. The SOC densities were estimated for 1198 soil samples located across India using a stratified random sampling that integrated land use, soil, topography and agro-ecological regions. Using Random forests (RF) based spatial prediction procedure with climatic, land cover, rock type, soil type, multi-year NDVI, irrigation status as independent input variables, models for predicting carbon density at 250 m spatial resolution were developed. For modelling with RF algorithm, about 898 soil profile observations (75% observations) were used, while the rest of 300 (25% of total observations) were used for validation. The Root Mean Square Error (RMSE) statistic was used to measure the degree of agreement between the predicted and observed values. The relationship between observed and predicted values was characterized by Mean Squared Deviations (MSD) parameter which was 3.19.

Activity data in the public domain is available but cannot be verified independently due to lack of open access to remote sensing data that is used by governmental agencies.

Table 25 Uncertainty in emission estimates from Grassland

IPCC ID	**GHG source & sink categories**	**Type of Uncertainty**	**Reason**	**Uncertainty (%)**		
				CO_2	**CH_4**	**N_2O**
3B3	Grassland	Estimation	Uncertainties in land-use and management activity and environmental data and uncertainties in carbon increase and loss, carbon stocks and expansion factor terms in the stock change/emission factors.	Not ascertained		

[42] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0607.pdf (refer section 3.5)
[43] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0809.pdf (refer section 2.2), http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/1112.pdf (refer section 2.21), http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/1314.pdf (refer section 3.1)

Source Category specific QA/QC

The data that have been used for this estimation are from National Remote Sensing Centre, Hyderabad. All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The emissions estimates of Phase I have been extended for the estimation done for this round and remain unchanged from before.

Cross-Verification

3B3. Grassland			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
INCCA (2007)	1,04,90,000	6,32,627	-93.97%
BUR (2010)	5,56,46,160	4,73,141	-99.15%

All the available data sources from National Remote Sensing Centre have been used. The calculations are consistent with the requirements of best practise as per 2006 IPCC guidelines. In case of INCCA report, the variation is mainly because INCCA report does not estimate emissions from the category 'Land converted to Grassland'. It only estimates emissions from 'Grassland remaining Grassland'. Hence, the variation from GHG Platform India results as both the categories have been considered for emission estimation. Furthermore, rate of change of biomass and carbon stock is not available in detail in the INCCA report. There is a need in the BUR report to provide greater details of data or of the assumptions that have been used while estimating emissions. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

Planned improvements

For the estimation of GHG emissions/removals from land, we will be looking at generating change matrices for selected states to validate the change matrices that we have been able to obtain from official sources. In addition, we will continue to scan relevant literature for improvements in tools and methodologies, as well as more precise data in the future.

3B5. Settlements

Category Description

This section provides details of estimating carbon stock changes and greenhouse gas emissions and removals associated with changes in biomass, dead organic matter (DOM), and soil carbon on lands classified as settlements. Settlements are defined as including all developed land -- i.e., residential, transportation, commercial, and production (commercial, manufacturing) infrastructure of any size, unless it is already included under other land-use categories. The land-use category Settlements includes soils, herbaceous perennial vegetation such as turf grass and garden plants, trees in rural settlements, homestead gardens and urban areas (Volume 4, Chapter 8, 2006 IPCC Guidelines).

The area under settlement is estimated to be approximately 8-9 Mha, which is less than 2% of the total land use in India. The net emissions from this category are very low (almost negligible) and therefore, the share of emissions from settlements in LULUCF sector is also negligible.

For this category, Land Use Change Matrix for Settlements has been derived from National Remote Sensing Centre (NRSC), Hyderabad. NRSC is a national organization hosted under Indian Space Research Organization (ISRO). Given below are details of activity data used in the sub-category:

Table 26 Overview of source categories of Settlements

IPCC ID	GHG source & sink categories	Type	Quality	Source
3B	**Land**			
3B5	Settlements	Secondary Data	High	National Remote Sensing Centre (available on request)
3B5a	Settlements Remaining Settlements	Secondary Data	High	National Remote Sensing Centre (available on request)
3B5bi	Forest Land converted to Settlements	Secondary Data	High	National Remote Sensing Centre (available on request)
3B5bii	Cropland converted to Settlements	Secondary Data	High	National Remote Sensing Centre (available on request)
3B5biii	Grassland converted to Settlements	Secondary Data	High	National Remote Sensing Centre (available on request)
3B5v	Other Land converted to Settlements	Secondary Data	High	National Remote Sensing Centre (available on request)

Methodology

Soils and DOM in Settlements may be sources or sinks of CO_2, depending on previous land use, topsoil burial or removal during development, current management, particularly with respect to nutrient and water applications, and amount of vegetation cover spread among roads, buildings and associated infrastructure (2006 IPCC Guidelines).

In this study, GHG emissions from settlements is estimated using the *Stock Difference Method*[44] from the category Land converted to Settlements. Mostly Croplands and Other Land got

[44] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_08_Ch8_Settlements.pdf

converted to settlements based on the land use change matrix. The steps followed in the estimation process for both the categories remain same with the only difference arising in choice/estimation of emission factors:

Steps followed:

Step 1:
Given below are details of subcategories of land converted to Settlements:

Table 27 Overview of emission factors used for settlements

IPCC ID	GHG source & sink categories	CO_2	
		Method Applied	Emission Factor
3B5	Settlements	T2	CS
3B5a	Settlements Remaining Settlements	T2	CS
3B5bi	Forest Land converted to Settlements	T2	CS
3B5bii	Cropland converted to Settlements	T2	CS
3B5biii	Grassland converted to Settlements	T2	CS
3B5v	Other Land converted to Settlements	T2	CS

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Step 2:
For activity data, Land Use Change Matrix as prepared by NRSC is used for Settlements. The change matrix provided gives changes in the land use pattern for the years (a) 2006-08, (b) 2008-11 and (c) 2011-13. Since, the data is not available for the years 2005 and 2013 land use pattern for these years has been considered to be same as for the years 2006 and 2012 respectively. This is because these changes in land use tend to be almost the same when looked at year on year.

Step 3:
The biomass stock change is estimated using the method and data described for croplands and grassland. In case of settlements, the input biomass is same as output biomass. Hence, the net biomass stock change is zero. Hence, there is no emission from settlement remaining settlement.

Step 4:
The annual change in organic C stocks in mineral soils is estimated using the equation given below of the IPCC methodology (Equation 2.25, (Refer Annex I for sample calculations)):

$$\Delta C_{mineral} = \frac{\left(SOC_0 - SOC_{(0-T)}\right)}{D}$$

$$SOC = \sum_{C,S,I} SOC_{REF_{C,S,I}} \cdot F_{LU_{C,S,I}} \cdot F_{MG_{C,S,I}} \cdot F_{I_{C,S,I}} \cdot A_{C,S,I}$$

where,

$\Delta C_{mineral}$ = annual change in carbon stocks in mineral soils, tonnes C yr^{-1}
SOC_0 = soil organic carbon stock in the last year of an inventory time, tonnes C
$SOC_{(0-T)}$ = soil organic carbon stock at the beginning of the inventory time, tonnes C

SOC_0 and $SOC_{(0-T)}$ are calculated using the SOC equation in the box where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T)

D	= Time Dependence, yr
C	= represents the climate zones, S the soil types, and I the set of management systems that are present in a country.
SOC_{REF}	= the reference carbon stock, tonnes C ha-1
F_{LU}	= stock change factor for land-use systems or sub-system for a particular land-use, dimensionless
F_{MG}	= stock change factor for management regime, dimensionless
F_I	= stock change factor for input of organic matter, dimensionless
A	= land area of the stratum being estimated, ha. All land in the stratum should have common biophysical conditions (i.e., climate and soil type) and management history over the inventory time to be treated together for analytical purposes

Due to lack of data during two points of time, the rate of change in SOC for settlements was determined from the country-specific reference soil organic C stocks from K. Sreenivas et al. 2016 and default stock change factors (F_{LU}, F_{MG}, F_I) as given by the 2006 IPCC Guidelines. Annual rates of stock change were calculated as the difference in stocks (over time) divided by the time dependence (D) of the stock change factors (with a default value of 20 years). The reference SOC is as determined by FSI for native forests. Based on the Tier I approach, for F_{LU}, F_{MG} and F_I, a default value of 0.82, 1.22 and 1 was considered respectively for the land transition from settlements to cropland (2006 IPCC Guidelines).

Since, there is no land conversion from Forest Land and Grassland to Settlements, no calculations have been performed for the same.

Step 5:
The total change in carbon stocks is calculated by adding up all values of the sub-categories estimates.

Uncertainties
NRSC has conducted accuracy assessment of the remote sensing land use and land classification. Stratified random points generated through image software was used to assess the accuracy of classification. The number sample points for each stratum was selected based on the proportion of the area. However, a minimum of 20 sample points was considered for each class to estimate the accuracy of the classified output. Ground truth data, legacy maps, and multi-temporal FCC have formed the basis for assessment and generation of Kappa co-efficient. For quality check, it was submitted to the QAS team. Refinement of crop classification areas obtained based on classification map at the end of the year was used.

The classification outputs were subjected to post classification accuracy assessment. The error matrix of accuracy assessment for different states was done. The overall classification accuracy is found to be 88.82% with a range of 83.05% to 95.31% in different states[45]

For subsequent years, the planimetric accuracy was stated, wherein it is less than one pixel in plain areas and less than 2 pixels in hilly terrains[46]. During 2013-14 it was <1 pixel in plains.

[45] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0607.pdf (refer section 3.5)
[46] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0809.pdf (refer section 2.2), http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/1112.pdf (refer section 2.21), http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/1314.pdf (refer section 3.1)

The standing stock or biomass stock outside forest area is which includes cropland is taken from the State of Forest Report (FSI). There are no estimates of precision levels.

SOC reference values for Forestland from M Kaul et al 2009 has not estimated uncertainty. In fact, the research paper has reported uncertainties in input variables due to very large spatial heterogeneity that affect net C flux from land use change.

The SOC of land use was from the study conducted by Srinivas *et al* from NRSA, wherein the SOC was spatially mapping at 250 m resolution and an estimate of their pool size in India was undertaken using many remote sensing derived data layers and data mining approach. The SOC densities were estimated for 1198 soil samples located across India using a stratified random sampling that integrated land use, soil, topography and agro-ecological regions. Using Random forests (RF) based spatial prediction procedure with climatic, land cover, rock type, soil type, multi-year NDVI, irrigation status as independent input variables, models for predicting carbon density at 250 m spatial resolution were developed. For modelling with RF algorithm, about 898 soil profile observations (75% observations) were used, while the rest of 300 (25% of total observations) were used for validation. The Root Mean Square Error (RMSE) statistic was used to measure the degree of agreement between the predicted and observed values. The relationship between observed and predicted values was characterized by Mean Squared Deviations (MSD) parameter which was 3.19.

Activity data in the public domain is available but cannot be verified independently due to lack of open access to remote sensing data that is used by governmental agencies.

Table 28 Uncertainty in emission estimates from Settlements

IPCC ID	**GHG source & sink categories**	**Type of Uncertainty**	**Reason**	**Uncertainty (%)**		
				CO_2	**CH_4**	**N_2O**
3B5	Settlements	Estimation	Uncertainty in this category arises from lack of accuracy in land area estimates, carbon increment and loss, carbon stocks, and expansion factor terms.	Not ascertained		

Source Category specific QA/QC

The data that have been used for this estimation are from National Remote Sensing Centre. All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The emissions estimates of Phase I have been extended for the estimation done for this round and remain unchanged from before.

Cross-Verification

3B5. Settlements			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
INCCA (2007)	-38,000	4,45,457	1272.26%
BUR (2010)	26,15,540	4,67,623	82.12%

All the available data sources from National Remote Sensing Centre have been used. The calculations are consistent with the requirements of best practise as per 2006 IPCC guidelines. In case of INCCA report, the variation is mainly because INCCA report does not estimate emissions from the category 'Land converted to Settlement'. It only estimate emissions from 'Settlement remaining Settlement'. Hence, the variation from GHG Platform India results as both the categories have been considered for emission estimation. Furthermore, rate of change of biomass and carbon stock is not available in detail in the INCCA report. There is a need in the BUR report to provide greater details of data or of the assumptions that have been made used while in making their calculations that has been used while estimating emissions. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

Planned improvements

For the estimation of GHG emissions/removals from land, we will be looking at generating change matrices for selected states to_2 validate the change matrices that we have been able to obtain from official sources. In addition, we will continue to scan relevant literature for improvements in tools and methodologies, as well as more precise data in the future.

3B6. Other Land

Category Description

For the sub-category 'other lands', it includes wasteland, snow covered area, rocky surfaces, water bodies, etc. Emissions from Other Land in the year 2005 were 8.2 million tCO_2e and it decreased by a CAGR of 1.1% till 2013. The emissions in the year 2013 were 7.4 million tCO_2e.

For this category, Land Use Change Matrix for Other Land has been derived from National Remote Sensing Centre (NRSC), Hyderabad. NRSC is a national organization hosted under Indian Space Research Organization (ISRO). Given below are details of activity data used in the sub-category:

Table 29 Overview of source categories of Other Land

IPCC ID	GHG source & sink categories	Type	Quality	Source

3B	**Land**			
3B6	Other Land	Secondary Data	High	National Remote Sensing Centre (available on request)
3B6a	Other Land Remaining Other Land	Secondary Data	High	National Remote Sensing Centre (available on request)
3b6bi	Forest Land converted to Other Land	Secondary Data	High	National Remote Sensing Centre (available on request)
3b6bii	Cropland converted to Other Land	Secondary Data	High	National Remote Sensing Centre (available on request)
3b6biii	Grassland converted to Other Land	Secondary Data	High	National Remote Sensing Centre (available on request)
3b6biv	Settlements converted to Other Land	Secondary Data	High	National Remote Sensing Centre (available on request)

Methodology

In this study, GHG emissions from Other Lands is estimated using the *Stock Difference Method* from the category Other Land Remaining Other Land and Land converted to Other Land. Mostly Croplands, Grassland and Settlements got converted to settlements based on the land use change matrix prepared by NRSC. The steps followed in the estimation process for both the categories remain same with the only difference arising in choice/estimation of emission factors:

Steps followed:
Step 1:
Given below are details of the subcategories of land use type converted to Settlements:

Table 30 Overview of Emission Factors used for Other Land

IPCC ID	**GHG source & sink categories**	**CO_2**	
		Method Applied	**Emission Factor**
3B5	Other land	T2	CS
3B6a	Other Land Remaining Other Land	T2	CS
3b6bi	Forest Land converted to Other Land	T2	CS
3b6bii	Cropland converted to Other Land	T2	CS
3b6biii	Grassland converted to Other Land	T2	CS
3b6biv	Settlements converted to Other Land	T2	CS

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Step 2:
For activity data, Land Use Change Matrix as prepared by NRSC is used for Other Land. The change matrix provided gives changes in the land use pattern for the years (a) 2006-08, (b) 2008-11 and (c) 2011-13. Since, the data is not available for the years 2005 and 2013 land use pattern for these years has been considered to be same as for the years 2006 and 2012 respectively. This is because these changes in land use tend to be almost the same when looked at year on year.

Step 3:
The biomass stock change is estimated using the method and data described for croplands and grassland.

Step 4:
The annual rate of change in SOC was obtained from K. Sreenivas et al. 2016 as the difference of SOC between for Croplands & Other Land, Grasslands & Other Land and Settlements & Other Land (divided by 20 years for the conversion rate based on IPCC methodology – refer equation 2.25 of Chapter 02, Volume 04 of 2006 IPCC Guidelines). Since, there is no land conversion from Forest Land to Other Land, no calculations have been performed for the same.

Step 5:
The total change in carbon stocks is calculated by adding up all values of the sub-categories estimates. Pl refer to Annexure 1 for sample calculation.

Uncertainties
NRSC has conducted accuracy assessment of the remote sensing land use and land classification. Stratified random points generated through image software was used to assess the accuracy of classification. The number sample points for each stratum was selected based on the proportion of the area. However, a minimum of 20 sample points was considered for each class to estimate the accuracy of the classified output. Ground truth data, legacy maps, and multi-temporal FCC have formed the basis for assessment and generation of Kappa co-efficient. For quality check, it was submitted to the QAS team. Refinement of crop classification areas obtained based on classification map at the end of the year was used.
The classification outputs were subjected to post classification accuracy assessment. The error matrix of accuracy assessment for different states was done. The overall classification accuracy is found to be 88.82% with a range of 83.05% to 95.31% in different states[47]

For subsequent years, the planimetric accuracy was stated, wherein it is less than one pixel in plain areas and less than 2 pixels in hilly terrains[48]. During 2013-14 it was <1 pixel in plains.

The standing stock or biomass stock outside forest area is which includes cropland is taken from the State of Forest Report (FSI). There are no estimates of precision levels.

SOC reference values for Forestland from M Kaul et al 2009 has not estimated uncertainty. In fact, the research paper has reported uncertainties in input variables due to very large spatial heterogeneity that affect net C flux from land use change.

The SOC of land use was from the study conducted by Srinivas *et al* from NRSC, wherein the SOC was spatially mapping at 250 m resolution and an estimate of their pool size in India was undertaken using many remote sensing derived data layers and data mining approach. The SOC densities were estimated for 1198 soil samples located across India using a stratified random sampling that integrated land use, soil, topography and agro-ecological regions. Using Random forests (RF) based spatial prediction procedure with climatic, land cover, rock type, soil type, multi-year NDVI, irrigation status as independent input variables, models for predicting carbon density at 250 m spatial resolution were developed. For modelling with RF algorithm, about 898 soil profile observations (75% observations) were used, while the rest

[47] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0607.pdf (refer section 3.5)
[48] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0809.pdf (refer section 2.2), http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/1112.pdf (refer section 2.21), http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/1314.pdf (refer section 3.1)

of 300 (25% of total observations) were used for validation. The Root Mean Square Error (RMSE) statistic was used to measure the degree of agreement between the predicted and observed values. The relationship between observed and predicted values was characterized by Mean Squared Deviations (MSD) parameter which was 3.19.

Activity data in the public domain is available but cannot be verified independently due to lack of open access to remote sensing data that is used by governmental agencies.

Table 31 Uncertainty in emission estimates from Other Land

IPCC ID	**GHG source & sink categories**	**Type of Uncertainty**	**Reason**	**Uncertainty (%)**		
				CO_2	**CH_4**	**N_2O**
3B5	Other Land	Estimation	Uncertainties in input variables due to very large spatial heterogeneity that affect net C flux from land use change. Uncertainties in land-use and management activity prior to conversion.	Not ascertained		

Source Category specific QA/QC

The data that have been used for this estimation are from National Remote Sensing Centre. All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The numbers for this estimation have been calculated in this phase. These were not estimated in phase I.

Cross-Verification

Government of India does not estimate emissions from this category. Therefore, calculations of variance cannot be done.

Planned improvements

For the estimation of GHG emissions/removals from land, we will be looking at generating change matrices for selected states to validate the change matrices that we have been able to obtain from official sources. In addition, we will continue to scan relevant literature for improvements in tools and methodologies, as well as more precise data in the future.

3C1a. Estimation of Emissions from Biomass Burning in Forest Land

Category Description

This section provides details of estimating non-carbon dioxide emissions from biomass burning in forest land. Both uncontrolled (wildfires) and managed (prescribed) fires can have a major impact on the non-CO_2 greenhouse gas emissions from forests.

The net emissions from this category were 0.31 million tCO_2e and 0.32 million tCO_2e in the years 2005 and 2013 respectively showing that the emissions grew at approximately 0.17%. The share of emissions from settlements in AFOLU sector is also very low.

For this category, there is no official data available on the area burnt in forests. The activity data has been derived for this category (please refer the methodology section for details) using the forest area as provided by FSI. Given below are details of activity data used in the sub-category:

Table 32 Overview of source categories of Biomass Burning in Forest Land

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**			
3C1a	Biomass Burning in Forest Land	Secondary Data	High	Forest Survey of India

Methodology

The methodological details for estimating emissions from Biomass burning in Forest Land are as under:

Table 33 Overview of Emission factors used for Biomass burning in Forest Land

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH_4		N_2O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
3.	**AFOLU**				
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**				
3C1a	Biomass burning in Forest Land	T2	CS	T2	CS

2006 IPCC guidelines is adopted for estimating the GHG emissions from forest fire. The following equation, (Refer Annex I for sample calculation) was used to estimate methane and nitrous oxide emissions by burning of biomass in forestland.

$$L_{fire} = A \cdot M_B \cdot C_f \cdot G_{ef} \cdot 10^{-3}$$

where,
L_{fire} = amount of greenhouse gas emissions from fire, tonnes of each GHG e.g., CH4, N2O, etc.
A = area burnt, ha
M_B = mass of fuel available for combustion, tonnes ha-1. This includes biomass, ground litter and dead wood.
C_f = combustion factor, dimensionless
G_{ef} = emission factor, g kg-1 dry matter burnt

Steps followed:

Step 1:
Non-CO_2 GHG emissions are estimated for the forestland subjected to biomass burning. Activity data for the area of the forest burnt was derived by apportioning the burnt area based on the NATCOM II.

NATCOM II provides the total burnt area in year 2000. Burnt area factor was calculated using this value.

This was further apportioned to all the years using total forest area provided by FSI. The quantity of biomass burnt per hectare is the average biomass as provided by NATCOM II.

Step 2:
Mass of fuel available for combustion (M_B) is estimated (in tonnes/ha). The value of the selected variable is 13.12 tonnes/ha as per NATCOM II and the same is adopted here as well.

Step 3:
In the absence of country specific values Combustion factor value (C_f) is selected from 2006 IPCC[49] Guidelines. The selected value is 0.36 based on the category 'all primary tropical forests'.

Step 4:
Further mass of fuel available for combustion was multiplied with combustion factor to estimate the amount for fuel combusted.

Step 5:
In the absence of adequate information on Country specific emission factors (G_{ef}) for methane and nitrous oxide gas were adopted from NATCOM II.

Step 6:
Finally, the value calculated using Step 4 was multiplied with the area and the country specific emission factor and then added together to estimate emissions from biomass burning in forestland. The above steps were repeated for the methane and nitrous oxide emissions. (Refer to Annexure 1 for sample calculation)

[49] Section 4.2.4.3, Pg 4.28, Chapter 4, Volume 4, IPCC 2006 Guidelines. Values selected from table 2.6, Chapter 2, Volume 4, IPCC 2006 Guidelines.

Uncertainties

The activity data for the area under forests at the state level is from Forest Survey of India reports. The forest cover assessment is based on satellite imagery. Internationally, the accuracy of classification of remote sensing data more than 85 percent is satisfactory. FSI prepared an error matrix for assessing the accuracy of classification based on remote sensing data by comparing agreement and disagreement between remote sensing derived classification with the reference data (ground truth) on a class by class basis at randomly selected locations. FSI has assessed the accuracy to be greater than 90% for all the years of survey considered for the inventory (FSI, 2011, 2013 and 2015).

The emission factors for biomass burning on forest land is considered from NATCOM II. Uncertainty in emission factors for biomass burning in forest land is not ascertained in NATCOM II.

Table 34 Uncertainty in emission estimation from Biomass burning in Forest Land

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO_2	CH_4	N_2O
3C1a	Biomass burning in Forests	Estimation	Precise data on burnt forest area is not available	Not ascertained		

Source Category specific QA/QC

The data that have been used for this estimation are from Forest Survey of India[50]. All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

Numbers pertaining to this category of emissions have been recalculated using India specific assumptions on area burnt as well as emissions factors. The variation in the results is due to

[50] http://fsi.nic.in/

use of updated activity data in Phase II. Assumptions have been made on official data on forests to calculate the area burnt as explained in the previous sections whereas in Phase I, area burnt in forestland was derived from FAO.

Year	Phase I Results	Phase II Results	Difference	% Change
2007	245460.7262	316724.66	71263.94	29%
2008	104052.9628	316640.83	212587.87	204%
2009	372334.9107	317536.30	-54798.61	-15%
2010	426578.5139	318431.77	-108146.75	-25%
2011	102341.4976	319327.24	216985.74	212%
2012	175585.5928	320190.73	144605.14	82%

Cross-Verification

3C1a. Biomass Burning in Forest Land			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
BUR (2010)	37,93,120	3,19,327	-92%

All the available data sources from Forest Survey of India[51] have been used. The calculations are consistent with the requirements of best practise as per 2006 IPCC guidelines. This category is not considered under emission estimation in the INCCA report. There is a need in the BUR report to provide greater details of data or of the assumptions that have been made used while in making their calculations that has been used while estimating emissions. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

Planned improvements

As and when more detailed surveys are carried out, these estimations will be improved.

3C1b. Biomass Burning in Cropland

Category Description

From a climate change perspective, burning of crop residues causes emissions of N_2O and CH_4. CO_2 emissions do not count since it is offset by the absorption of CO_2 in the process of photosynthesis that caused the biomass growth at the outset.

Table 35 Overview of source categories of Biomass Burning in Cropland

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
3.	AFOLU			
3C	Aggregate sources and non-CO_2			

[51] http://fsi.nic.in/

	Emissions Sources on Land			
3C1b	Biomass Burning in Cropland	Secondary	Medium (Data for residues is obtained as a ratio of crop yields)	Ministry of Agriculture, Government of India for crop yields. Ratio of residue to economic yield taken from Jain et al (2014)

Methodology

The methodological details for estimating emissions from Biomass Burning in Cropland are as under:

Table 36 Overview of emission factors used for biomass burning in cropland

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH_4		N_2O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
3.	**AFOLU**				
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**				
3C1b	Biomass Burning in Cropland	T1	CS	T1	CS

In the absence of data on amount of area burnt the methodology used here for estimating emissions from biomass burning in cropland is adopted from NATCOM II. **Steps followed**:

Step 1:

Crop residue is burnt in many Indian states particularly in Punjab, Haryana and Western Uttar Pradesh leading to greenhouse gas emissions Bhatia et al. (2013)[52]. The crop considered for biomass burning in cropland in India for this study are rice, wheat, cotton, maize, millets, sugarcane, jute, mustard and groundnut). Emissions from crop residue burning was calculated using the following equation[53]:

$$FBCR = \sum Crops(A \cdot B \cdot C \cdot D \cdot E \cdot F)$$

Where,
FBCR is the emissions from residue burning,
A is the crop production,
B is the residue to crop ratio,
C is the dry matter fraction,
D is the fraction burnt[54]
E is the fraction oxidized,
F is the emission factor for CH_4 and N_2O
(Refer Annex I for sample calculations)

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[52]https://www.researchgate.net/publication/256376771_Methane_and_nitrous_oxide_emissions_from_Indian_rice_paddies_agricultural_soils_and_crop_residue_burning

[53]https://www.researchgate.net/publication/256376771_Methane_and_nitrous_oxide_emissions_from_Indian_rice_paddies_agricultural_soils_and_crop_residue_burning

[54] Fraction Burnt for wheat straw (Rest of India) is 0.10 and Fraction Burnt for wheat in Haryana, Punjab, HP and UP is 0.23

Step 2:
State-wise crop production data for above mentioned crops were obtained from MoA (2011) and a ratio of residue to economic yield was taken from Bandyopadhyay et. al. 2001.

Step 3:
Fractions of residues burned in field was taken from Gadde et al. (2009) for rice and for other crops (wheat, maize, millet, groundnut, rapeseed & mustered, cotton and sugarcane) was taken from Jain et al (2014). Fraction of residues oxidized was obtained from Turn et al (1997), and Rapeseed-Mustard crop from Streets et al. 1993 Streets et al. (2003a, b) and Venkatraman et al. (2006). The emission factors for different pollutants emitted from residue burning were taken from Andreae and Merlet (2001).

Step 4:
In this study, a bottom up approach was used, i.e. state-wise emissions from burning of crop residues was calculated for all the Indian states and it was then added up to get national level estimates.

Uncertainties

Precise data on residue yields and their uses are not available. Assumptions have been made with regard to the amount of crop residue burnt every year in India. The uncertainty associated with the activity data cannot be quantified due to limitations of the data. Estimations are based on expert estimations that are available from published studies in the public domain. India specific emission factors have been derived from a study by Bhatia et al 2013[55]. According to this study, uncertainty in emission factors arise due to climatic conditions, soil type, water usage etc. Various biological, chemical and physical properties of soil influence the emissions from soil to the atmosphere.

Table 37 Uncertainty in emission estimation from Biomass Burning in Cropland

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO_2	CH_4	N_2O
3C1b	Biomass burning in Cropland	Estimation	No specific activity data on crop burning available. Therefore, assumptions have been made to estimate the proportion of crop residues burnt every year. Further, uncertainty arise due to various variables used in the assessment such as fraction of residue burnt, area estimation, etc.	Not ascertained		

[55] http://onlinelibrary.wiley.com/doi/10.1002/ghg.1339/full

Source Category specific QA/QC

The data that have been used for this estimation are calculated from Ministry of Agriculture[56] and peer reviewed literature mentioned above in the methodology section. All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The numbers for this estimation that pertain to Phase I of this project have not been recalculated

Verification

3C1a. Biomass Burning in Cropland			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
INCCA (2007)	66,06,000	57,36,934	-13.16%
BUR (2010)	79,15,060	58,01,227	-26.71%

The data that have been used for this estimation are calculated from Ministry of Agriculture[57] and peer reviewed literature mentioned above in the methodology section.
Variation with the INCCA report can be attributed mainly due to lack of activity data in the report. INCCA report does not give detailed activity data in terms of residue burnt in Indian states. Hence, it is difficult to analyse the variation without comparing the base data. The BUR report does not provide details of data or of the assumptions that have been made in making their calculations. Therefore, it is difficult to unpack the BUR inventory and analyze why our calculations are different from official calculations.

Planned improvements

As and when more detailed surveys are carried out, these estimations will be improved.

Estimation of Emissions from Agricultural Soils, including from:

[56] http://eands.dacnet.nic.in/LUS_2000_2005.htm
[57] http://eands.dacnet.nic.in/LUS_2000_2005.htm

3C4. Direct N_2O emissions from managed soils
&
3C5. Indirect N_2O emissions from Managed Soils

Category Description

A portion of nitrogenous fertilisers applied in agricultural soils are lost into the atmosphere through direct emissions of N_2O through nitrification and denitrification. In addition, there are also indirect emissions of N_2O through volatilization losses, leaching and runoffs.

Table 38 Overview of source categories of N2O emissions from Managed Soils

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
3.	**AFOLU**			
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**			
3C4	Direct N_2O emissions from managed soils	Secondary	High	Fertilizer consumption data available from Fertiliser Association of India (www.faidelhi.org)[58]
3C5	Indirect N_2O emissions from managed soils	Secondary	High	Fertilizer consumption data available from Fertiliser Association of India (www.faidelhi.org)

Methodology

The methodological details for estimation of N_2O emissions from agriculture soils are as under:

Table 39 Overview of emission factors used for N_2O emissions from Managed Soils

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH_4		N_2O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
3.	**AFOLU**				
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**				
3C4	Direct N_2O emissions from managed soils	T2	CS		
3C5	Indirect N_2O emissions from managed soils	T2	CS		

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Step 1:

As already mentioned above, data on consumption of fertilisers was gathered from Fertiliser Association of India. For estimating quantity of urea consumed by all the states, we apportioned share of urea consumption from total nitrogen fertilizers by summing up fertilizers such as Urea, Ammonium Sulphate(A/S), Calcium Nitrate (CAN), Monoammonium

[58] Data on fertilizer consumption was collected in person from the office of Fertiliser Association of India, New Delhi.

Phosphate (MAP) and Diammonium Phosphate (DAP). The quantity of urea in each state was estimated by multiplying the total N fertilizer consumption by the respective proportion of N in that fertilizer. Quantity of other N fertilizer consumed in each states and UT were obtained by subtracting the urea amount from total N fertilizer.

Step 2:
For the calculation of the nitrogen loss from volatilization of NH_3 and NO_x, a magnitude of 15 percent per kg of urea and other fertilizers was considered instead of IPCC fraction of 10 percent as most Indian soils are low in acidity and high in average temperature therefore resulting in more volatilization losses. The fraction of N lost through leaching is 10 percent of N applied to the soil.

Step 3:
Revised N_2O emission factor of 0.7 percent per kg of urea and other N fertilizers applied to the soil after discounting the N lost through volatilization (NH_3 and NO_x) and leaching loss of N (Bhatia e. al. 2004[59]). The default IPCC emission factor for N_2O emission for atmospheric NH_3 and NO_x is 1 percent; however, considering characteristics of Indian soils, 0.5 percent emission factor was used for N_2O from volatilized N. Similarly, emission factor used for deposited N from leaching and runoff was 0.5 percent (Bhatia et al 2013).

Uncertainties

Disaggregated data beyond state level in different parts of the country are not available. Assumptions have been made with regard to the usage of fertilizers applied to the agricultural fields. Therefore, the uncertainty associated with the activity data cannot be quantified due to limitations of the data. India specific emission factors have been derived from a study by Bhatia et al 2013. According to this study, uncertainty in emission factors arise due to climatic conditions, soil type, water usage etc. Various biological, chemical and physical properties of soil influence the emissions from soil to the atmosphere.

Table 40 Uncertainty in emission estimates from N_2O emissions from Managed Soils

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO_2	CH_4	N_2O
3C4 and 3C5	Agriculture Soils	Estimation	According to 2006 IPCC guidelines (Chapter 11, Volume 04)[60], uncertainties in estimates of emissions from managed soils are caused by uncertainties related to the emission factors that arise from natural variability, partitioning fractions, activity data, lack of coverage of measurements, spatial aggregation, and lack of	Not Ascertained		

59 http://www.iisc.ernet.in/currsci/aug102004/317.pdf
60 http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO_2	CH_4	N_2O
			information on specific on-farm practices.			

Source Category specific QA/QC

The data that have been used for this estimation are from Fertiliser Association of India[61] All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The numbers for this estimation that pertain to Phase I of this project have not been recalculated

Cross-Verification

3C4 & 3C5. Agriculture Soils			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
INCCA (2007)	4,34,00,000	4,29,23,921	-1.10%
BUR (2010)	8,10,80,500	4,91,13,010	-39.43%

All the available data sources from Fertiliser Association of India[62] have been used. The calculations are consistent with the requirements of best practise as per 2006 IPCC Guidelines. Variation in results with the INCCA report is mainly due to rounding-off factors. There is a need in the BUR report to provide greater details of data or of the assumptions that have been made used while in making their calculations that has been used while estimating emissions. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

[61] www.faidelhi.org
[62] www.faidelhi.org

Planned improvements

As and when more detailed surveys are carried out, these estimations will be improved.

3C7. Estimation of Emissions from Rice Cultivation

Category Descriptions

Paddy fields are a large source of methane emissions from agriculture. Methane emissions arise due to anaerobic decomposition of organic materials from flooded paddy fields.

Table 41 Overview of Source Categories of Rice Cultivation

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
3.	**AFOLU**			
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**			
3C7	Rice Cultivation	Secondary	High	Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmer's Welfare, Government of India

Methodology

The methodological details for estimation of emissions from rice cultivation are as under:

Table 42 Overview of Emission Factors used for Rice Cultivation

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH_4		N_2O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
3.	**AFOLU**				
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**				
3C7	Rice Cultivation	T3	CS		

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

The methodology used was the same as that used in NATCOMM II 2012. It has been referred from Gupta et al., (2009) and Pathak et al., (2010) using 2006 IPCC guidelines. The methane emissions are estimated by multiplying the total paddy rice area under different water management regimes (ha) with corresponding Emission Factor. Separate calculations were made for each state and union territory (UT) of India and the national level as well as for each rice ecosystems (i.e., irrigated, rain-fed, and deep-water rice production) and then summed up to estimate the national total.

The equation used was:

$$E_{RC} = A_C \cdot EF_W \cdot 10^{-6}$$

Where,

E_{RC} = CH_4 emissions from rice cultivation (Gg year^{-1}),
A_C = area of rice cultivation under management C (ha)
EF_W = factor applied for different types of water management (kg CH_4 ha^{-1})

10^{-6} = to convert Kg into Gg
(Refer Annex I for sample calculations)

Step1:
We first calculated the percentage of area under rice under respective water management regime for each state. The water management regimes in each state were assumed to be the same as that available in Pathak et al 2010, Bhatia A 2013 and Huke & Huke 1997. The rainfed area was also sub-divided into rainfed flood prone (27.1%) and rainfed drought prone (72.9%) based on the literature reference Huke and Huke 1997. The irrigated rice area was further divided into the irrigated continuously flooded (26.9%), irrigated single aeration (35.7%) and irrigated multiple aeration (37.4%) based on Gupta et al. 2009.

Step2:
Next, we multiplied India specific emission factor of each water management regime with proportion of area under cultivation under each water management across all states in India.

Step 3:
To convert data into Kg to Gg, we multiplied by 10^{-6}.

The specific emission factors (from Bhatia et. al 2012) used were as follows:

Table 43 Emission Factor for different water regime for Rice Cultivation

Emission from different water regime for rice cultivation	**Emission** (kg CH_4/ha)
Continuous Flooding	162
Single Aeration	66
Multiple Aeration	18
Flood Prone	190
Drought Prone	66
Deep Water	190
Upland	0

Uncertainties
Precise and disaggregated data on different water management regimes for rice cultivation are not available. Therefore, the uncertainty associated with the activity data cannot be quantified due to limitations of the data. India specific emission factors have been derived from a study by Bhatia et al 2012. According to this study, uncertainty in emission factors arise due to climatic conditions, soil type, water usage etc. Various biological, chemical and physical properties of soil influence the emissions from soil to the atmosphere. In rice cultivation category, uncertainties also arise due to non-availability of harvested area under each water regime especially area under single and multiple aeration (Bhatia et al 2012).

Table 44 Uncertainty in emission estimation from Rice Cultivation

IPCC ID	**GHG source & sink categories**	**Type of Uncertainty**	**Reason**	**Uncertainty (%)**		
				CO_2	**CH_4**	**N_2O**
3C7	Rice cultivation	Estimation	Precise and disaggregated data on water regimes for rice cultivation in	Not Ascertained		

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO_2	CH_4	N_2O
			different parts of the country is not available.			

Source Category specific QA/QC

The data that have been used for this estimation are from Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmer's Welfare, Government of India[63] . All the parameters, units and conversion factors have been labelled properly. If any assumptions have been made for calculations, it has been cross-verified with the associated external expert and explanation for the same has been provided in this document. The activity data and emission factors used has been properly archived within the calculation sheets. Extrapolation and interpolation for years for which data is not available has been done through assuming a linear trend. Data entry was done in-house and validation of data was done through sample checks physically as well as through validation techniques such as through plotting and using trend charts. Sources of the data and emission factors has been cited across this document and the calculation sheets. The emission factors and other conversion factors applied for emission estimates are consistent across the categories and also across the years. If there is a different emission factor used for any source category, a valid justification regarding the same has been provided in this document. In terms of completeness, the exercise has covered all the categories and sub-categories from AFOLU sector responsible for emissions in India unless they are not relevant to the country or there is no data available for making any estimations what so ever. The results have been verified with the experts associated with this exercise using trends and the official numbers and have also been peer reviewed by WRI – India.

Recalculation

The numbers for this estimation that pertain to Phase I of this project have not been recalculated

Cross-Verification

3C7. Rice Cultivation			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO_2e)		Emissions (tonnes CO_2e)	(Percentage)
INCCA (2007)	6,98,67,000	7,06,39,752	1.11%
BUR (2010)	7,13,67,950	6,89,40,747	-3.40%

The calculations are consistent with the requirements of best practise as per 2006 IPCC guidelines. The variation in GHGPI results with the INCAA and BUR results is due to rounding off calculations.

Planned improvements

As and when more detailed surveys are carried out, these estimations will be improved.

[63] http://eands.dacnet.nic.in/LUS_2000_2005.htm

Public Consultation and Outreach

Vasudha Foundation as part of the platform organized a regional roundtable meeting in India Habitat Centre, New Delhi on 6th April 2017 and also participated in a roundtable organized by WRI India in Mumbai on 17th March 2017, to reach out and capture views of potential users of the Platform's data such as policymakers, research institutions, experts and the media. The meeting was primarily aimed to capture feedback on the current adopted methodology, suitability of activity data and emission factors and improve emission estimation results. The possible approach for adopting Tier III methodologies in future was also discussed during the roundtable. For the AFOLU sector, most of the suggestions were from the LULUCF category. It was recommended that the platform should use the IPCC Gain-Loss Approach instead of the conventionally used Stock Difference Method for estimating emissions of the land and forestry sector. However, due to lack of availability of the data and emission factors, it is cumbersome to use the gain loss approach. Further, Government of India also uses the stock difference approach for preparing estimates for the national inventories. Therefore, the platform decided not to deviate from the officially adopted methodology due to possibility of wide variations of results from official inventories.

Recommendations

The major recommendations that emanate from this exercise are as follows:

- Data transparency of closely held data by official agencies on land use is essential for the public to be able to engage constrictively in the process of discussing and disseminating GHG inventories. Without public awareness and consultations, any initiatives that require public participation in dealing with climate change will not be successful.
- One of the more specific aspects of this is the relatively expensive access to remote sensing data held by National Remote Sensing Centre, Hyderabad. Unless there is wider and cheaper access to this data, public participation in understanding and estimating GHG emissions from land use in India will remain low. Further, public awareness of changes in land use having implications for dealing climate change will remain limited.
- There are various aspects of national GHG inventories that need greater attention to have more complete and accurate inventories. For example, more precise data are needed regarding production and use of crop residues than are available at present. Another example is that dealing with use of fertilisers or manure at the farm level. Unless these data gaps can be filled, it will be impossible for India to move from Tier II methodologies towards Tier III methodologies for estimating the country's GHG emissions
- More specific emission factors, perhaps disaggregated at the state level if possible, need to be developed to make more precise calculations for AFOLU sector as a whole

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Annexure I

1. IPCC equation 10.19, Emission Estimation from Enteric Fermentation

$$Emissions = EF_{(T)} \cdot \left(\frac{N_{(T)}}{10^6}\right)$$

Where,

$Emissions$ = *methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}*
$EF_{(T)}$ = *emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}*
$N_{(T)}$ = *the number of head of livestock species/category T in the country*
T = *species/category of livestock*

Sample Calculation:

For enteric fermentation emissions from Indigenous Dairy Cattle in year 2013:

T = Indigenous Dairy Cattle
$EF_{(Indigenous\ Dairy\ Cattle)}$[64] = 24 kg CH_4 $head^{-1}$ yr^{-1}
$N_{(Indigenous\ Dairy\ Cattle)}$ = 4,81,41,000[65]

- ⇨ Emissions = 24 * (4,81,41,000)/10^6
- ⇨ Emissions = 1,347.95 Gg CH_4 yr^{-1}...(1)
- ⇨ Similarly, using the same equation, emissions from Indigenous Non-Dairy Cattle are 2,315.81 Gg$CH_4$$yr^{-1}$...(2)

2. IPCC equation 10.20, Emission Estimation from Enteric Fermentation

$$Total\ CH_{4_{Enteric}} = \sum_i E_i$$

Where,

$Total\ CH_{4_{Enteric}}$ = *total methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}*
E_i = *Emissions for the i^{th} livestock categories and subcategories*

Sample Calculation:

Total CH_4 emissions from enteric fermentation from Indigenous Cattle are:

Total CH_4 emissions = Emissions (Indigenous Dairy Cattle) + Emissions (Indigenous Non Dairy Cattle)

- ⇨ Total CH_4 emissions = (1) + (2)

[64] Source: India's Second National Communications to the UNFCCC, 2004
[65] Using CAGR, livestock derived using 19th Livestock Census of India

⇨ Total CH_4 emissions = 1,347.95 GgCH_4 yr^{-1} + 2,315.81 Gg$CH_4$$yr^{-1}$
⇨ Total CH_4 emissions = 3,662.76 GgCH_4 yr^{-1}

3. IPCC equation 10.21, Emission Factor for Enteric Fermentation

$$EF = \frac{[GE \cdot Y_m \cdot 365]}{55.65}$$

Where,

EF = *Emission factor (Kg methane / animal / year),*
GE = *Gross energy intake (MJ[66] / animal / year),*
Y_m = *Methane conversion rate which is the fraction of gross energy feed converted to methane*

Sample Calculation:
For indigenous dairy cattle in India, dry matter intake is approximately 2%[67]. Average body weight of indigenous dairy cattle is 175 kg. The conversion factor (CF) used for arriving at GE is 18.45 MJ/kg feed. These factors are used to calculate Gross Energy Intake.
Now,
GE = 60.99 MJ/animal/year
Y_m = 6%[68]
Therefore,

⇨ EF = (60.99 x 6% x 365)/(55.65)
⇨ EF = 24 Kg CH_4/animal/year

4. IPCC equation 10.22, Emission Estimation from Manure Management

$$CH_{4_{Manure}} = \sum_{(T)} \frac{\left(EF_{(T)} \cdot N_{(T)}\right)}{10^6}$$

Where,

$CH_{4_{Manure}}$ = *methane emissions from Manure Management, Gg CH_4 yr^{-1}*
$EF_{(T)}$ = *emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}*
$N_{(T)}$ = *the number of head of livestock species/category T in the country*
T = *species/category of livestock*

Sample Calculation:
Considering methane emissions from manure management for indigenous dairy cattle in year 2013,
T = Indigenous Dairy Cattle

[66] Assumed to be 18.45
[67] Swamy and Bhattacharya (2006)
[68] Swamy and Bhattacharya (2006)

$EF^{69}{}_{(Indigenous\ Dairy\ Cattle)}$ = 3.50 kg CH_4 $head^{-1}$ yr^{-1}
$N_{(Indigenous\ Dairy\ Cattle)}$ = 4,81,41,000[70]

- ⇨ Emissions = 3.5 * (4,81,41,000)/10^6
- ⇨ Emissions = 168.50 Gg CH_4 yr^{-1}……………………………………………………………………(3)
- ⇨ Similarly, using the same equation, emissions from Indigenous Non-Dairy Cattle are 233.14 GgCH_4yr^{-1}…………………………………………………………………………………(4)

Total CH_4 emissions (manure) = Manure Management Emissions (Indigenous Dairy Cattle) + Manure Management Emissions (Indigenous Non Dairy Cattle)

- ⇨ Total CH_4 emissions (manure) = (3) + (4)
- ⇨ Total CH_4 emissions (manure) = 168.50 GgCH_4 yr^{-1} + 233.14 GgCH_4yr^{-1}
- ⇨ Total CH_4 emissions = 401.64 GgCH_4 yr^{-1}

5. IPCC equation 10.25[71], Emission Estimation from Manure Management

$$N_2O_{animals} = N_2O_{AWMS} = N_T \cdot (N_{ex(T)} \cdot AWMS_T \cdot EF_{3(AWMS)})$$

Where,

$N_2O_{animals}$ = N_2O emissions from animal production in a country (kg N/ yr)
N_2O_{AWMS} = N_2O emissions from Animal Waste Management System in the country (kg N/ yr);
N_T = number of animals of type T in the country
$N_{ex(T)}$ = N excretion of animals of type T in the country (kg N/animal/yr)
$AWMS_T$ = fraction of $N_{ex(T)}$ that is managed in one of the different distinguished animal waste management systems for animals of type T in the country
$EF_{3(AWMS)}$ = N_2O emission factor for an AWMS (kg N_2O -N/ kg of N_{ex} in AWMS)
T = type of animal category

Sample Calculation:

Nitrogen emissions from manure management are calculated using the above equation. However, under this exercise, emission factor was obtained from India's second national communications to the UNFCCC. Therefore, the factors $(N_{ex(T)} \cdot AWMS_T \cdot EF_{3(AWMS)})$ are directly sourced from NATCOMM II.

Considering nitrous dioxide emissions from manure management for indigenous dairy cattle in year 2013,

Emission Factor = 0.0006 kgN_2O/head/year

69 Source: India's Second National Communications to the UNFCCC, 2004
70 Using CAGR, livestock derived using 19th Livestock Census of India
71 http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf - page 10.53

Population = N_T = 4,81,41,000[72]

⇨ $N_2O_{animals}$ = 0.0006 x 4,81,41,000
⇨ $N_2O_{animals}$ = 28,884 Gg N_2O

6. IPCC Equation 2.5, Emission Estimation from Land

Stock Difference Method

$$\Delta C = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$

Where,
ΔC *= Annual Carbon stock change in pool (tonnes C yr^{-1})*
C_{t_2} *= Carbon stock in the pool at time t_2*
C_{t_1} *= Carbon stock in the pool at time t_1*

Sample Calculation:
Assuming: t_2 = 2013
t_1 = 2011

C_{t_2} = 7044[73] MtC ……………………………………………………………..………….. (5)

C_{t_1} = 6941[74] MtC ……………………………….....………………………………………. (6)

Therefore, ΔC = ((5)-(6))/(2013-2011)
⇨ ΔC = (7044 – 6941)/(2013-2011) MtC
⇨ ΔC = -51.50 MtC

7. IPCC Equation 2.25 , Emission Estimation from Land

$$\Delta C_{mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

$$SOC = \sum_{C,S,I} SOC_{REF_{C,S,I}} \cdot F_{LU_{C,S,I}} \cdot F_{MG_{C,S,I}} \cdot F_{I_{C,S,I}} \cdot A_{C,S,I}$$

where,
$\Delta C_{mineral}$ *= annual change in carbon stocks in mineral soils, tonnes C yr^{-1}*

72 Using CAGR, livestock derived using 19th Livestock Census of India
73 State of Forest Report 2015
74 State of Forest Report 2013

SOC_0 = *soil organic carbon stock in the last year of an inventory time, tonnes C*
$SOC_{(0-T)}$ = *soil organic carbon stock at the beginning of the inventory time, tonnes C*

SOC_0 *and* $SOC_{(0-T)}$ *are calculated using the SOC equation in the box where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T)*

D = *Time Dependence, 20 years*
C = *represents the climate zones, S the soil types, and I the set of management systems that are present in a country.*
SOC_{REF} = *the reference carbon stock, tonnes C ha-1*
F_{LU} = *stock change factor for land-use systems or sub-system for a particular land-use, dimensionless*
F_{MG} = *stock change factor for management regime, dimensionless*
F_I = *stock change factor for input of organic matter, dimensionless*
A = *land area of the stratum being estimated, ha. All land in the stratum should have common biophysical conditions (i.e., climate and soil type) and management history over the inventory time to be treated together for analytical purposes*
Sample Calculation:

Considering Land use category 'Grassland remaining grassland' in Andhra Pradesh

$SOC_{(0-T)}$[75] = 38 tC/ha…………………………………………………………………………(7)
F_{LU}[76] = 1
F_{MG}[77] = 0.97
F_I[78] = 1

Considering Area = 1 hectare for grassland remaining grassland in Andhra Pradesh,

$$SOC_{(0)} = \sum_{C,S,I} SOC_{REF_{C,S,I}} \cdot F_{LU_{C,S,I}} \cdot F_{MG_{C,S,I}} \cdot F_{I_{C,S,I}} \cdot A_{C,S,I}$$

⇨ $SOC_{(0)}$ = 38 x 1 x 0.97 x 1 x 1
⇨ $SOC_{(0)}$ = 36.86 tC/ha…………………………………………………………………………….(8)

Now,

$$\Delta C_{mineral} = \frac{(SOC_0 - SOC_{(0-T)})}{D}$$

[75] 0 = Grassland; Source: Rao S. (2016)
[76] Considering Level = All as per IPCC 2006 Guidelines, Volume 4, Chapter 6
[77] Considering Level = Moderately degraded as per IPCC 2006 Guidelines, Volume 4, Chapter 6; FMG for tropical = 0.97, FMG for tropical montane = 0.96
[78] Considering Level of Input = Medium as per IPCC 2006 Guidelines, Volume 4, Chapter 6

Therefore, from (7) & (8)

$\Delta C_{mineral}$ = {(8) – (7)}/20

⇨ $\Delta C_{mineral}$ = {36.86 – 38}/20

⇨ $\Delta C_{mineral}$ = -0.06 tC/ha/year

8. IPCC Equation 2.27, Emission Estimation from Biomass Burning

$$L_{fire} = A \cdot M_B \cdot C_f \cdot G_{ef} \cdot 10^{-3}$$

Where,

L_{fire} *= amount of greenhouse gas emissions from fire, tonnes of each GHG e.g.,* CH_4, N_2O, *etc.*

A = area burnt, ha

M_B *= mass of fuel available for combustion, tonnes ha-1. This includes biomass, ground litter and dead wood.*

C_f *= combustion factor, dimensionless*

G_{ef} *= emission factor, g kg-1 dry matter burnt*

Sample Calculation:

Consider biomass burning[79] in Indian Forests in year 2013.

Area burnt in year 2013 (in ha) = A = 3,04,679

Mass of fuel available for combustion (in t/ha) = 13.12

Combustion Factor = 0.36

Emission factor for methane gas (g/kg dry matter burnt) = 9

Emission factor for nitrous dioxide gas (g/kg dry matter burnt) = 0.11

Therefore,

Methane emissions from biomass burning can be calculated as:

⇨ L_{fire} = (3,04,679 x 13.12 x 0.36 x 9)/1000

⇨ L_{fire} = 12,760 tonnes of methane

Similarly, nitrous oxide emissions from biomass burning are 155.9 tonnes of N2O.

9. Equation used for Biomass Burning in cropland[80]

$$FBCR = \sum Crops(A \cdot B \cdot C \cdot D \cdot E \cdot F)$$

Where,

FBCR is the emissions from residue burning,

A is the crop production,

B is the residue to crop ratio,

C is the dry matter fraction,

D is the fraction burnt

E is the fraction oxidized,

F is the emission factor for CH_4 *and* N_2O

[79] Note: Source for all the data in this calculation is from India's Second National Communications.

[80] Bhatia et al. (2013); http://onlinelibrary.wiley.com/doi/10.1002/ghg.1339/full

Sample Calculation:

Consider Residue burning in rice field in Punjab for year 2013,

Rice Production in year 2013 in Punjab ('000 tonnes) = A = 11,294
Residue to Crop Ratio[81] = B = 1.50
Dry Matter Fraction[82] = C = 0.86
Fraction Burnt[83] = D = 0.80
Combustion Factor[84] = E = 0.89
Emission Factor for CH_4[85] = F = 2.70 g/kg

Therefore,

Emissions from Residue Burning in Punjab's Rice fields =

- ⇨ FBCR = A * B * C * D * E * F
- ⇨ FBCR = (11,294 x 1.50 x 0.86 x 0.80 x 0.89 x 2.70)/1000
- ⇨ FBCR = 28.007 Gg
- ⇨ FBCR = 28,007.94 tCH_4

10. Equation used for emission estimation from Rice Cultivation[86]

$$E_{RC} = A_C \cdot EF_W \cdot 10^{-6}$$

Where,

E_{RC} = CH_4 emissions from rice cultivation (Gg CH_4 $year^{-1}$),
A_C = area of rice cultivation under management C (ha)
EF_W = emission factor applied for different types of water management (kg CH_4 ha^{-1})
10^{-6} = to convert Kg into Gg

Sample Calculation

Consider rice cultivation in Punjab in year 2013 and intermittent multiple aeration water management is used in Punjab.
Therefore, area of rice cultivation under intermittent multiple aeration management in Punjab in 2013 (in '000 ha) = A_C = 2,837
Emission Factor for intermittent multiple aeration management[87] = EF_W = 18 kg CH_4/ha
Hence,

- ⇨ E_{RC} = (2,837 * 18)/1000
- ⇨ E_{RC} = 51.06 Gg CH_4/year

[81] Jain et al. (2014)
[82] Jain et al. (2014)
[83] Calculations based on data from Gadde et al. (2009)
[84] Turn et al. (1997)
[85] Andrea and Merlot (2001)
[86] Gupta et al. (2009) and Pathak et al. (2010)
[87] India's Second National Communications to the UNFCCC