



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

2005-2013



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## Credits and Acknowledgments

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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 specially 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 <sub>4</sub>	Methane
CO <sub>2</sub>	Carbon Dioxide
EF	Emission Factor
FSI	Forest Survey of India
GHG	Green House Gas
Gol	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 <sub>2</sub> O	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

<b>Version</b>	<b>Date</b>	<b>Description</b>
<b>I.0</b>	28 <sup>th</sup> September 2017	<i>This draft methodology note includes an estimation and analysis of India's annual state-level GHG emissions for the period 2005-2013 for the AFOLU Sector, prepared by Vasudha Foundation under the GHG Platform India initiative (<a href="http://www.ghgplatform-india.org">www.ghgplatform-india.org</a>).</i>
<b>I.1</b>	17 <sup>th</sup> November 2017	<i>This draft methodology note includes an estimation and analysis of India's annual state-level GHG emissions for the period 2005-2013 for the AFOLU Sector, prepared by Vasudha Foundation under the GHG Platform India initiative (<a href="http://www.ghgplatform-india.org">www.ghgplatform-india.org</a>).</i>
<b>I.2</b>	15 <sup>th</sup> May 2018	<i>Finalised Document with updated Verification Section</i>

## 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<sub>2</sub>e (~7% of the total economywide emissions) to the emissions of India in 2013. The major contributing key sources categories of emissions from AFOLU sector are livestock and rice cultivation. Land use, as a whole, is a net sink, primarily due to CO<sub>2</sub> removals by forests in India. Table I Overview of Emissions from AFOLU sector in 2005 and 2013 gives details of emissions from this sector in the year 2005 and 2013.

*Table I Overview of Emissions from AFOLU sector in 2005 and 2013<sup>1</sup>*

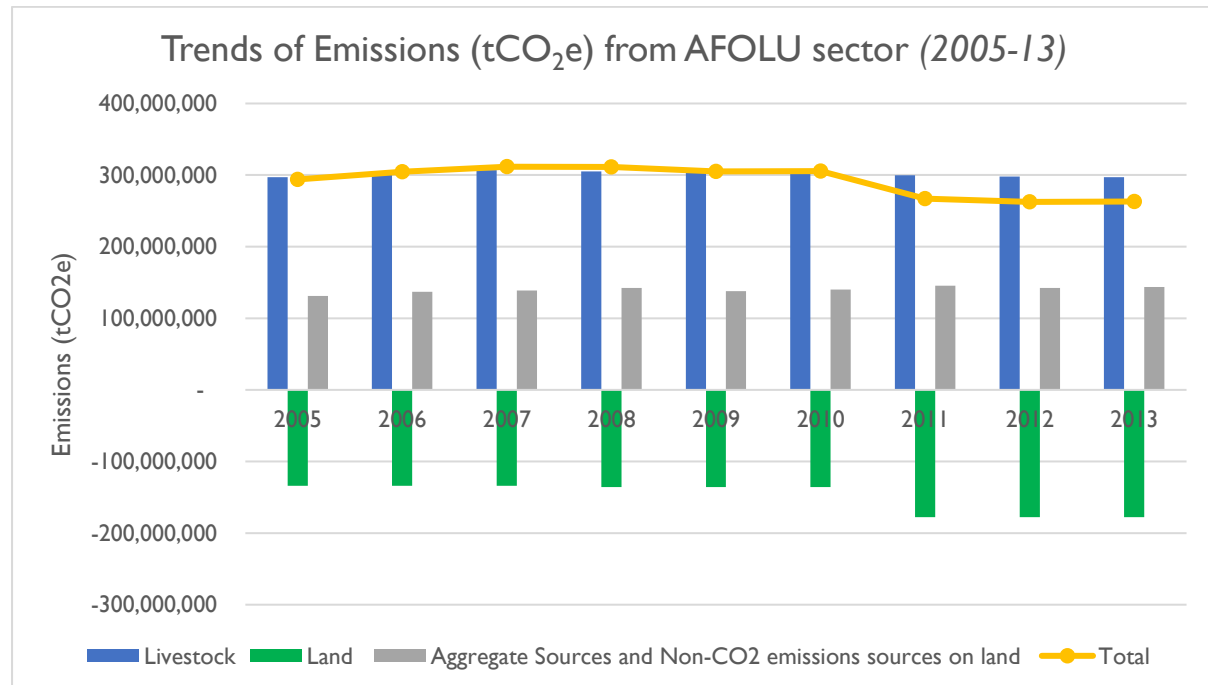
IPCC Code	Sector/ Sub-sector	Emissions in 2005 (in million tCO <sub>2</sub> e) AR2 GWP	Emissions in 2013 (in million tCO <sub>2</sub> e) AR2 GWP	Percentage change in Emissions	Emissions in 2005 (in million tCO <sub>2</sub> e) AR5 GWP	Emissions in 2013 (in million tCO <sub>2</sub> e) AR5 GWP	Percentage 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 <sub>2</sub> 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%

<sup>1</sup> Please refer to AFOLU sector file, worksheet 'Summary'

<b>IPCC Code</b>	<b>Sector/ Sub-sector</b>	<b>Emissions in 2005 (in million tCO<sub>2</sub>e) AR2 GWP</b>	<b>Emissions in 2013 (in million tCO<sub>2</sub>e) AR2 GWP</b>	<b>Percentage change in Emissions</b>	<b>Emissions in 2005 (in million tCO<sub>2</sub>e) AR5 GWP</b>	<b>Emissions in 2013 (in million tCO<sub>2</sub>e) AR5 GWP</b>	<b>Percentage change in Emissions</b>
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 <sub>2</sub> O emissions from managed soils	29.95	40.27	34.45%	25.60	34.42	34.45%
3C5	Indirect N <sub>2</sub> O emissions from managed soil	7.59	10.21	34.45%	6.49	8.73	34.45%
3C6	Indirect N <sub>2</sub> O 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, the GHG emissions from this sector have decreased, primarily due to increased removals of CO<sub>2</sub> from the forests.

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



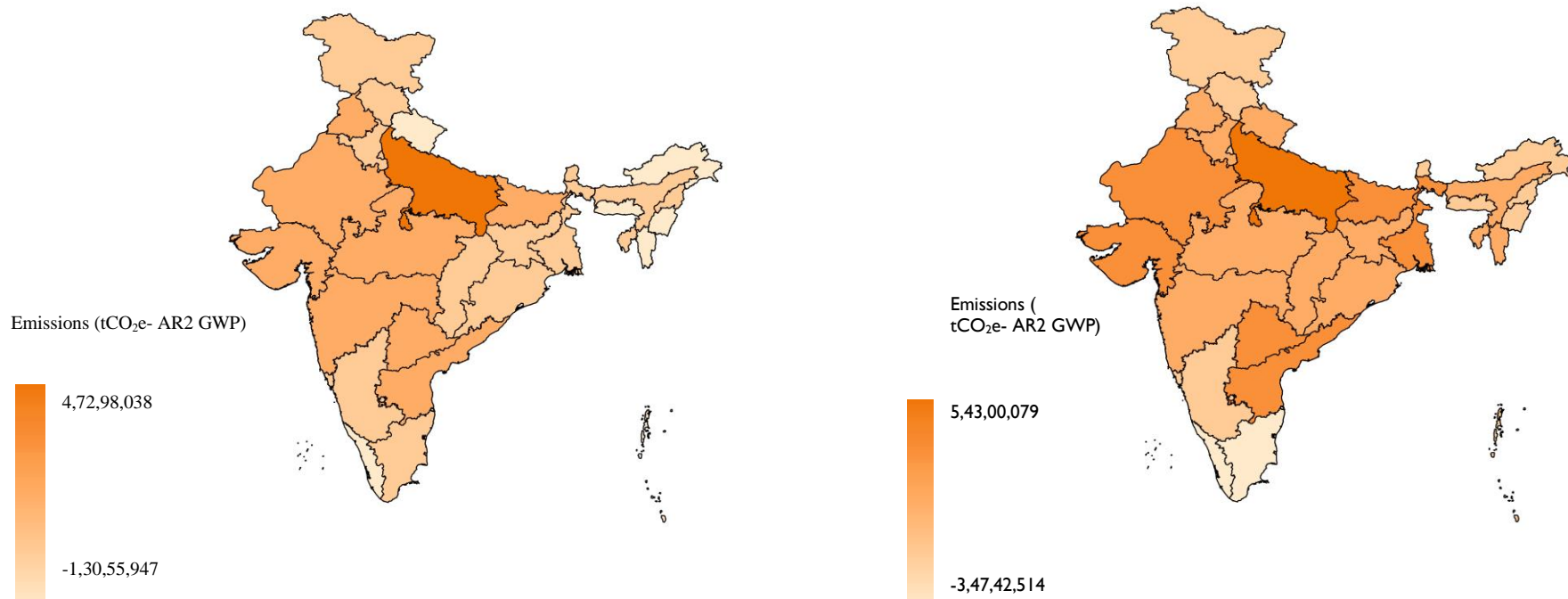
The major emitting sub-sectors in the AFOLU sector (without Land Use, Land Use Change and Forestry (LULUCF) sector) are enteric fermentation contributing to almost 58% emissions followed by rice cultivation with 20% contribution in the year 2013. The other sub-sectors are very small contributors to the emissions from AFOLU in the same year.

Top states with maximum emissions from the AFOLU sector in year 2005 and 2013 are as follows:

Table 2 State-wise Emission estimates in year 2005 and 2013

State/Union Territory with maximum emissions in 2005	Emissions in 2005 (million tCO <sub>2</sub> e)	Percentage Share in Total AFOLU Emissions (2005)	State/Union Territory with maximum emissions in 2013	Emissions in 2013 (million tCO <sub>2</sub> e)	Percentage Share in Total AFOLU Emissions (2013)
Uttar Pradesh	47.30	24%	Uttar Pradesh	54.30	31%
Rajasthan	22.08	11%	Andhra Pradesh	27.58	16%
Andhra Pradesh	20.99	11%	Rajasthan	25.61	15%
Bihar	19.57	10%	Bihar	24.38	14%
Maharashtra	16.29	8%	West Bengal	21.22	12%
Madhya Pradesh	15.77	8%	Gujarat	20.07	12%
Gujarat	15.10	8%	Maharashtra	15.95	9%
Rest of India	41.52	21%	Rest of India	-15.34	-9%

Figure 1. State-wise emission estimates from India in 2005 and 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 and/or state 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. The platform seeks to add value to the 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<sub>2</sub>), Methane (CH<sub>4</sub>) and Nitrous Oxide (N<sub>2</sub>O) with total carbon dioxide equivalent (CO<sub>2</sub>e) 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<sub>2</sub> emissions sources on land
  - 3C1a. Emissions from biomass burning in forests
  - 3C1b. Emissions from biomass burning in croplands
  - 3C4. Direct N<sub>2</sub>O emissions from managed soils
  - 3C5. Indirect N<sub>2</sub>O 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<sub>2</sub>O emissions from Manure Management



Emission estimates are being provided for the period CY2005- CY2013. Activity data for the agriculture sector is available for the fiscal year i.e. April-March. However, this data has been converted into calendar year by assuming that 1/4<sup>th</sup> of the emissions of the previous fiscal year and 3/4<sup>th</sup> of the emissions of the current fiscal year are equal to 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 Nationally Determined Contributions, 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 all years 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.

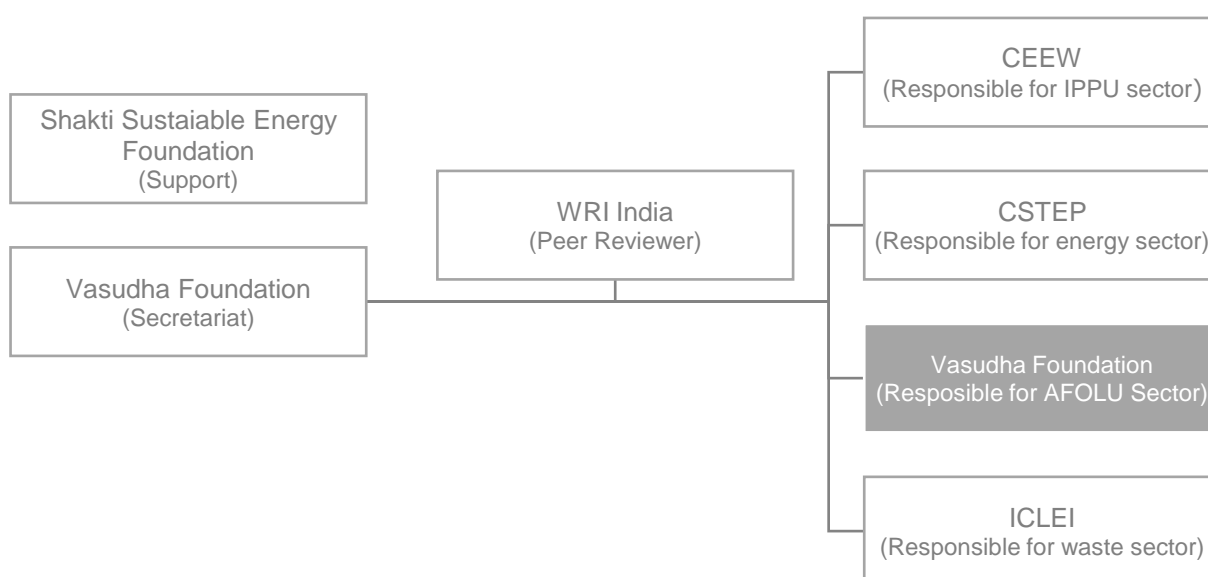


Figure 2 Institutional Arrangement of GHG Platform India

**Registered Address:**

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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](mailto:chirag.gajjar@wri.org)

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**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 guidelines for

national GHG inventories<sup>2</sup> (hereafter referred as IPCC guidelines). The estimates arrived at by the platform have been reviewed by the external experts that were engaged 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 shall be available for open access on [www.ghgplatform-india.org](http://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<sub>2</sub> emission sources on land, standard methods described in 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 case of the later, reasonable assumptions were made in consultation with the experts associated with this exercise as well as based on 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 defaults 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 3 Overview of activity data for AFOLU sector*

IPC C ID	NAME OF SECTOR	PRINCIPAL DATA SOURCE	PRINCIPAL COLLECTION MECHANISM
3A1	Enteric Fermentation	Livestock Census of India for 2007 and 2012	<ul style="list-style-type: none"> <li>Activity Data derived from Livestock Census of India from <u>Ministry of Agriculture</u></li> </ul>

<sup>2</sup> <http://www.ipcc-nggip.iges.or.jp/public/2006gl>

<b>3A2</b>	Manure Management	Livestock Census of India for 2007 and 2012	<ul style="list-style-type: none"> <li>Activity Data derived from Livestock Census of India from <u>Ministry of Agriculture</u></li> </ul>
<b>3B1</b>	Forest Land	Forest Survey of India, Dehradun	<ul style="list-style-type: none"> <li><u>Forest Survey of India, Dehradun</u></li> </ul>
<b>3B2</b>	Cropland	National Remote Sensing Centre, Hyderabad	<ul style="list-style-type: none"> <li>National Remote Sensing Centre<sup>3</sup>, Hyderabad</li> </ul>
<b>3B3</b>	Grassland	National Remote Sensing Centre, Hyderabad	<ul style="list-style-type: none"> <li>National Remote Sensing Centre<sup>4</sup>, Hyderabad</li> </ul>
<b>3B5</b>	Settlements	National Remote Sensing Centre, Hyderabad	<ul style="list-style-type: none"> <li>National Remote Sensing Centre<sup>5</sup>, Hyderabad</li> </ul>
<b>3B6</b>	Other land	National Remote Sensing Centre, Hyderabad	<ul style="list-style-type: none"> <li>National Remote Sensing Centre<sup>6</sup>, Hyderabad</li> </ul>
<b>3C1a</b>	Biomass Burning in Forest Land	Forest Survey of India, Dehradun	<ul style="list-style-type: none"> <li><u>Forest Survey of India, Dehradun</u></li> </ul>
<b>3C1b</b>	Biomass Burning in Cropland	Quantity of residue generated derived as a ratio of production. Quantity of residues burnt derived based on scientific studies	<ul style="list-style-type: none"> <li>Activity Data derived from <u>Ministry of Agriculture</u></li> <li>Residue to crop ratio derived from <u>Bandyopadhyay et. al. 2001</u></li> <li>Ratio of burning of rice straw derived from <u>Gadde et. al. 2009</u></li> <li>Ratio of burning of other crop residues derived from <u>Jain et. al. 2014</u></li> <li>Combustion factors of different residues taken from <u>Turn et. al. (1997)</u>, <u>Streets et. al. 2003</u>, and <u>Jain et. al. 2014</u></li> </ul>
<b>3C4</b>	Direct N <sub>2</sub> O emissions from managed soils	Fertilizer consumption data	<ul style="list-style-type: none"> <li>Activity Data derived from Fertiliser Association of India (Available in soft copy)</li> </ul>
<b>3C5</b>	Indirect N <sub>2</sub> O emissions from managed soils	Fertilizer consumption data	<ul style="list-style-type: none"> <li>Activity Data derived from Fertiliser Association of India (Available in soft copy)</li> </ul>
<b>3C7</b>	Rice Cultivation	Directorate of Economics and Statistics, Department	<ul style="list-style-type: none"> <li>Activity Data derived from <u>Ministry of Agriculture</u></li> </ul>

<sup>3</sup> Land Use Change Matrix available on request from National Remote Sensing Centre, Hyderabad<sup>4</sup> Land Use Change Matrix available on request from National Remote Sensing Centre, Hyderabad<sup>5</sup> Land Use Change Matrix available on request from National Remote Sensing Centre, Hyderabad<sup>6</sup> Land Use Change Matrix available on request from National Remote Sensing Centre, Hyderabad

		of Agriculture, Cooperation and Farmer's Welfare, Government of India	
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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<sub>2</sub> 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<sub>2</sub>O Emissions from Manure Management

3D Other

#### Brief description of key source categories

The key sources of emissions for this sector are enteric fermentation and rice cultivation, which together account for around half of the emissions from agriculture. 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 calculated 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).<sup>7</sup>

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<sup>7</sup> <http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html>

### 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

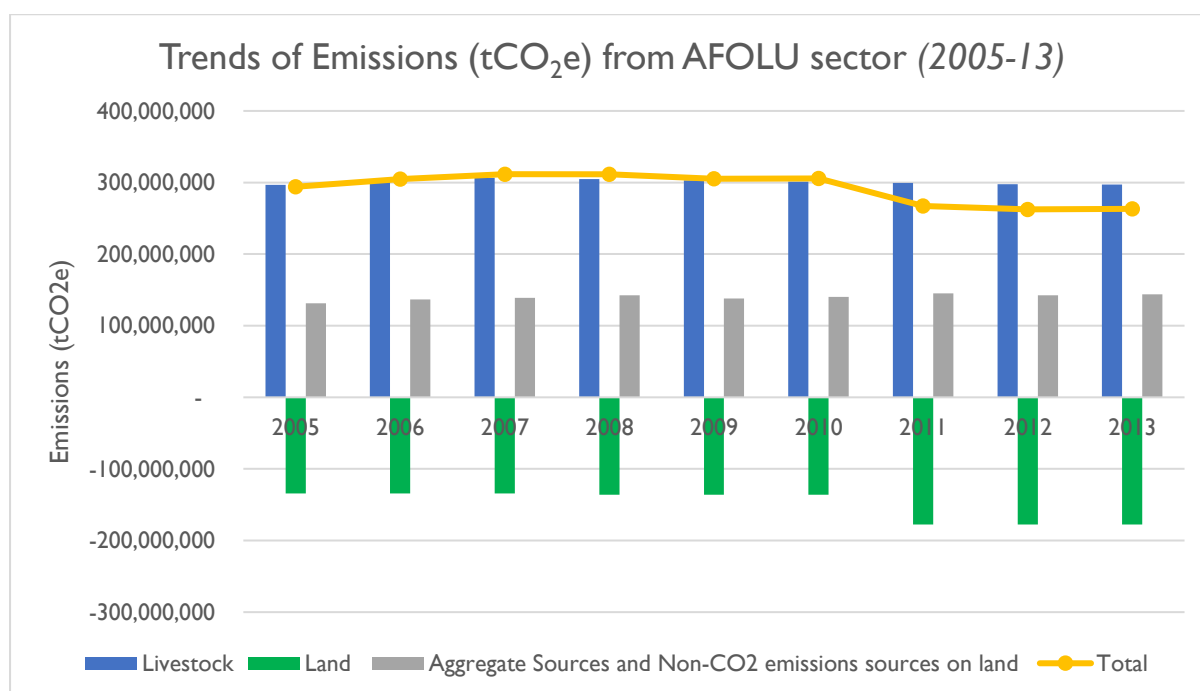
3C6. Indirect N<sub>2</sub>O emissions from Manure Management

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



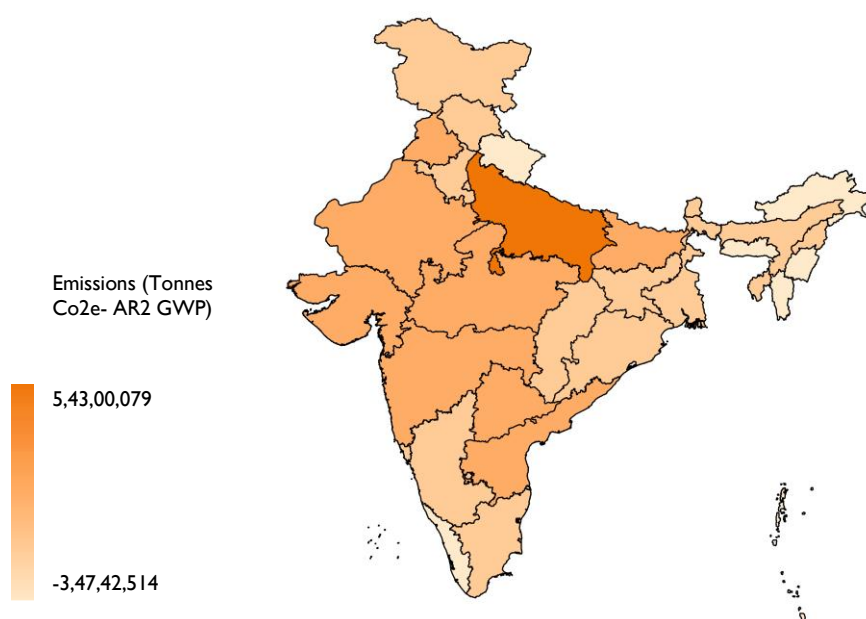
**Figure 3 Trends of Emissions from AFOLU Sector**

The above graph shows that the total emissions from AFOLU sector followed a linear trend from 2005-13. There was a marginal decrease of approximately 40 Million tCO<sub>2</sub>e in total emissions from 2010 (214 Million tCO<sub>2</sub>e) to 2011 (174 Million tCO<sub>2</sub>e). This decrease can be attributed to increase in absorption of GHGs from India's forests.

States with maximum emissions from the AFOLU sector in year 2005 and 2013 are as follows:

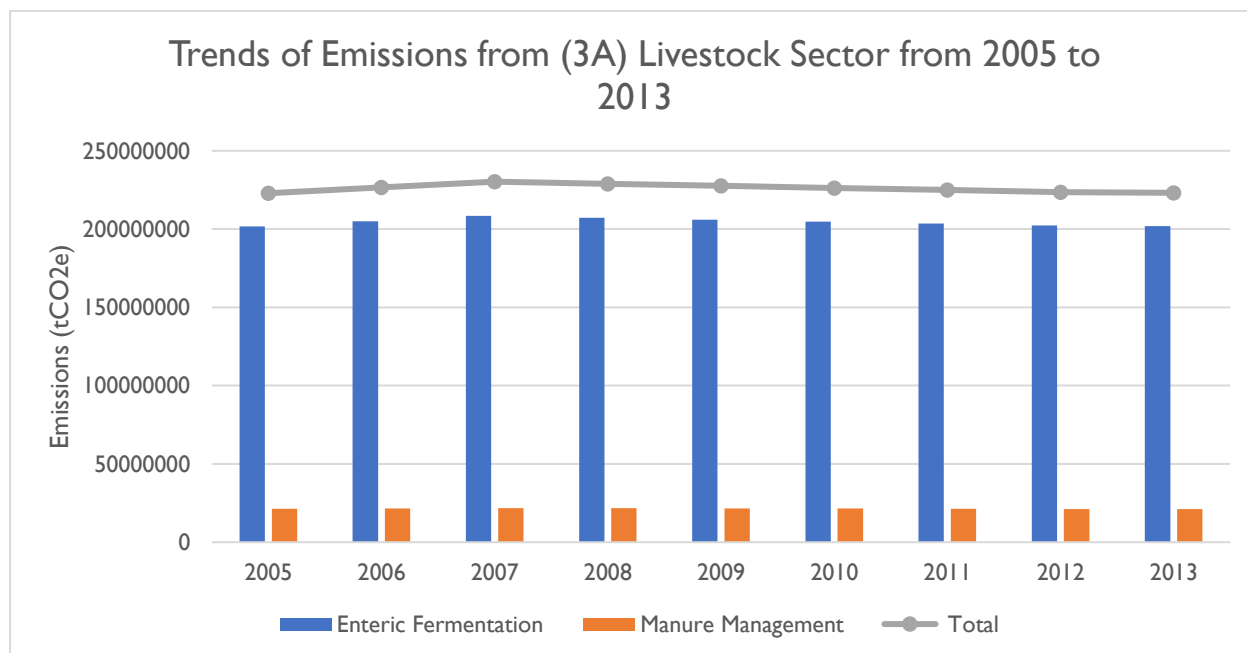
**Table 4 State-wise Emission estimates in year 2005 and 2013**

State/Union Territory with maximum emissions in 2005	Emissions in 2005 (million tCO <sub>2</sub> e)	Percentage Share in Total AFOLU Emissions (2005)	State/Union Territory with maximum emissions in 2013	Emissions in 2013 (million tCO <sub>2</sub> e)	Percentage Share in Total AFOLU Emissions (2013)
Uttar Pradesh	47.30	24%	Uttar Pradesh	54.30	31%
Rajasthan	22.08	11%	Andhra Pradesh	27.58	16%
Andhra Pradesh	20.99	11%	Rajasthan	25.61	15%
Bihar	19.57	10%	Bihar	24.38	14%
Maharashtra	16.29	8%	West Bengal	21.22	12%
Madhya Pradesh	15.77	8%	Gujarat	20.07	12%
Gujarat	15.10	8%	Maharashtra	15.95	9%
Rest of India	41.52	21%	Rest of India	-15.34	-9%



**Figure 4. India's AFOLU Sector Emissions Profile in 2013**

As seen above, maximum emissions are from the state of Uttar Pradesh. This is because Uttar Pradesh has a high density of livestock population contributing to maximum livestock emissions from the country. Also, the removals of emissions from Uttar Pradesh's forest sector are nearly 75,000 tCO<sub>2</sub>e, which is low compared to the other states.



**Figure 5 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



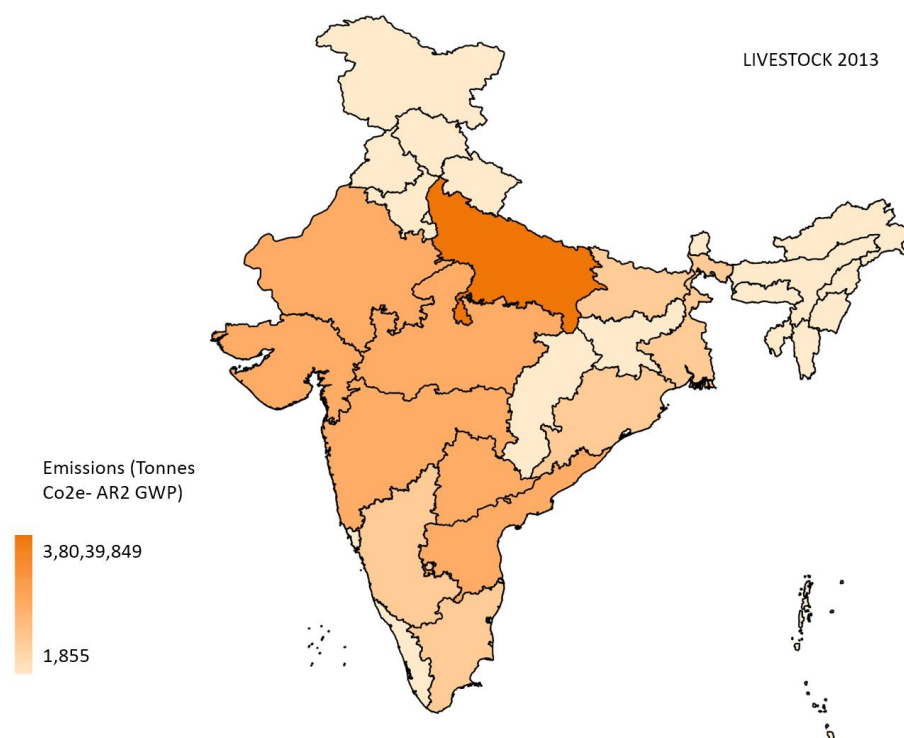
declined to 505 million in 2013.<sup>8</sup> The compound annual growth rate of population during the livestock census years (2007 and 2012) was -0.68%. The growth rate (CAGR) of emissions from this sector was 0.02% from 2005 to 2013.

At the state level analysis, following are the states with maximum emissions in year 2013 and their growth rate from 2005 to 2013 from the livestock sector:

Table 5. Livestock Sector Emissions Profile of Indian States

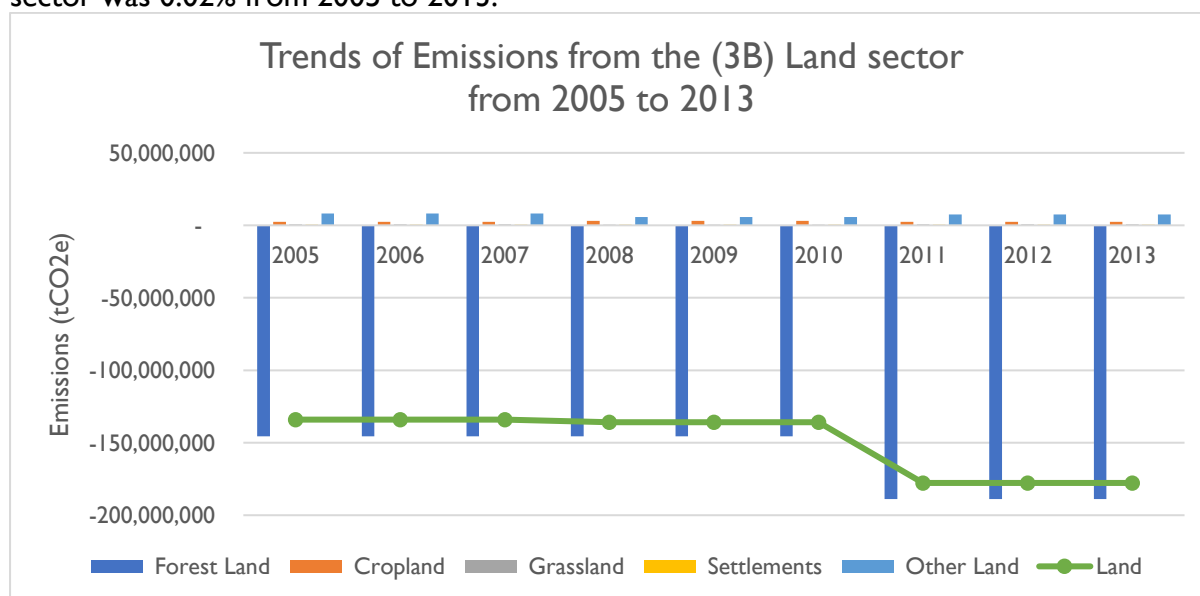
State/Union Territory with maximum emissions in 2013	Base year Emissions in 2005 (million tCO <sub>2</sub> e)	Final year Emissions in 2013 (million tCO <sub>2</sub> e)	CAGR (%)	Percentage Share in Total Livestock Emissions (2013)
Uttar Pradesh	30.86	38.04	3%	17%
Rajasthan	18.74	21.62	2%	10%
Madhya Pradesh	20.03	18.25	-1%	8%
Andhra Pradesh	19.50	17.73	-1%	8%
Maharashtra	17.23	15.88	-1%	7%
Gujarat	12.11	15.71	3%	7%
Bihar	13.08	14.96	2%	7%
West Bengal	11.46	10.81	-1%	5%
Karnataka	11.39	10.40	-1%	5%
Odisha	10.12	8.46	-2%	4%
Tamil Nadu	9.89	7.62	-3%	3%
Chhattisgarh	7.43	7.59	0%	3%
Assam	6.48	7.29	1%	3%
Jharkhand	7.11	7.26	0%	3%
Punjab	5.89	6.04	0%	3%
Haryana	5.67	5.82	0%	3%
Jammu and Kashmir	3.62	2.88	-3%	1%
Himachal Pradesh	2.37	2.23	-1%	1%
Rest of India	6.78	5.99	-2%	3%

<sup>8</sup> <http://dahd-archive.nic.in/dahd/statistics/livestock-census.aspx>



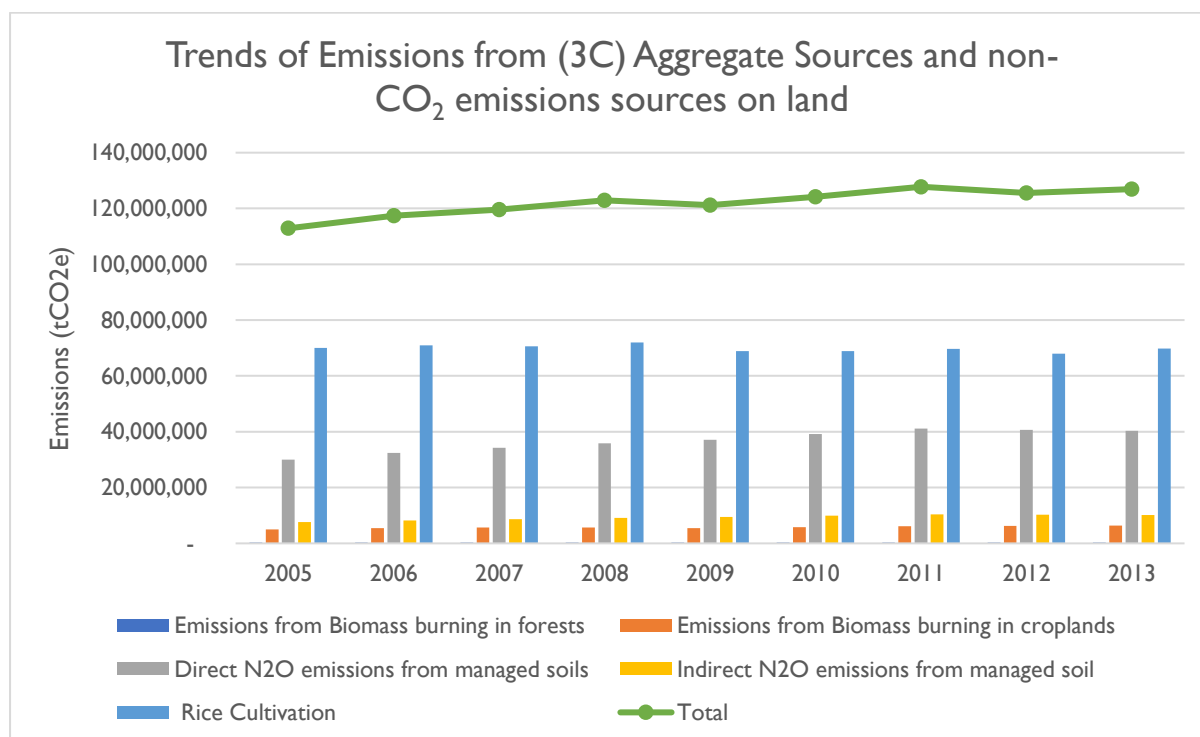
**Figure 6. India's Livestock Sector Emissions Profile in 2013**

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 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.



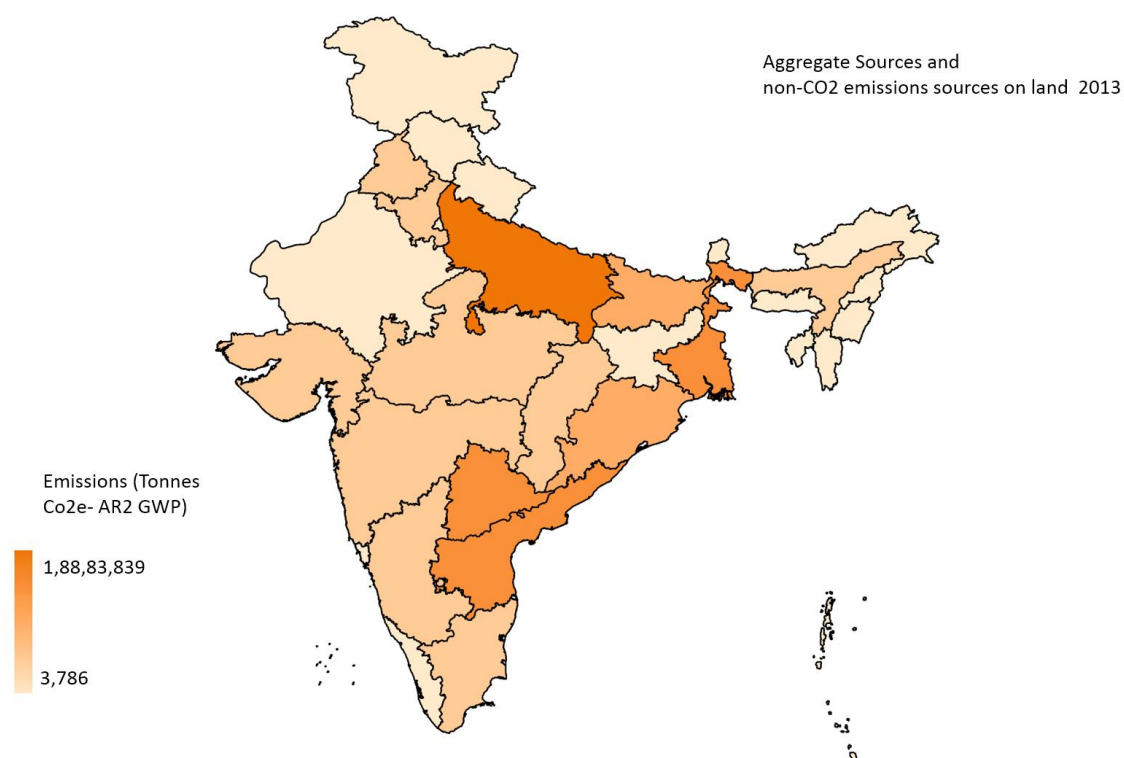
**Figure 7 Trends of Emissions from Land Sector**

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 tCO<sub>2</sub>e to -177.73 Million tCO<sub>2</sub>e 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 8 Trends of emissions from Aggregate sources and non-CO<sub>2</sub> emissions sources on land**

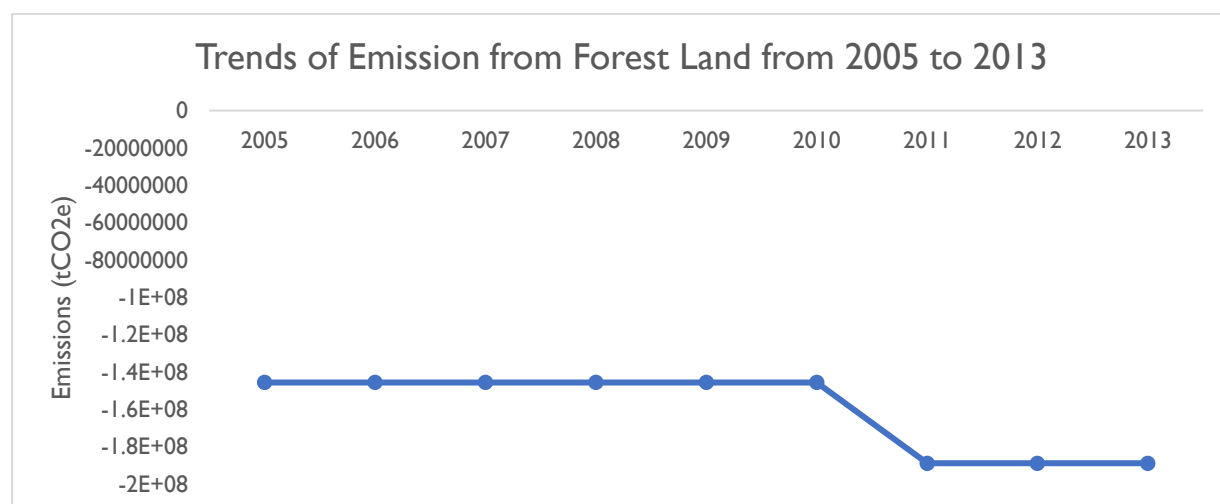
Emissions from the category (3C) aggregate sources and non-carbon dioxide emission sources on land have increased over the years. It observed a net growth of 13% and compound growth of 1.37%. Major contribution of emissions (~55%) in this category comes from rice cultivation followed by direct nitrous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



**Figure 9. India's Aggregate Sources and Non-CO2 emissions sources on Land Emissions in 2013**

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

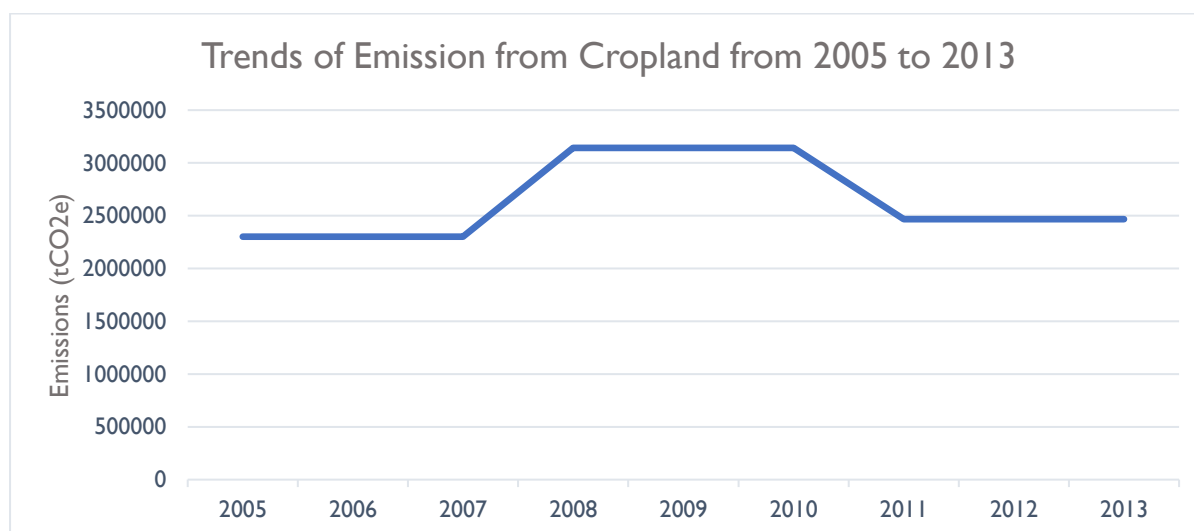
### 3B1 Forest Land



**Figure 10 Trends of emissions from Forest Land**

As per FSI<sup>9</sup>, 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 11 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<sup>10</sup>, the land use change from the categories cropland remaining cropland, and land converted to cropland increased from 2008-11. This further led to an 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%.

<sup>9</sup> <http://fsi.nic.in/isfr-2015/isfr-2015-growing-stock.pdf>

<sup>10</sup> NRSC Change Matrix is provided in a hard copy on request.

## 3B3 Grasslands

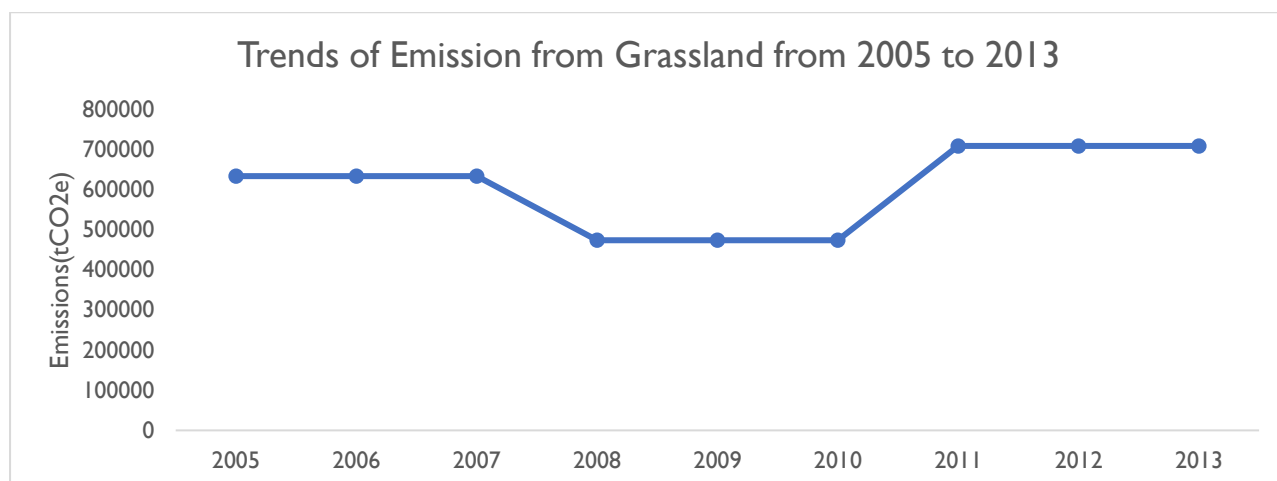


Figure 12 Trends of emissions from Grassland

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

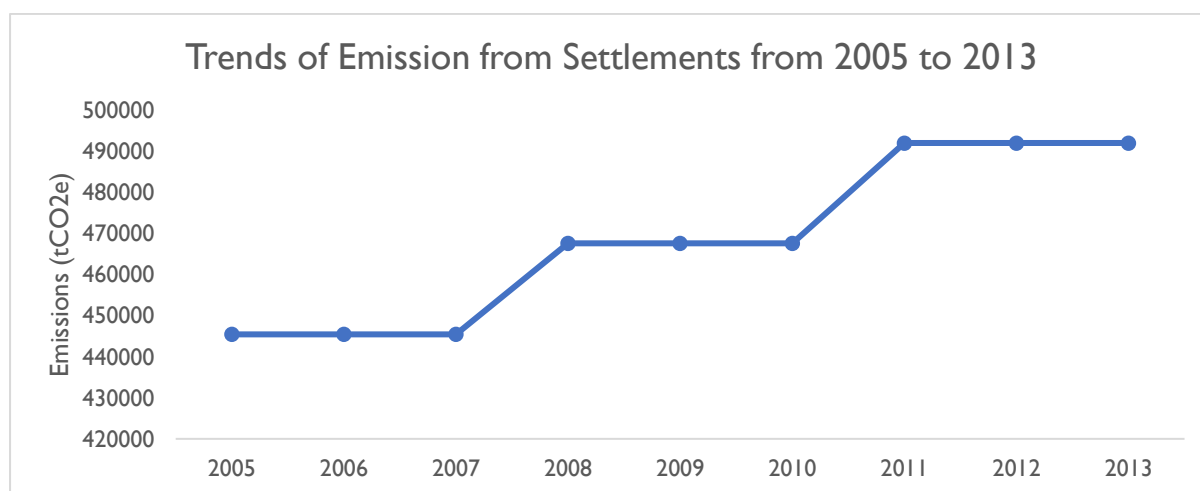
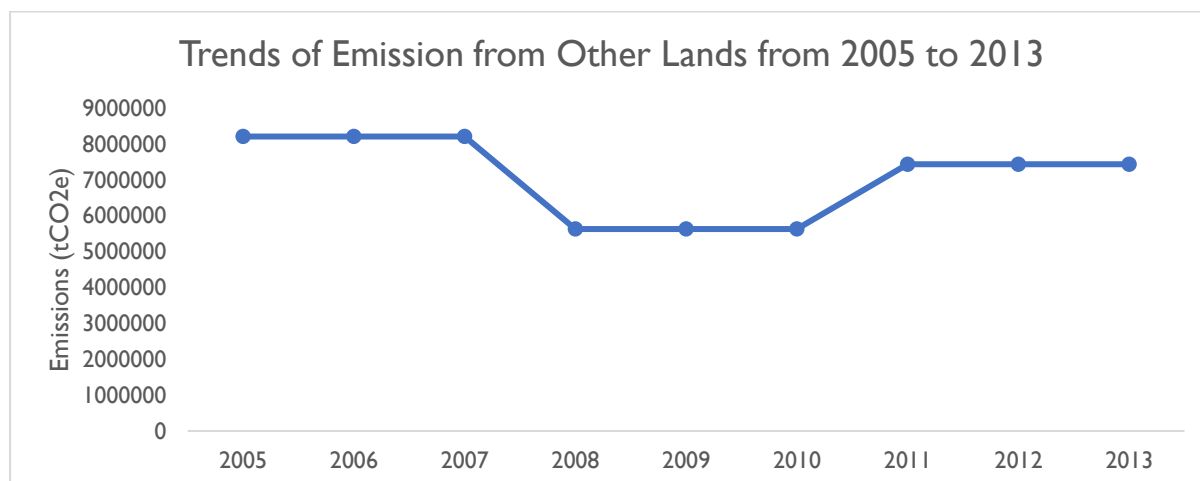


Figure 13 Trends of Emissions from Settlements

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

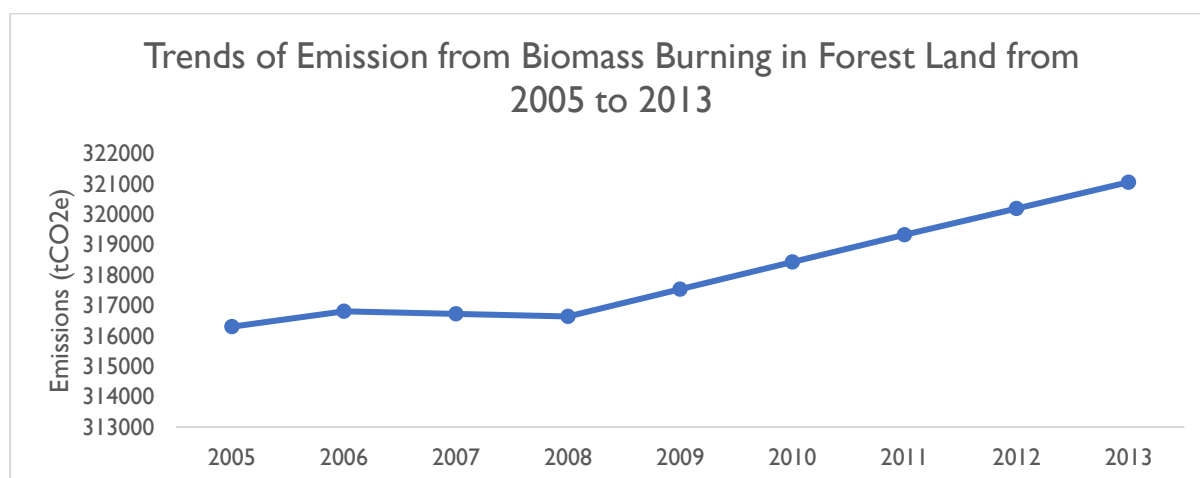
### 3B6 Other Lands



*Figure 14 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% for the reporting period.

### 3C1 Biomass Burning in Forest Land



*Figure 15 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% for the reporting period. The overall contribution of this sub-sector in the AFOLU sector is also negligible.

## 3C2 Biomass Burning in Croplands

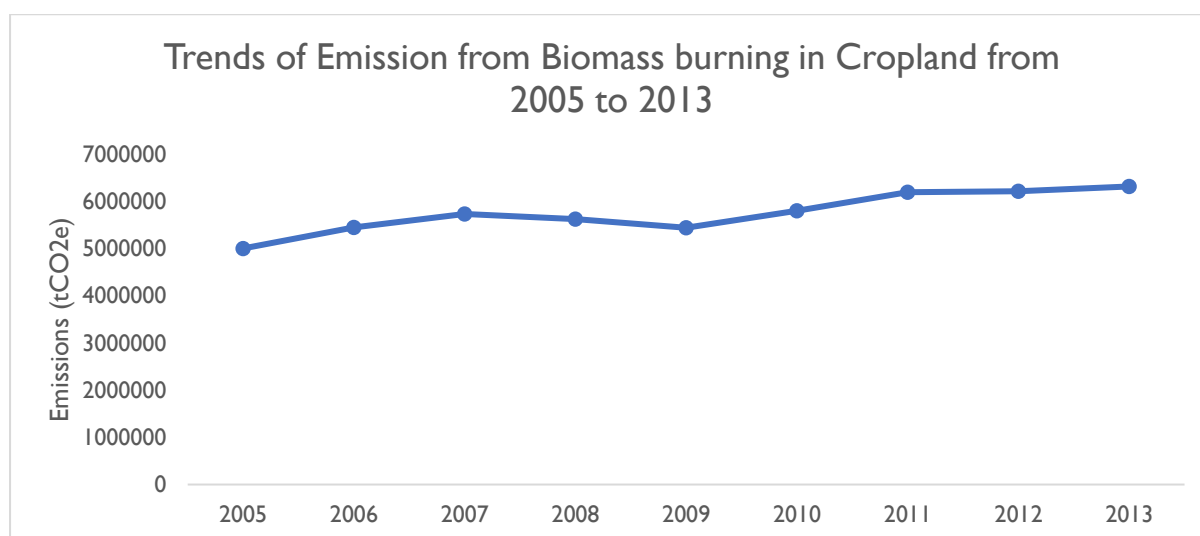


Figure 16 Trends of emission from biomass burning in cropland

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% for the reporting period.

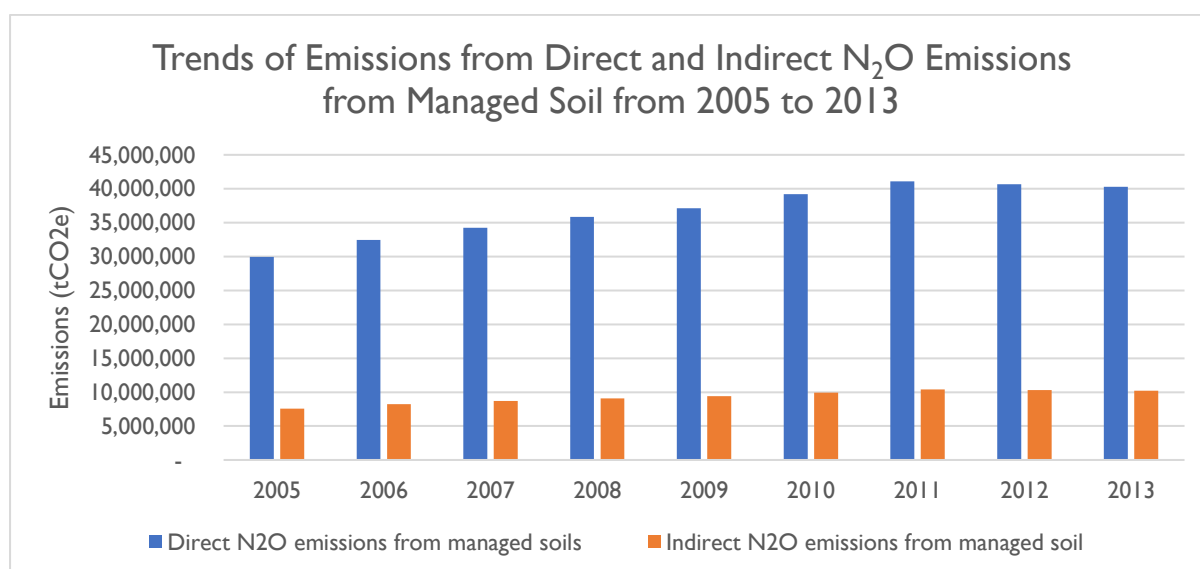
3C3 & 3C4 Direct and Indirect N<sub>2</sub>O Emissions from Managed Soils

Figure 17 Trends of emissions from direct and indirect N<sub>2</sub>O 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 for the reporting period.



## 3C5 Rice Cultivation

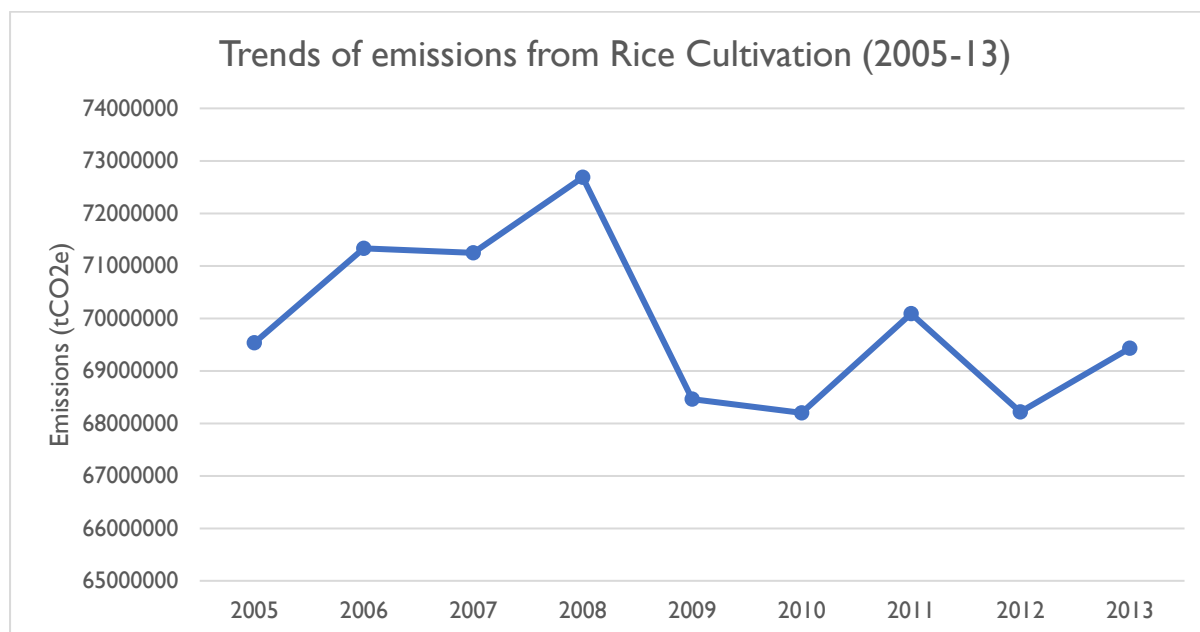


Figure 18 Trends of emission from rice cultivation

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

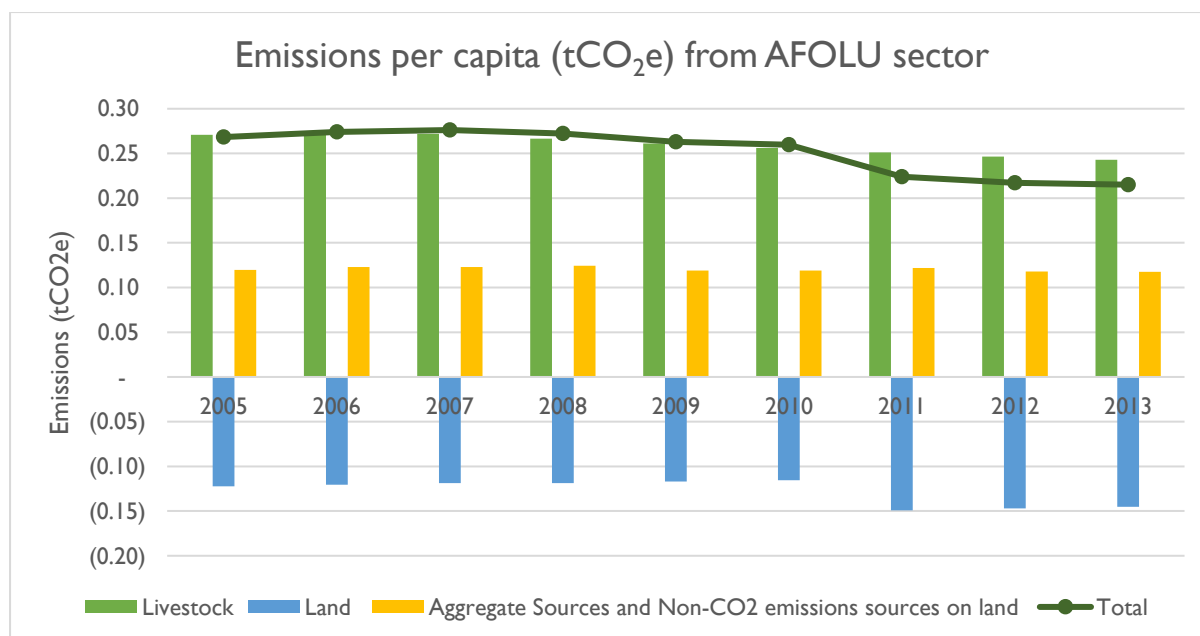
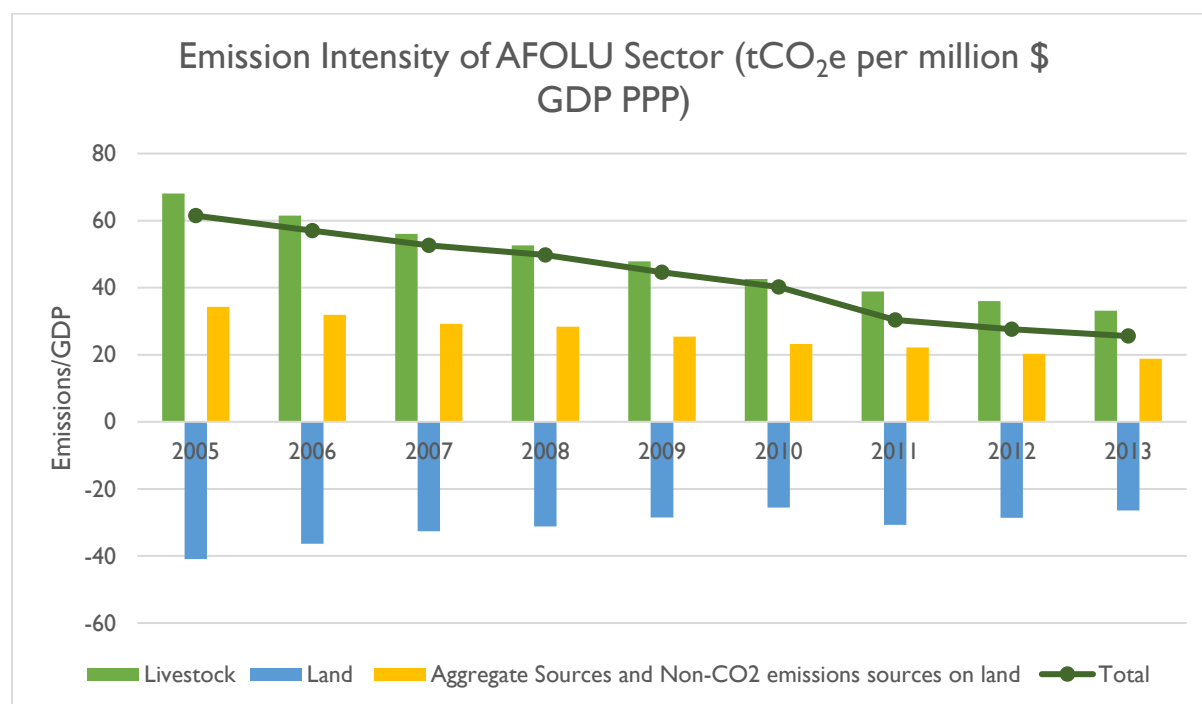


Figure 19 Trends of emission per capita population from AFOLU sector

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<sup>11</sup>).



**Figure 20 Trends of emissions intensity of AFOLU sector**

<sup>11</sup> <http://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GDP.PCAP.PP.KD&country=IND>

## 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 6 Overview of Emission Estimates from different gases.*

IPCC Code	Sector/ Sub-sector	Total Emissions from 2005 to 2013 (in million tonnes)			
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub> e
<b>3</b>	<b>AFOLU</b>	<b>1342.99</b>	<b>126.87</b>	<b>1.40</b>	<b>1789.59</b>
<b>3A</b>	<b>Livestock</b>		<b>95.04</b>	<b>0.02</b>	<b>2034.22</b>
<b>3A1</b>	Enteric Fermentation		<b>87.49</b>		<b>1840.91</b>
<b>3A2</b>	Manure Management		<b>7.55</b>	<b>0.02</b>	<b>193.31</b>
<b>3B</b>	<b>Land</b>	<b>-1343.00</b>			<b>-1343.00</b>
<b>3B1</b>	Forest Land	<b>-1440.21</b>			<b>-1440.21</b>
<b>3B2</b>	Cropland	<b>23.73</b>			<b>23.73</b>
<b>3B3</b>	Grassland	<b>5.44</b>			<b>5.44</b>
<b>3B5</b>	Settlements	<b>4.22</b>			<b>4.22</b>
<b>3B6</b>	Other Land	<b>63.83</b>			<b>63.83</b>
<b>3C</b>	Aggregate Sources and non-CO <sub>2</sub> emissions sources on land		<b>31.83</b>	<b>1.39</b>	<b>1098.37</b>
<b>3C1a</b>	Emissions from Biomass burning in forests		<b>0.12</b>	<b>0.00</b>	<b>2.86</b>
<b>3C1b</b>	Emissions from biomass burning in croplands		<b>1.77</b>	<b>0.05</b>	<b>51.79</b>
<b>3C4</b>	Direct N <sub>2</sub> O emissions from managed soils			<b>1.07</b>	<b>330.84</b>
<b>3C5</b>	Indirect N <sub>2</sub> O emissions from managed soil			<b>0.27</b>	<b>83.88</b>
<b>3C7</b>	Rice Cultivation		<b>29.95</b>		<b>628.99</b>

Between 2005 and 2013, there has been a decrease of approximately 1.95% (CAGR) in the CO<sub>2</sub> 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<sub>2</sub> equivalent emissions. This is negligible if looked at in the context of year on year emissions growth in this sector.

Given below are details of the state level estimates from the AFOLU sector in year 2005 and 2013. Details of category wise emission estimates from the states can be found in Annexure II.

*Table 7. State level emission estimates from AFOLU sector*

State/Union Territory	Emissions in 2005 (in million tonnes)	Emissions in 2013 (in million tonnes)
<b>Andaman and Nicobar Island</b>	-1.87	-2.67
<b>Andhra Pradesh</b>	20.99	27.58
<b>Arunachal Pradesh</b>	-13.06	-12.60
<b>Assam</b>	8.86	10.22
<b>Bihar</b>	19.57	24.38
<b>Chandigarh</b>	0.02	-0.07
<b>Chhattisgarh</b>	6.88	5.97
<b>Dadra and Nagar Haveli</b>	0.05	0.13

<b>Daman and Diu</b>	0.00	-0.07
<b>Delhi</b>	0.26	0.12
<b>Goa</b>	-0.37	-0.22
<b>Gujarat</b>	15.10	20.07
<b>Haryana</b>	10.04	10.90
<b>Himachal Pradesh</b>	0.05	-0.21
<b>Jammu and Kashmir</b>	1.83	-9.40
<b>Jharkhand</b>	2.83	6.44
<b>Karnataka</b>	8.31	0.57
<b>Kerala</b>	-6.78	-34.74
<b>Lakshadweep</b>	0.01	0.01
<b>Madhya Pradesh</b>	15.77	15.92
<b>Maharashtra</b>	16.29	15.95
<b>Manipur</b>	-1.53	-1.50
<b>Meghalaya</b>	-1.90	-0.40
<b>Mizoram</b>	-2.51	1.58
<b>Nagaland</b>	1.84	0.07
<b>Odisha</b>	5.90	10.87
<b>Puducherry</b>	0.13	0.02
<b>Punjab</b>	11.33	12.69
<b>Rajasthan</b>	22.08	25.61
<b>Sikkim</b>	-0.55	-0.41
<b>Tamil Nadu</b>	9.30	-34.02
<b>Tripura</b>	1.47	0.99
<b>Uttar Pradesh</b>	47.30	54.30
<b>Uttarakhand</b>	-1.40	4.48
<b>West Bengal</b>	2.39	21.22

### 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<sup>12</sup> at current values. The largest sectoral contribution to India's GDP was from the services sector (50.6%<sup>13</sup>), while the contribution of Industry and agriculture was 30.8%<sup>14</sup> and 18.6%<sup>15</sup> 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

<sup>12</sup> World Development Indicators, <https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=IN>

<sup>13</sup> World Development Indicators, <https://data.worldbank.org/indicator/NV.SRV.TETC.ZS?locations=IN>

<sup>14</sup> World Development Indicators, <https://data.worldbank.org/indicator/NV.IND.TOTL.ZS?locations=IN>

<sup>15</sup> World Development Indicators, <https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=IN>

3A1. Enteric Fermentation. Activity Data taken from the Livestock Census of India<sup>16</sup>. Methane Emission factors used are the same as those used for India NATCOMM – II<sup>17</sup>. 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 IPCC. 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.

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<sub>2</sub> 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 – II approach.

3C4. Direct N<sub>2</sub>O 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<sub>2</sub>O 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.

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<sup>16</sup> <http://dahd-archive.nic.in/dahd/statistics/livestock-census.aspx>

<sup>17</sup> <http://unfccc.int/resource/docs/natc/indnc2.pdf>

### 3A. Estimation of Emissions from Livestock

#### 3A1. Enteric Fermentation

##### Category Description

Enteric fermentation resulting in emissions of CH<sub>4</sub> 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<sub>4</sub>. Detailed emission estimates from Livestock can be found in Annexure III and from enteric fermentation in Annexure IV. Emissions under this source have been calculated as per the following livestock categories:

*Table 8 Overview of source categories of Enteric Fermentation*

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
<b>3.</b>	<b>AFOLU</b>			
<b>3A</b>	<b>Livestock</b>			
<b>3A1</b>	<b>Enteric Fermentation</b>			
3A1a	Cattle			
3A1ai	Dairy cows (Indigenous and Cross Bred)	Secondary	High	<a href="#"><u>Livestock Census of India for 2007 and 2012</u></a>
3A1a ii	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	Secondary	High	<a href="#"><u>Livestock Census of India for 2007 and 2012</u></a>
3A1b	Buffalo (dairy and non-dairy)	Secondary	High	<a href="#"><u>Livestock Census of India for 2007 and 2012</u></a>
3A1c	Sheep	Secondary	High	<a href="#"><u>Livestock Census of India for 2007 and 2012</u></a>
3A1d	Goats	Secondary	High	<a href="#"><u>Livestock Census of India for 2007 and 2012</u></a>
3A1e	Camels	Secondary	High	<a href="#"><u>Livestock Census of India for 2007 and 2012</u></a>
3A1f	Horses and ponies	Secondary	High	<a href="#"><u>Livestock Census of India for 2007 and 2012</u></a>
3A1g	Donkeys	Secondary	High	<a href="#"><u>Livestock Census of India for 2007 and 2012</u></a>
3A1h	Pigs`	Secondary	High	<a href="#"><u>Livestock Census of India for 2007 and 2012</u></a>

## Methodology

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

*Table 9 Methodology details of emission estimation from enteric fermentation*

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH <sub>4</sub>	
		METHOD APPLIED	EMISSION FACTOR
<b>3.</b>	<b>AFOLU</b>		
<b>3A</b>	<b>Livestock</b>		
<b>3A1</b>	<b>Enteric Fermentation</b>		
<b>3A1a</b>	Cattle	T2	CS
<b>3A1ai</b>	Dairy cows (Indigenous and Cross Bred)	T2	CS
<b>3A1aii</b>	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	T2	CS
<b>3A1b</b>	Buffalo (dairy and non-dairy)	T2	CS
<b>3A1c</b>	Sheep	T2	CS
<b>3A1d</b>	Goats	T2	CS
<b>3A1e</b>	Camels	T1	D
<b>3A1f</b>	Horses and ponies	T1	D
<b>3A1g</b>	Donkeys	T1	D
<b>3A1h</b>	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 10 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)	<ul style="list-style-type: none"> <li>▪ “Cross-bred” dairy cows</li> <li>▪ “Indigenous cows” (non-descript or desi) dairy cows.</li> <li>▪ “Buffaloes”</li> </ul>
b) Non-dairy cattle	<ul style="list-style-type: none"> <li>▪ Young cattle (cross bred cows, indigenous cows and buffaloes):               <ul style="list-style-type: none"> <li>a) Below 1 year<sup>18</sup></li> </ul> </li> </ul>

<sup>18</sup> 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.

	b) 1-3 years <sup>19</sup> ▪ 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 Ratio

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 11 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	
	Below 1 year	40
	1 to 3 years	140
Crossbred cattle	Dairy	275
	Non-dairy:	

<sup>19</sup> 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.



	Mature males	300
	Mature females	275
	Young stock	
	Below 1 year	60
	1 to 3 years	180
Buffalo	Dairy	275
	Non-dairy:	
	Mature males	300
	Mature females	275
	Young stock	
	Below 1 year	70
	1 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 12 Methane Conversion Factor for Livestock based on Swamy and Bhattacharya (2006)<sup>20</sup>*

Category of Livestock		Methane Conversion Factor (%)
Indigenous cattle, crossbred cattle and buffaloes	Dairy	6.00
	Below 1 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<sup>21</sup>. Thus, the emission factors that have been used in this estimation are the same as the ones used in NATCOM II 2012 for bovines. For other categories, the emission factors are taken from 2006 IPCC guidelines.

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

<sup>20</sup> <http://www.iisc.ernet.in/currsci/nov252006/1340.pdf>

<sup>21</sup> <http://unfccc.int/resource/docs/natc/indnc2.pdf>

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

Where,

$EF$  = Emission factor (Kg methane / animal / year),

$GE$  = Gross energy intake ( $\text{MJ}^{22}$  / 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 13. Emission factor of each sub-group in terms of kilograms of methane per animal per year**

Category	Sub-category	Age group	Methane emission factor	Source
			( $\text{kgCH}_4/\text{head}/\text{year}$ )	
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	2006 IPCC guidelines
Goat			5.00	2006 IPCC guidelines
Horses & Ponies			18.00	2006 IPCC guidelines
Donkeys			10.00	2006 IPCC guidelines
Camels			46.00	2006 IPCC guidelines
Pigs			1.00	2006 IPCC guidelines
Poultry			0.00	2006 IPCC guidelines

### 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

<sup>22</sup> Assumed to be 18.45

I for sample calculation) and summed using IPCC equation 10.20 (Refer Annex I for sample calculation) given below:

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

Where,

$Emissions$  = methane emissions from Enteric Fermentation, Gg CH<sub>4</sub> yr<sup>-1</sup>  
 $EF_{(T)}$  = emission factor for the defined livestock population, kg CH<sub>4</sub> head<sup>-1</sup> yr<sup>-1</sup>  
 $N_{(T)}$  = 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<sub>4</sub> yr<sup>-1</sup>  
 $E_i$  = Emissions for the i<sup>th</sup> 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 14. Uncertainties in emission estimation from Enteric Fermentation**

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE OF UNCERTAINTY	REASON	UNCERTAINTY (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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<sup>23</sup>. 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

<sup>23</sup> <http://dahd.nic.in/documents/statistics/livestock-census>

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

Not relevant since emission estimates pertaining to state level has been calculated first time.

## Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of Gol emissions and the platform estimates:

*Table 15. Verification for Enteric Fermentation*

3A1. Enteric Fermentation			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(Percentage)
INCCA (2007)	21,20,95,800	20,84,22,685	-1.73%
BUR (2010)	22,70,33,520	20,47,91,060	-9.80%

In case of verification with INCCA, the minor variation of 1.73% 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. 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. Detailed

emission estimates from Livestock can be found in Annexure III and from manure management in Annexure V.

*Table 16 Overview of source categories of Manure Management*

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
<b>3.</b>	<b>AFOLU</b>			
<b>3A</b>	<b>Livestock</b>			
<b>3A2</b>	Manure Management			
3A2a	Cattle	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2ai	Dairy cows (Indigenous and Cross Bred)	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2aii	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2b	Buffalo (dairy and non-dairy)	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2c	Sheep	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2d	Goats	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2e	Camels	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2f	Horses and ponies	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2g	Donkeys	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2h	Pigs	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>
3A2i	Poultry	Secondary	Medium	<u>Livestock Census of India for 2007 and 2012</u>

## Methodology

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

*Table 17 Methodological details for emission estimation from Manure Management*

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH <sub>4</sub>		N <sub>2</sub> O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
<b>3.</b>	<b>AFOLU</b>				
<b>3A</b>	<b>Livestock</b>				
<b>3A2</b>	<b>Manure Management</b>				
<b>3A2a</b>	Cattle	TI	CS	TI	D
<b>3A2ai</b>	Dairy cows (Indigenous and Cross Bred)	TI	CS	TI	D

<b>3A2aii</b>	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	TI	CS	TI	D
<b>3A2b</b>	Buffalo (dairy and non-dairy)	TI	CS	TI	D
<b>3A2c</b>	Sheep	TI	CS	TI	D
<b>3A2d</b>	Goats	TI	CS	TI	D
<b>3A2e</b>	Camels	TI	D	TI	D
<b>3A2f</b>	Horses and ponies	TI	CS	TI	D
<b>3A2g</b>	Donkeys	TI	CS	TI	D
<b>3A2h</b>	Pigs	TI	CS	TI	D
<b>3A2i</b>	Poultry	TI	D	TI	D

Notes: TI: 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<sub>4</sub> emission factors for various categories of animals, for this category were as follows:

**Table 18 Methane emission factors for emission estimation from manure management as per NATCOM II24 and IPCC 2006 REVISED GUIDELINES**

Category	Sub-Category	Age Group	Manure Management (kg CH <sub>4</sub> /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	2006 IPCC guidelines
Goat			0.22	2006 IPCC guidelines
Horses and Ponies			2.19	2006 IPCC guidelines
Donkeys			0.90	2006 IPCC guidelines
Camels			2.56	2006 IPCC guidelines
Pigs			4.00	2006 IPCC guidelines
Poultry			0.00	2006 IPCC guidelines

### 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 I for Sample Calculation) as given below:

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

Where,

$CH_{4_{Manure}}$  = methane emissions from Manure Management, Gg CH<sub>4</sub> yr<sup>-1</sup>

$EF_{(T)}$  = emission factor for the defined livestock population, kg CH<sub>4</sub> head<sup>-1</sup> yr<sup>-1</sup>

$N_{(T)}$  = 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.

<sup>24</sup> <http://unfccc.int/resource/docs/natc/indnc2.pdf>

## 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<sup>25</sup> 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 19 Nitrogen emission factor for emission estimation from manure management*

Category of Livestock	Nitrogen emissions per animal (kgN <sub>2</sub> O/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<sub>2</sub>O emissions were calculated in the following manner:

IPCC equation 10.25<sup>26</sup> (Refer Annex I for sample calculations) that was used was the following:

$$N_2O_{animals} = N_2O_{AWMS} = \sum [N_T \cdot N_{ex(T)} \cdot AWMS_T \cdot EF_3(AWMS)] \cdot \frac{44}{28}$$

where,

$N_2O_{animals}$  = N<sub>2</sub>O emissions from animal production in a country (kg N/ yr)

$N_2O_{AWMS}$  = N<sub>2</sub>O 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)

<sup>25</sup> 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>

<sup>26</sup> [http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4\\_Volume4/V4\\_10\\_Ch10\\_Livestock.pdf](http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf) - page 10.53



$AWMS_T$	= 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 20 Uncertainties of emission estimation from manure management*

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE OF UNCERTAINTY	REASON	UNCERTAINTY (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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%.

## Source Category Specific QA/QC

The data that have been used for this estimation are from Livestock Census of India for 2007 and 2012<sup>27</sup> 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

<sup>27</sup> <http://dahd.nic.in/documents/statistics/livestock-census>

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

Not relevant since emission estimates pertaining to state level has been calculated first time.

## Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of Gol emissions and the platform estimates:

*Table 21. Verification of Manure Management*

3A2. Manure Management			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(Percentage)
INCCA (2007)	24,36,700	2,18,44,214	796%
BUR (2010)	27,68,110	2,14,86,588	676%

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.

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<sub>2</sub>e. 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 22. Overview of source categories of Forest Land*

IPCC ID	GHG source & sink categories	Type	Quality	Source
<b>3B</b>	<b>Land</b>			
3B1	Forest Land <sup>28</sup>	Secondary Data	High	<u>Forest Survey of India</u>

<sup>28</sup> 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

## Methodology

### Steps followed:

#### 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 23 Overview of emission factors used for forest land*

IPCC ID	GHG source & sink categories	CO <sub>2</sub>	
		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<sup>29</sup>, 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,

$\Delta C$  is Annual Carbon stock change in pool (tonnes C yr<sup>-1</sup>)

$C_{t_2}$  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<sup>30</sup> 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.

<sup>29</sup> [http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4\\_Volume4/V4\\_02\\_Ch2\\_Generic.pdf](http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf)

<sup>30</sup> [http://fsi.nic.in/details.php?pgID=sb\\_15](http://fsi.nic.in/details.php?pgID=sb_15)

**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, 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<sup>31</sup>) and hence not considered significant.

*Table 24 Uncertainties of emission estimation from forest land*

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
3BI	Forest Land	Estimation	Lack of data on underlying assumptions for carbon stock calculations such as stand age, species composition, etc.	Not ascertained		

<sup>31</sup> [http://fsi.nic.in/carbon\\_stock/chapter-3.pdf](http://fsi.nic.in/carbon_stock/chapter-3.pdf)

## Source Category specific QA/QC

The data that have been used for this estimation are from Forest Survey of India<sup>32</sup>. 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

Not relevant since emission estimates pertaining to state level has been calculated first time.

## Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of Gol emissions and the platform estimates:

*Table 25 Verification of Forest Land Estimates*

3B1. Forest Land			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(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%

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

<sup>32</sup> <http://fsi.nic.in/>

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

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 2.4 million tCO<sub>2</sub>e and in the base year 2005 it was 2.3 million tCO<sub>2</sub>e 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. Detailed state wise emission estimates from Land category can be found in Annexure VI and from Cropland in Annexure VIII.

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 26 Overview of source categories of Cropland*

IPCC ID	GHG source & sink categories	Type	Quality	Source
<b>3B</b>	<b>Land</b>			
3B2	Cropland	Secondary Data	High	National Remote Sensing Centre
3B2a	Cropland Remaining Cropland	Secondary Data	High	National Remote Sensing Centre
3B2bi	Forestland converted to Cropland	Secondary Data	High	National Remote Sensing Centre
3B2bii	Grassland converted to Cropland	Secondary Data	High	National Remote Sensing Centre
3B2biv	Settlements converted to Cropland	Secondary Data	High	National Remote Sensing Centre
3B2bv	Other Land converted to Cropland	Secondary Data	High	National Remote Sensing Centre

## 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 27 Overview of emission factors used for cropland*

IPCC ID	GHG source & sink categories	CO <sub>2</sub>	
		Method Applied	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 and 2013 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 28 Biomass carbon stock in Croplands*

Category	2004 <sup>a</sup>	2013 <sup>b</sup>
Growing Stock in TOF (million cum)	1616.25	1573.34
Total stock in above ground biomass <sup>33</sup> (Mt)	1811.44	1736.35
Total stock in below ground biomass <sup>34</sup> (Mt)	489.09	476.11
Total biomass (Mt)	2300.53	2239.46
Total biomass Carbon <sup>35</sup> (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

<sup>33</sup> 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](http://www.envfor.nic.in/mef/Technical_Paper.pdf))

<sup>34</sup> Based on IPCC Guidelines; Below Ground Biomass – Root Shoot Ratio is 0.27

<sup>35</sup> Carbon Fraction is 0.5

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:

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

$$SOC = \sum_{C,S,I} SOC_{REF,C,S,I} \cdot F_{LU,C,S,I} \cdot F_{MG,C,S,I} \cdot F_{I,C,S,I} \cdot A_{C,S,I}$$

where,

$\Delta C_{\text{mineral}}$  = annual change in carbon stocks in mineral soils, tonnes C yr<sup>-1</sup>  
 $SOC_0$  = 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<sup>-1</sup>  
 $F_{LU}$  = 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 coefficient. 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.<sup>36</sup>

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<sup>37</sup>. 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 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 29 Uncertainty in emission estimates from cropland**

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
3B2	Cropland	Estimation	Lack of access to finer resolution data to map land	Not ascertained		

<sup>36</sup> <http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0607.pdf> (refer section 3.5)

<sup>37</sup> <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)

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
			use changes. Lack of availability of region specific carbon stock data based on topography and climatic regions.			

### 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

Not relevant since emission estimates pertaining to state level has been calculated first time.

### Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of GoI emissions and the platform estimates:

*Table 30 Verification of Cropland Estimates*

3B2. Cropland			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(Percentage)
INCCA (2007)	-20,75,20,000	23,01,407	101.11%
BUR (2010)	-11,07,57,170	31,42,534	102.84%

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 0.6 million tCO<sub>2</sub>e and in the base year 2005 it was 0.7 million tCO<sub>2</sub>e showing an increment of 1.26% (compounded annually). Share of emissions from grasslands in LULUCF sector is very small. Detailed state wise emission estimates from Land category can be found in Annexure VI and from Grassland in Annexure IX.

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 31 Overview of source categories of Grassland*

IPCC ID	GHG source & sink categories	Type	Quality	Source
<b>3B</b>	<b>Land</b>			
<b>3B3</b>	Grassland	Secondary Data	High	National Remote Sensing Centre
<b>3B3a</b>	Grassland Remaining Grassland	Secondary Data	High	National Remote Sensing Centre
<b>3b3bi</b>	Forest Land converted to Grassland	Secondary Data	High	National Remote Sensing Centre

<b>3b3bii</b>	Cropland converted to Grassland	Secondary Data	High	National Sensing Centre	Remote
<b>3b3biii</b>	Settlements converted to Grassland	Secondary Data	High	National Sensing Centre	Remote
<b>3b3bv</b>	Other Land converted to Grassland	Secondary Data	High	National Sensing Centre	Remote

## 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 32 Overview of emission factors used for grasslands**

IPCC ID	GHG source & sink categories	CO <sub>2</sub>	
		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 33 Biomass Carbon Stock in Grassland**

Category	2004 <sup>a</sup>	2013 <sup>b</sup>
<b>Growing Stock in TOF (million cum)</b>	1616.25	1573.34
<b>Total stock in above ground biomass<sup>38</sup> (Mt)</b>	1811.44	1736.35
<b>Total stock in below ground biomass<sup>39</sup> (Mt)</b>	489.09	476.11
<b>Total biomass (Mt)</b>	2300.53	2239.46
<b>Total biomass Carbon<sup>40</sup> (MtC)</b>	1150.26	1119.46
<b>Rate of Change of Biomass Carbon (MtC/yr)</b>	-3.39	
<b>Rate of Change of Biomass Carbon (tC/ha/yr)</b>	-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)):

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

$$SOC = \sum_{C,S,I} SOC_{REF,C,S,I} \cdot F_{LU,C,S,I} \cdot F_{MG,C,S,I} \cdot F_{I,C,S,I} \cdot A_{C,S,I}$$

<sup>38</sup> 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](http://www.envfor.nic.in/mef/Technical_Paper.pdf))

<sup>39</sup> Based on IPCC 2006 Guidelines; Below Ground Biomass – Root Shoot Ratio is 0.27

<sup>40</sup> Carbon Fraction is 0.5



where,

$\Delta C_{\text{mineral}}$  = annual change in carbon stocks in mineral soils, tonnes C yr<sup>-1</sup>

$SOC_0$  = 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<sup>-1</sup>

$F_{LU}$  = 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 coefficient. 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<sup>41</sup>

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<sup>42</sup>. 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 34 Uncertainty in emission estimates from Grassland*

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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		

<sup>41</sup> <http://bhuvar.nrs.gov.in/gis/thematic/tools/document/LULC250/0607.pdf> (refer section 3.5)

<sup>42</sup> <http://bhuvar.nrs.gov.in/gis/thematic/tools/document/LULC250/0809.pdf> (refer section 2.2), <http://bhuvar.nrs.gov.in/gis/thematic/tools/document/LULC250/1112.pdf> (refer section 2.21), <http://bhuvar.nrs.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

Not relevant since emission estimates pertaining to state level has been calculated first time.

### Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of Gol emissions and the platform estimates:

*Table 35 Verification of Grassland Estimates*

3B3. Grassland			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(Percentage)
INCCA (2007)	1,04,90,000	6,32,627	-93.97%
BUR (2010)	5,56,46,160	4,73,141	-99.15%

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. Detailed state wise emission estimates from Land category can be found in Annexure VI and from Settlements in Annexure X.

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 36 Overview of source categories of Settlements*

IPCC ID	GHG source & sink categories	Type	Quality	Source
<b>3B</b>	<b>Land</b>			
3B5	Settlements	Secondary Data	High	National Remote Sensing Centre
3B5a	Settlements Remaining Settlements	Secondary Data	High	National Remote Sensing Centre
3B5bi	Forest Land converted to Settlements	Secondary Data	High	National Remote Sensing Centre
3B5bii	Cropland converted to Settlements	Secondary Data	High	National Remote Sensing Centre
3B5biii	Grassland converted to Settlements	Secondary Data	High	National Remote Sensing Centre
3B5v	Other Land converted to Settlements	Secondary Data	High	National Remote Sensing Centre

## Methodology

Soils and DOM in Settlements may be sources or sinks of CO<sub>2</sub>, 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*<sup>43</sup> from the category Land converted to Settlements. Mostly Croplands and Other Land got 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 37 Overview of emission factors used for settlements*

IPCC ID	GHG source & sink categories	CO <sub>2</sub>	
		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.

<sup>43</sup> [http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4\\_Volume4/V4\\_08\\_Ch8\\_Settlements.pdf](http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_08_Ch8_Settlements.pdf)

**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)):

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

$$SOC = \sum_{C,S,I} SOC_{REF,C,S,I} \cdot F_{LU,C,S,I} \cdot F_{MG,C,S,I} \cdot F_{I,C,S,I} \cdot A_{C,S,I}$$

where,

$\Delta C_{\text{mineral}}$  = annual change in carbon stocks in mineral soils, tonnes C yr<sup>-1</sup>

$SOC_0$  = 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<sup>-1</sup>

$F_{LU}$  = 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 coefficient. 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<sup>44</sup>

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<sup>45</sup>. 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.

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<sup>44</sup> <http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0607.pdf> (refer section 3.5)

<sup>45</sup> <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)

**Table 38 Uncertainty in emission estimates from Settlements**

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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

Not relevant since emission estimates pertaining to state level has been calculated first time.

### Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of GoI emissions and the platform estimates:

**Table 39 Verification of Settlements Estimates**

3B5. Settlements			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(Percentage)
INCCA (2007)	-38,000	4,45,457	1272.26%
BUR (2010)	26,15,540	4,67,623	82.12%



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<sub>2</sub> 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<sub>2</sub>e and it decreased by a CAGR of 1.1% till 2013. The emissions in the year 2013 were 7.4 million tCO<sub>2</sub>e.

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). Detailed state wise emission estimates from Land category can be found in Annexure VI and from Other Land in Annexure XI.

Given below are details of activity data used in the sub-category:

*Table 40 Overview of source categories of Other Land*

IPCC ID	GHG source & sink categories	Type	Quality	Source
<b>3B</b>	<b>Land</b>			
<b>3B6</b>	Other Land	Secondary Data	High	National Remote Sensing Centre
<b>3B6a</b>	Other Land Remaining Other Land	Secondary Data	High	National Remote Sensing Centre
<b>3b6bi</b>	Forest Land converted to Other Land	Secondary Data	High	National Remote Sensing Centre
<b>3b6bii</b>	Cropland converted to Other Land	Secondary Data	High	National Remote Sensing Centre
<b>3b6biii</b>	Grassland converted to Other Land	Secondary Data	High	National Remote Sensing Centre
<b>3b6biv</b>	Settlements converted to Other Land	Secondary Data	High	National Remote Sensing Centre



## 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 4I Overview of Emission Factors used for Other Land*

IPCC ID	GHG source & sink categories	CO <sub>2</sub>	
		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 I 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 coefficient. 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<sup>46</sup>

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<sup>47</sup>. 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 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.

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<sup>46</sup> <http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0607.pdf> (refer section 3.5)

<sup>47</sup> <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)

*Table 42 Uncertainty in emission estimates from Other Land*

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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

Not relevant since emission estimates pertaining to state level has been calculated first time.

### 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.

### 3C. Estimation of Emissions from Aggregate Sources and non-CO<sub>2</sub> emissions from sources on land

#### 3C1a. 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<sub>2</sub> greenhouse gas emissions from forests.

The net emissions from this category were 0.31 tCO<sub>2</sub>e and 0.32 tCO<sub>2</sub>e 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. Detailed state wise emission estimates from Aggregate Sources and non-CO<sub>2</sub> emissions from sources on land category can be found in Annexure XII and from Biomass Burning in Forest Land in Annexure XIII.

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 43 Overview of source categories of Biomass Burning in Forest Land*

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
<b>3C</b>	<b>Aggregate sources and non-CO<sub>2</sub> Emissions Sources on Land</b>			
3C1a	Biomass Burning in Forest Land	Secondary Data	High	<u>Forest Survey of India</u>

##### Methodology

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

*Table 44 Overview of Emission factors used for Biomass burning in Forest Land*

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH <sub>4</sub>		N <sub>2</sub> O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
<b>3.</b>	<b>AFOLU</b>				
<b>3C</b>	<b>Aggregate sources and non-CO<sub>2</sub> Emissions Sources on Land</b>				
<b>3C1a</b>	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., CH<sub>4</sub>, N<sub>2</sub>O, etc.

$A$  = area burnt, ha

$M_B$  = mass of fuel available for combustion, tonnes ha<sup>-1</sup>. This includes biomass, ground litter and dead wood.

$C_f$  = combustion factor, dimensionless

$G_{ef}$  = emission factor, g kg<sup>-1</sup> dry matter burnt

### Steps followed:

#### Step 1:

Non-CO<sub>2</sub> 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 <sup>48</sup> 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.

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<sup>48</sup> 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.

**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 I for sample calculation)

**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 45 Uncertainty in emission estimation from Biomass burning in Forest Land*

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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<sup>49</sup>. 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

<sup>49</sup> <http://fsi.nic.in/>

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

Not relevant since emission estimates pertaining to state level has been calculated first time.

### Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of Gol emissions and the platform estimates:

*Table 46 Verification of Biomass Burning in Forest Land*

3C1a. Biomass Burning in Forest Land			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(Percentage)
BUR (2010)	37,93,120	3,19,327	-92%

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<sub>2</sub>O and CH<sub>4</sub>. CO<sub>2</sub> emissions do not count since it is offset by the absorption of CO<sub>2</sub> in the process of photosynthesis that caused the biomass growth at the outset.

Detailed state wise emission estimates from Aggregate Sources and non-CO<sub>2</sub> emissions from sources on land category can be found in Annexure XII and from Biomass Burning in Cropland in Annexure XIV.

*Table 47 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 <sub>2</sub> 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 48 Overview of emission factors used for biomass burning in cropland*

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH <sub>4</sub>		N <sub>2</sub> O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
3.	AFOLU				
3C	Aggregate sources and non-CO <sub>2</sub> Emissions Sources on Land				
3C1b	Biomass Burning in Cropland	TI	CS	TI	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)<sup>50</sup>. 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<sup>51</sup>:

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

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<sup>52</sup>

E is the fraction oxidized,

F is the emission factor for CH<sub>4</sub> and N<sub>2</sub>O

(Refer Annex I for sample calculations)

**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.

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<sup>50</sup>[https://www.researchgate.net/publication/256376771\\_Methane\\_and\\_nitrous\\_oxide\\_emissions\\_from\\_Indian\\_rice\\_paddies\\_agricultural\\_soils\\_and\\_crop\\_residue\\_burning](https://www.researchgate.net/publication/256376771_Methane_and_nitrous_oxide_emissions_from_Indian_rice_paddies_agricultural_soils_and_crop_residue_burning)

<sup>51</sup>[https://www.researchgate.net/publication/256376771\\_Methane\\_and\\_nitrous\\_oxide\\_emissions\\_from\\_Indian\\_rice\\_paddies\\_agricultural\\_soils\\_and\\_crop\\_residue\\_burning](https://www.researchgate.net/publication/256376771_Methane_and_nitrous_oxide_emissions_from_Indian_rice_paddies_agricultural_soils_and_crop_residue_burning)

<sup>52</sup> 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

## 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<sup>53</sup>. 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 49 Uncertainty in emission estimation from Biomass Burning in Cropland*

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
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		

## Source Category specific QA/QC

The data that have been used for this estimation are calculated from Ministry of Agriculture<sup>54</sup> 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.

<sup>53</sup> <http://onlinelibrary.wiley.com/doi/10.1002/qh.1339/full>

<sup>54</sup> [http://eands.dacnet.nic.in/LUS\\_2000\\_2005.htm](http://eands.dacnet.nic.in/LUS_2000_2005.htm)

## Recalculation

Not relevant since emission estimates pertaining to state level has been calculated first time.

## Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of GoI emissions and the platform estimates:

*Table 50 Verification of Biomass Burning in Cropland*

3C1a. Biomass Burning in Cropland			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(Percentage)
INCCA (2007)	66,06,000	57,36,934	-13.16%
BUR (2010)	79,15,060	58,01,227	-26.71%

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:

### 3C4. Direct N<sub>2</sub>O emissions from managed soils

&

### 3C5. Indirect N<sub>2</sub>O 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<sub>2</sub>O through nitrification and denitrification. In addition, there are also indirect emissions of N<sub>2</sub>O through volatilization losses, leaching and runoffs. Detailed state wise emission estimates from Aggregate Sources and non-CO<sub>2</sub> emissions from sources on land category can be found in Annexure XII and from Direct N<sub>2</sub>O emissions from managed soils in Annexure XV and Indirect N<sub>2</sub>O emissions from managed soils in Annexure XVI.

*Table 51 Overview of source categories of N<sub>2</sub>O emissions from Managed Soils*

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
<b>3.</b>	<b>AFOLU</b>			
<b>3C</b>	<b>Aggregate sources and non-CO<sub>2</sub> Emissions Sources on Land</b>			
<b>3C4</b>	Direct N <sub>2</sub> O emissions from managed soils	Secondary	High	Fertilizer consumption data available from Fertiliser Association of India ( <a href="http://www.faidelhi.org">www.faidelhi.org</a> ) <sup>55</sup>
<b>3C5</b>	Indirect N <sub>2</sub> O emissions from managed soils	Secondary	High	Fertilizer consumption data available from Fertiliser Association of India ( <a href="http://www.faidelhi.org">www.faidelhi.org</a> )

### Methodology

The methodological details for estimation of N<sub>2</sub>O emissions from agriculture soils are as under:

*Table 52 Overview of emission factors used for N<sub>2</sub>O emissions from Managed Soils*

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH <sub>4</sub>		N <sub>2</sub> O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
<b>3.</b>	<b>AFOLU</b>				
<b>3C</b>	<b>Aggregate sources and non-CO<sub>2</sub> Emissions Sources on Land</b>				
<b>3C4</b>	Direct N <sub>2</sub> O emissions from managed soils	T2	CS		
<b>3C5</b>	Indirect N <sub>2</sub> O 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 I:

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 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

<sup>55</sup> Data on fertilizer consumption was collected in person from the office of Fertiliser Association of India, New Delhi.

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  $\text{NH}_3$  and  $\text{NO}_x$ , 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  $\text{N}_2\text{O}$  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 ( $\text{NH}_3$  and  $\text{NO}_x$ ) and leaching loss of N (Bhatia e. al. 2004<sup>56</sup>). The default IPCC emission factor for  $\text{N}_2\text{O}$  emission for atmospheric  $\text{NH}_3$  and  $\text{NO}_x$  is 1 percent; however, considering characteristics of Indian soils, 0.5 percent emission factor was used for  $\text{N}_2\text{O}$  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 53 Uncertainty in emission estimates from  $\text{N}_2\text{O}$  emissions from Managed Soils*

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				$\text{CO}_2$	$\text{CH}_4$	$\text{N}_2\text{O}$
3C4 and 3C5	Agriculture Soils	Estimation	According to 2006 IPCC guidelines (Chapter 11, Volume 04) <sup>57</sup> , 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 information on specific on-farm practices.	Not Ascertained		

<sup>56</sup> <http://www.iisc.ernet.in/currsci/aug102004/317.pdf>

<sup>57</sup> [http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4\\_Volume4/V4\\_11\\_Ch11\\_N2O&CO2.pdf](http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf)

## Source Category specific QA/QC

The data that have been used for this estimation are from Fertiliser Association of India<sup>58</sup>. 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

Not relevant since emission estimates pertaining to state level has been calculated first time.

## Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of GoI emissions and the platform estimates:

*Table 54 Verification of Agriculture Soil Estimates*

3C4 & 3C5. Agriculture Soils			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(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%

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.

<sup>58</sup> [www.faidelhi.org](http://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.

Detailed state wise emission estimates from Aggregate Sources and non-CO<sub>2</sub> emissions from sources on land category can be found in Annexure XII and from Rice Cultivation in Annexure XVII.

*Table 55 Overview of Source Categories of Rice Cultivation*

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
3.	AFOLU			
3C	Aggregate sources and non-CO <sub>2</sub> Emissions Sources on Land			
3C7	Rice Cultivation	Secondary	High	<u>Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmer's Welfare, Government of India</u>

## Methodology

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

*Table 56 Overview of Emission Factors used for Rice Cultivation*

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH <sub>4</sub>		N <sub>2</sub> O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
3.	AFOLU				
3C	Aggregate sources and non-CO <sub>2</sub> 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<sub>4</sub> emissions from rice cultivation (Gg year<sup>-1</sup>),

$A_C$  = area of rice cultivation under management C (ha)

$EF_W$  = factor applied for different types of water management (kg CH<sub>4</sub> ha<sup>-1</sup>)

$10^{-6}$  = 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 57 Emission Factor for different water regime for Rice Cultivation*

Emission from different water regime for rice cultivation	Emission (kg CH <sub>4</sub> /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 58 Uncertainty in emission estimation from Rice Cultivation*

IPCC ID	GHG source & sink categories	Type of Uncertainty	Reason	Uncertainty (%)		
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
3C7	Rice cultivation	Estimation	Precise and disaggregated data on water regimes for rice cultivation in different parts of the country is not available.	Not Ascertained		

### 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<sup>59</sup>. 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

Not relevant since emission estimates pertaining to state level has been calculated first time.

### Verification

For the purpose of verification, adequate steps have been carried out to ensure the reliability of results, consistency in methodology and assumptions. The calculations are consistent with the methodology mentioned in 2006 IPCC guidelines.

<sup>59</sup> [http://eands.dacnet.nic.in/LUS\\_2000\\_2005.htm](http://eands.dacnet.nic.in/LUS_2000_2005.htm)

The aggregated emissions for this source category have also been compared with national inventories for India. Given below are details of the deviation in assessment of Gol emissions and the platform estimates:

*Table 59 Verification of Rice Cultivation Estimates*

3C7. Rice Cultivation			
Official Inventory		GHG Platform India	Variation
Emissions (tonnes CO <sub>2</sub> e)		Emissions (tonnes CO <sub>2</sub> e)	(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 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.

### Public Consultation and Outreach

Vasudha Foundation as part of the platform organized a regional roundtable meeting in India Habitat Centre, New Delhi on 6<sup>th</sup> April 2017 and also participated in a roundtable organized by WRI India in Mumbai on 17<sup>th</sup> 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 constructively 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<sub>4</sub> yr<sup>-1</sup>

$EF_{(T)}$  = emission factor for the defined livestock population, kg CH<sub>4</sub> head<sup>-1</sup> yr<sup>-1</sup>

$N_{(T)}$  = 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

$EF_{60}^{(Indigenous Dairy Cattle)} = 24 \text{ kg CH}_4 \text{ head}^{-1} \text{ yr}^{-1}$

$N_{(Indigenous Dairy Cattle)} = 4,81,41,000^{61}$

⇒ Emissions = 24 \* (4,81,41,000)/10<sup>6</sup>

⇒ Emissions = 1,347.95 Gg CH<sub>4</sub> yr<sup>-1</sup> .....(1)

⇒ Similarly, using the same equation, emissions from Indigenous Non-Dairy Cattle are 2,315.81 GgCH<sub>4</sub>yr<sup>-1</sup> .....(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<sub>4</sub> yr<sup>-1</sup>

$E_i$  = Emissions for the i<sup>th</sup> livestock categories and subcategories

#### Sample Calculation:

Total CH<sub>4</sub> emissions from enteric fermentation from Indigenous Cattle are:

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<sup>60</sup> Source: India's Second National Communications to the UNFCCC, 2004

<sup>61</sup> Using CAGR, livestock derived using 19<sup>th</sup> Livestock Census of India

Total CH<sub>4</sub> emissions = Emissions (Indigenous Dairy Cattle) + Emissions (Indigenous Non Dairy Cattle)

$$\begin{aligned}\Rightarrow \text{Total CH}_4 \text{ emissions} &= (1) + (2) \\ \Rightarrow \text{Total CH}_4 \text{ emissions} &= 1,347.95 \text{ GgCH}_4 \text{ yr}^{-1} + 2,315.81 \text{ GgCH}_4 \text{ yr}^{-1} \\ \Rightarrow \text{Total CH}_4 \text{ emissions} &= 3,662.76 \text{ GgCH}_4 \text{ yr}^{-1}\end{aligned}$$

### 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<sup>62</sup> / 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%<sup>63</sup>. 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,

$$GE = 60.99 \text{ MJ/animal/year}$$

$$Y_m = 6\%^{64}$$

Therefore,

$$\Rightarrow EF = (60.99 \times 6\% \times 365)/(55.65)$$

$$\Rightarrow EF = 24 \text{ Kg CH}_4/\text{animal/year}$$

### 4. IPCC equation 10.22, Emission Estimation from Manure Management

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

<sup>62</sup> Assumed to be 18.45

<sup>63</sup> Swamy and Bhattacharya (2006)

<sup>64</sup> Swamy and Bhattacharya (2006)

Where,

$CH_{4Manure}$  = 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

$EF_{(Indigenous Dairy Cattle)}^{65} = 3.50$  kg  $CH_4$  head $^{-1}$   $yr^{-1}$

$N_{(Indigenous Dairy Cattle)} = 4,81,41,000^{66}$

- ⇒ 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 Gg $CH_4$  $yr^{-1}$  .....(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 Gg $CH_4$   $yr^{-1}$  + 233.14 Gg $CH_4$  $yr^{-1}$
- ⇒ Total  $CH_4$  emissions = 401.64 Gg $CH_4$   $yr^{-1}$

## 5. IPCC equation 10.25<sup>67</sup>, 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

<sup>65</sup> Source: India's Second National Communications to the UNFCCC, 2004

<sup>66</sup> Using CAGR, livestock derived using 19<sup>th</sup> Livestock Census of India

<sup>67</sup> [http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4\\_Volume4/V4\\_10\\_Ch10\\_Livestock.pdf](http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf) - page 10.53

**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<sub>2</sub>O/head/year

Population = N<sub>T</sub> = 4,81,41,000<sup>68</sup>

$$\Rightarrow N_2O_{animals} = 0.0006 \times 4,81,41,000$$

$$\Rightarrow N_2O_{animals} = 28,884 \text{ Gg N}_2\text{O}$$

**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,

$\Delta C$  = Annual Carbon stock change in pool (tonnes C yr<sup>-1</sup>)

$C_{t_2}$  = Carbon stock in the pool at time  $t_2$

$C_{t_1}$  = Carbon stock in the pool at time  $t_1$

**Sample Calculation:**

Assuming:  $t_2 = 2013$

$t_1 = 2011$

$$C_{t_2} = 7044^{69}$$

MtC.....

.....(5)

$C_{t_1}$  = 6941<sup>70</sup> MtC

.....

.....(6)

Therefore,  $\Delta C = ((5)-(6))/(2013-2011)$

$$\Rightarrow \Delta C = (7044 - 6941)/(2013-2011) \text{ MtC}$$

$$\Rightarrow \Delta C = -51.50 \text{ MtC}$$

<sup>68</sup> Using CAGR, livestock derived using 19<sup>th</sup> Livestock Census of India

<sup>69</sup> State of Forest Report 2015

<sup>70</sup> State of Forest Report 2013

**7. IPCC Equation 2.25 , Emission Estimation from Land**

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

$$SOC = \sum_{C,S,I} SOC_{REF,C,S,I} \cdot F_{LU,C,S,I} \cdot F_{MG,C,S,I} \cdot F_{I,C,S,I} \cdot A_{C,S,I}$$

where,

$\Delta C_{\text{mineral}}$  = annual change in carbon stocks in mineral soils, tonnes C yr<sup>-1</sup>

$SOC_0$  = 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<sup>-1</sup>

$F_{LU}$  = 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

$$SOC_{(0-T)}^{71} = \text{tC/ha} \dots \dots \dots (7) \quad 38$$

$$F_{LU}^{72} = 1$$

$$F_{MG}^{73} = 0.97$$

$$F_I^{74} = 1$$

<sup>71</sup> 0 = Grassland; Source: Rao S. (2016)

<sup>72</sup> Considering Level = All as per IPCC 2006 Guidelines, Volume 4, Chapter 6

<sup>73</sup> Considering Level = Moderately degraded as per IPCC 2006 Guidelines, Volume 4, Chapter 6; FMG for tropical = 0.97, FMG for tropical montane = 0.96

<sup>74</sup> Considering Level of Input = Medium as per IPCC 2006 Guidelines, Volume 4, Chapter 6

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

$$SOC_{(0)} = \sum_{C,S,I} SOC_{REF,C,S,I} \cdot F_{LU,C,S,I} \cdot F_{MG,C,S,I} \cdot F_{I,C,S,I} \cdot A_{C,S,I}$$

$$\Rightarrow SOC_{(0)} = 38 \times 1 \times 0.97 \times 1 \times 1$$

$$\Rightarrow SOC_{(0)} = 36.86$$

tC/ha.....  
.....(8)

Now,

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

Therefore, from (7) & (8)

$$\Delta C_{mineral} = \{(8) - (7)\}/20$$

$$\Rightarrow \Delta C_{mineral} = \{36.86 - 38\}/20$$

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

## 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<sub>4</sub>, N<sub>2</sub>O, etc.

$A$  = area burnt, ha

$M_B$  = mass of fuel available for combustion, tonnes ha<sup>-1</sup>. This includes biomass, ground litter and dead wood.

$C_f$  = combustion factor, dimensionless

$G_{ef}$  = emission factor, g kg<sup>-1</sup> dry matter burnt

### Sample Calculation:

Consider biomass burning<sup>75</sup> 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,

<sup>75</sup> Note: Source for all the data in this calculation is from India's Second National Communications.



Methane emissions from biomass burning can be calculated as:

$$\Rightarrow L_{fire} = (3,04,679 \times 13.12 \times 0.36 \times 9)/1000$$

$$\Rightarrow L_{fire} = 12,760 \text{ tonnes of methane}$$

Similarly, nitrous oxide emissions from biomass burning are 155.9 tonnes of N<sub>2</sub>O.

## 9. Equation used for Biomass Burning in cropland<sup>76</sup>

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

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<sub>4</sub> and N<sub>2</sub>O

### 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<sup>77</sup> = *B* = 1.50

Dry Matter Fraction<sup>78</sup> = *C* = 0.86

Fraction Burnt<sup>79</sup> = *D* = 0.80

Combustion Factor<sup>80</sup> = *E* = 0.89

Emission Factor for CH<sub>4</sub><sup>81</sup> = *F* = 2.70 g/kg

Therefore,

Emissions from Residue Burning in Punjab's Rice fields =

$$\Rightarrow FBCR = A \cdot B \cdot C \cdot D \cdot E \cdot F$$

$$\Rightarrow FBCR = (11,294 \times 1.50 \times 0.86 \times 0.80 \times 0.89 \times 2.70)/1000$$

$$\Rightarrow FBCR = 28.007 \text{ Gg}$$

$$\Rightarrow FBCR = 28,007.94 \text{ tCH}_4$$

<sup>76</sup> Bhatia et al. (2013)

<sup>77</sup> Jain et al. (2014)

<sup>78</sup> Jain et al. (2014)

<sup>79</sup> Calculations based on data from Gadde et al. (2009)

<sup>80</sup> Turn et al. (1997)

<sup>81</sup> Andrea and Merlot (2001)

**10. Equation used for emission estimation from Rice Cultivation<sup>82</sup>**

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

Where,

$E_{RC}$  = CH<sub>4</sub> emissions from rice cultivation (Gg CH<sub>4</sub> year<sup>-1</sup>),

$A_C$  = area of rice cultivation under management C (ha)

$EF_W$  = emission factor applied for different types of water management (kg CH<sub>4</sub> ha<sup>-1</sup>)

$10^{-6}$  = 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<sup>83</sup> =  $EF_W$  = 18 kg CH<sub>4</sub>/ha

Hence,

$$\Rightarrow E_{RC} = (2,837 * 18)/1000$$

$$\Rightarrow E_{RC} = 51.06 \text{ Gg CH}_4/\text{year}$$

<sup>82</sup> Gupta et al. (2009) and Pathak et al. (2010)

<sup>83</sup> India's Second National Communications to the UNFCCC

## Annexure II

Emission estimates (in million tCO<sub>2</sub>e) from 3. AFOLU sector from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	-1.87	-1.86	-1.86	-1.86	-1.86	-1.87	-2.67	-2.67	-2.67
Andhra Pradesh	20.99	22.46	23.59	23.89	22.14	23.49	28.33	26.35	27.58
Arunachal Pradesh	-13.06	-13.07	-13.07	-13.36	-13.35	-13.33	-12.63	-12.62	-12.60
Assam	8.86	8.76	9.15	9.52	9.70	9.93	10.20	10.14	10.22
Bihar	19.57	20.79	21.76	21.70	21.14	20.63	23.88	24.58	24.38
Chandigarh	0.02	0.02	0.02	0.02	0.02	0.02	-0.07	-0.07	-0.07
Chhattisgarh	6.88	7.07	7.20	7.11	7.14	7.21	5.88	5.93	5.97
Dadra and Nagar Haveli	0.05	0.06	0.06	0.06	0.05	0.05	0.13	0.13	0.13
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	-0.07	-0.07
Delhi	0.26	0.27	0.28	0.27	0.25	0.23	0.14	0.12	0.12
Goa	-0.37	-0.37	-0.37	-0.37	-0.38	-0.38	-0.21	-0.22	-0.22
Gujarat	15.11	15.76	16.53	17.25	17.66	18.65	19.30	19.26	20.07
Haryana	10.04	10.11	10.32	10.53	10.65	10.77	10.93	10.97	10.90
Himachal Pradesh	0.05	0.05	0.05	-0.01	-0.05	-0.07	-0.17	-0.20	-0.21
Jammu and Kashmir	1.83	1.90	1.98	1.66	1.53	1.37	-9.14	-9.26	-9.40
Jharkhand	2.83	3.22	3.48	3.36	2.96	2.54	6.31	6.48	6.44
Karnataka	8.31	8.71	9.13	9.20	9.23	9.27	1.98	0.87	0.57
Kerala	-6.78	-6.85	-6.94	-6.99	-7.05	-7.12	-34.64	-34.71	-34.74

<b>Lakshadweep</b>	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01
<b>Madhya Pradesh</b>	15.77	16.81	17.75	16.90	16.56	16.14	16.25	15.85	15.92
<b>Maharashtra</b>	16.29	16.76	17.19	17.02	17.07	17.48	16.57	15.71	15.95
<b>Manipur</b>	-1.53	-1.56	-1.58	-1.57	-1.58	-1.54	-1.47	-1.55	-1.50
<b>Meghalaya</b>	-1.90	-1.88	-1.86	-1.88	-1.88	-1.88	-0.37	-0.43	-0.40
<b>Mizoram</b>	-2.51	-2.52	-2.51	-2.55	-2.57	-2.58	1.59	1.58	1.58
<b>Nagaland</b>	1.84	1.86	1.85	1.86	1.82	1.80	0.11	0.08	0.07
<b>Odisha</b>	5.90	5.66	5.21	4.59	4.35	4.60	11.01	10.69	10.87
<b>Puducherry</b>	0.13	0.14	0.13	0.11	0.12	0.11	0.04	0.03	0.02
<b>Punjab</b>	11.33	11.26	11.16	11.36	11.55	11.77	12.45	12.75	12.69
<b>Rajasthan</b>	22.08	22.60	23.10	22.31	22.67	23.37	24.69	25.18	25.61
<b>Sikkim</b>	-0.55	-0.56	-0.56	-0.48	-0.49	-0.49	-0.42	-0.42	-0.41
<b>Tamil Nadu</b>	9.30	9.89	10.07	9.83	9.17	8.69	-32.24	-33.62	-34.02
<b>Tripura</b>	1.47	1.48	1.51	1.42	1.41	1.43	1.01	1.00	0.99
<b>Uttar Pradesh</b>	47.30	47.82	48.07	50.26	51.07	52.22	51.76	53.25	54.30
<b>Uttarakhand</b>	-1.40	-1.22	-1.04	-1.15	-1.23	-1.26	4.59	4.51	4.48
<b>West Bengal</b>	2.39	4.83	6.03	5.88	5.06	3.30	21.96	21.78	21.22

## Annexure III

Emission estimates (in million tCO<sub>2</sub>e) from 3A. Livestock sector from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Andhra Pradesh	19.50	20.42	21.34	20.72	20.09	19.47	18.84	18.22	17.73
Arunachal Pradesh	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34
Assam	6.48	6.74	7.01	7.05	7.09	7.12	7.16	7.20	7.29
Bihar	13.08	13.57	14.05	14.17	14.28	14.40	14.52	14.63	14.96
Chandigarh	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Chhattisgarh	7.43	7.55	7.67	7.64	7.62	7.60	7.58	7.56	7.59
Dadra and Nagar Haveli	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.26	0.28	0.29	0.27	0.25	0.24	0.22	0.20	0.19
Goa	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07
Gujarat	12.12	12.45	12.78	13.25	13.73	14.20	14.67	15.14	15.71
Haryana	5.67	5.63	5.59	5.62	5.66	5.69	5.72	5.75	5.82
Himachal Pradesh	2.37	2.38	2.38	2.35	2.33	2.30	2.27	2.24	2.23
Jammu and Kashmir	3.62	3.70	3.78	3.62	3.47	3.31	3.16	3.00	2.88
Jharkhand	7.11	7.33	7.54	7.49	7.44	7.38	7.33	7.28	7.26
Karnataka	11.39	11.73	12.08	11.78	11.49	11.19	10.90	10.61	10.40
Kerala	1.54	1.50	1.46	1.38	1.31	1.24	1.17	1.10	1.05

<b>Lakshadweep</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Madhya Pradesh</b>	20.03	20.76	21.48	20.91	20.33	19.75	19.17	18.59	18.25
<b>Maharashtra</b>	17.23	17.19	17.16	16.93	16.71	16.48	16.26	16.03	15.88
<b>Manipur</b>	0.33	0.31	0.29	0.28	0.27	0.26	0.25	0.24	0.24
<b>Meghalaya</b>	0.61	0.63	0.65	0.65	0.66	0.66	0.67	0.67	0.69
<b>Mizoram</b>	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05
<b>Nagaland</b>	0.41	0.41	0.41	0.38	0.34	0.31	0.27	0.24	0.22
<b>Odisha</b>	10.12	9.88	9.64	9.41	9.19	8.97	8.74	8.52	8.46
<b>Puducherry</b>	0.06	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05
<b>Punjab</b>	5.89	5.69	5.48	5.57	5.65	5.74	5.82	5.90	6.04
<b>Rajasthan</b>	18.74	19.09	19.44	19.78	20.12	20.46	20.80	21.14	21.62
<b>Sikkim</b>	0.11	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12
<b>Tamil Nadu</b>	9.89	10.40	10.91	10.33	9.75	9.17	8.59	8.00	7.62
<b>Tripura</b>	0.60	0.63	0.66	0.66	0.66	0.66	0.66	0.66	0.67
<b>Uttar Pradesh</b>	30.86	30.96	31.05	32.15	33.24	34.33	35.43	36.52	38.04
<b>Uttarakhand</b>	2.24	2.39	2.54	2.48	2.42	2.36	2.30	2.24	2.20
<b>West Bengal</b>	11.46	12.63	13.80	13.27	12.75	12.23	11.71	11.18	10.81

## Annexure IV

Emission estimates (in million tCO<sub>2</sub>e) from 3A1. Enteric Fermentation sector from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Andhra Pradesh	17.74	18.59	19.43	18.86	18.29	17.72	17.15	16.58	16.14
Arunachal Pradesh	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28
Assam	5.72	5.95	6.18	6.22	6.27	6.31	6.35	6.40	6.48
Bihar	11.83	12.27	12.72	12.83	12.94	13.05	13.16	13.27	13.57
Chandigarh	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Chhattisgarh	6.69	6.80	6.92	6.90	6.88	6.86	6.84	6.82	6.85
Dadra and Nagar Haveli	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.24	0.25	0.26	0.25	0.23	0.21	0.19	0.17	0.17
Goa	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
Gujarat	10.99	11.30	11.60	12.03	12.45	12.88	13.30	13.73	14.25
Haryana	5.11	5.07	5.03	5.06	5.09	5.11	5.14	5.17	5.23
Himachal Pradesh	2.17	2.17	2.17	2.15	2.12	2.10	2.08	2.05	2.04
Jammu and Kashmir	3.32	3.39	3.46	3.32	3.18	3.04	2.90	2.75	2.64
Jharkhand	6.40	6.60	6.81	6.76	6.71	6.66	6.61	6.56	6.54
Karnataka	10.36	10.67	10.99	10.72	10.45	10.19	9.92	9.65	9.46
Kerala	1.40	1.37	1.33	1.26	1.19	1.12	1.06	0.99	0.95

<b>Lakshadweep</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Madhya Pradesh</b>	18.13	18.80	19.46	18.93	18.41	17.88	17.35	16.82	16.51
<b>Maharashtra</b>	15.66	15.62	15.58	15.38	15.17	14.96	14.76	14.55	14.41
<b>Manipur</b>	0.27	0.25	0.23	0.23	0.22	0.21	0.21	0.20	0.19
<b>Meghalaya</b>	0.52	0.53	0.54	0.55	0.55	0.56	0.56	0.57	0.58
<b>Mizoram</b>	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
<b>Nagaland</b>	0.32	0.32	0.32	0.29	0.26	0.24	0.21	0.18	0.16
<b>Odisha</b>	9.16	8.95	8.73	8.53	8.33	8.13	7.93	7.73	7.68
<b>Puducherry</b>	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.04
<b>Punjab</b>	5.35	5.16	4.97	5.05	5.13	5.20	5.28	5.35	5.47
<b>Rajasthan</b>	17.08	17.41	17.73	18.04	18.34	18.65	18.95	19.26	19.69
<b>Sikkim</b>	0.10	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.11
<b>Tamil Nadu</b>	8.99	9.46	9.93	9.40	8.87	8.34	7.81	7.28	6.93
<b>Tripura</b>	0.52	0.55	0.58	0.57	0.57	0.57	0.57	0.57	0.57
<b>Uttar Pradesh</b>	27.84	27.94	28.04	29.03	30.02	31.01	32.00	32.99	34.36
<b>Uttarakhand</b>	2.04	2.18	2.31	2.26	2.20	2.15	2.09	2.04	2.00
<b>West Bengal</b>	10.35	11.39	12.42	11.96	11.49	11.02	10.55	10.08	9.75



## Annexure V

Emission estimates (in million tCO<sub>2</sub>e) from 3A2. Manure Management sector from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Andhra Pradesh	1.76	1.83	1.91	1.86	1.80	1.75	1.69	1.64	1.59
Arunachal Pradesh	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Assam	0.76	0.79	0.83	0.82	0.82	0.81	0.81	0.80	0.81
Bihar	1.25	1.29	1.33	1.34	1.35	1.35	1.36	1.36	1.39
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.73	0.74	0.75	0.75	0.75	0.75	0.74	0.74	0.75
Dadra and Nagar Haveli	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
Goa	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gujarat	1.12	1.15	1.18	1.23	1.27	1.32	1.36	1.41	1.46
Haryana	0.56	0.56	0.56	0.57	0.57	0.58	0.58	0.59	0.59
Himachal Pradesh	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.19	0.19
Jammu and Kashmir	0.30	0.31	0.31	0.30	0.29	0.28	0.26	0.25	0.24
Jharkhand	0.71	0.73	0.74	0.73	0.73	0.73	0.73	0.72	0.72
Karnataka	1.03	1.06	1.09	1.06	1.03	1.01	0.98	0.96	0.94
Kerala	0.14	0.13	0.13	0.13	0.12	0.12	0.11	0.11	0.11

<b>Lakshadweep</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Madhya Pradesh</b>	1.90	1.96	2.02	1.97	1.92	1.87	1.82	1.77	1.74
<b>Maharashtra</b>	1.58	1.58	1.57	1.55	1.54	1.52	1.50	1.48	1.47
<b>Manipur</b>	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04
<b>Meghalaya</b>	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11
<b>Mizoram</b>	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
<b>Nagaland</b>	0.09	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06
<b>Odisha</b>	0.97	0.94	0.91	0.88	0.86	0.83	0.81	0.79	0.78
<b>Puducherry</b>	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
<b>Punjab</b>	0.55	0.53	0.51	0.52	0.52	0.53	0.54	0.55	0.56
<b>Rajasthan</b>	1.66	1.68	1.71	1.74	1.78	1.81	1.85	1.88	1.93
<b>Sikkim</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Tamil Nadu</b>	0.90	0.94	0.98	0.93	0.88	0.83	0.78	0.73	0.69
<b>Tripura</b>	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09
<b>Uttar Pradesh</b>	3.02	3.02	3.01	3.11	3.22	3.32	3.43	3.53	3.68
<b>Uttarakhand</b>	0.20	0.22	0.23	0.23	0.22	0.22	0.21	0.20	0.20
<b>West Bengal</b>	1.11	1.24	1.37	1.32	1.26	1.21	1.15	1.10	1.06

## Annexure VI

Emission estimates (in million tCO<sub>2</sub>e) from 3B. Land sector from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	-10.63	-10.63	-10.63	-10.63	-10.63	-10.63	-5.01	-5.01	-5.01
Andhra Pradesh	-13.43	-13.43	-13.43	-13.50	-13.50	-13.50	-13.06	-13.06	-13.06
Arunachal Pradesh	-2.12	-2.12	-2.12	-2.41	-2.41	-2.41	-2.02	-2.02	-2.02
Assam	-4.05	-4.05	-4.05	-4.07	-4.07	-4.07	-1.96	-1.96	-1.96
Bihar	-6.53	-6.53	-6.53	-6.87	-6.87	-6.87	-7.81	-7.81	-7.81
Chandigarh	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.09	-0.09	-0.09
Chhattisgarh	0.18	0.18	0.18	0.10	0.10	0.10	-0.03	-0.03	-0.03
Dadra and Nagar Haveli	-1.99	-1.99	-1.99	-1.99	-1.99	-1.99	-1.93	-1.93	-1.93
Daman and Diu	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.18	-0.18	-0.18
Delhi	-2.71	-2.71	-2.71	-2.71	-2.71	-2.71	-2.94	-2.94	-2.94
Goa	-3.21	-3.21	-3.21	-3.21	-3.21	-3.21	-13.73	-13.73	-13.73
Gujarat	-6.15	-6.15	-6.15	-5.96	-5.96	-5.96	-2.42	-2.42	-2.42
Haryana	-6.35	-6.35	-6.35	-6.34	-6.34	-6.34	-13.65	-13.65	-13.65
Himachal Pradesh	-7.60	-7.60	-7.60	-7.64	-7.64	-7.64	-34.87	-34.87	-34.87
Jammu and Kashmir	-9.01	-9.01	-9.01	-9.20	-9.20	-9.20	-9.24	-9.24	-9.24
Jharkhand	-7.53	-7.53	-7.53	-7.60	-7.60	-7.60	-7.76	-7.76	-7.76
Karnataka	-2.54	-2.54	-2.54	-2.45	-2.45	-2.45	-2.47	-2.47	-2.47
Kerala	-4.04	-4.04	-4.04	-4.01	-4.01	-4.01	-2.58	-2.58	-2.58
Lakshadweep	-2.81	-2.81	-2.81	-2.81	-2.81	-2.81	1.38	1.38	1.38
Madhya Pradesh	2.95	2.95	2.95	2.60	2.60	2.60	1.53	1.53	1.53
Maharashtra	-12.48	-12.48	-12.48	-12.54	-12.54	-12.54	-6.18	-6.18	-6.18
Manipur	-0.63	-0.63	-0.63	-0.61	-0.61	-0.61	-0.09	-0.09	-0.09

<b>Meghalaya</b>	-1.58	-1.58	-1.58	-1.61	-1.61	-1.61	-2.30	-2.30	-2.30
<b>Mizoram</b>	-0.51	-0.51	-0.51	-0.54	-0.54	-0.54	-0.54	-0.54	-0.54
<b>Nagaland</b>	-5.88	-5.88	-5.88	-5.84	-5.84	-5.84	-46.30	-46.30	-46.30
<b>Odisha</b>	1.01	1.01	1.01	0.86	0.86	0.86	0.36	0.36	0.36
<b>Puducherry</b>	-1.84	-1.84	-1.84	-1.84	-1.84	-1.84	-3.55	-3.55	-3.55
<b>Punjab</b>	-4.29	-4.29	-4.29	-4.30	-4.30	-4.30	1.57	1.57	1.57
<b>Rajasthan</b>	-18.53	-18.53	-18.53	-19.71	-19.71	-19.71	0.28	0.28	0.28
<b>Sikkim</b>	-2.06	-2.06	-2.06	-1.98	-1.98	-1.98	-2.72	-2.72	-2.72
<b>Tamil Nadu</b>	-0.14	-0.14	-0.14	-0.11	-0.11	-0.11	-0.24	-0.24	-0.24
<b>Tripura</b>	0.10	0.10	0.10	0.03	0.03	0.03	0.09	0.09	0.09
<b>Uttar Pradesh</b>	0.54	0.54	0.54	1.21	1.21	1.21	0.80	0.80	0.80
<b>Uttarakhand</b>	0.18	0.18	0.18	0.14	0.14	0.14	0.20	0.20	0.20
<b>West Bengal</b>	-0.19	-0.19	-0.19	-0.21	-0.21	-0.21	-0.28	-0.28	-0.28

## Annexure VII

Emission estimates (in million tCO<sub>2</sub>e) from 3B1. Forest Land category from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	-10.65	-10.65	-10.65	-10.65	-10.65	-10.65	-5.01	-5.01	-5.01
Andhra Pradesh	-14.09	-14.09	-14.09	-14.09	-14.09	-14.09	-13.55	-13.55	-13.55
Arunachal Pradesh	-2.41	-2.41	-2.41	-2.41	-2.41	-2.41	-2.19	-2.19	-2.19
Assam	-3.07	-3.07	-3.07	-3.07	-3.07	-3.07	-0.95	-0.95	-0.95
Bihar	-7.17	-7.17	-7.17	-7.17	-7.17	-7.17	-8.26	-8.26	-8.26
Chandigarh	-0.02	-0.02	-0.02	-0.02	-0.02	-0.02	-0.09	-0.09	-0.09
Chhattisgarh	-0.52	-0.52	-0.52	-0.52	-0.52	-0.52	-0.35	-0.35	-0.35
Dadra and Nagar Haveli	-1.99	-1.99	-1.99	-1.99	-1.99	-1.99	-1.93	-1.93	-1.93
Daman and Diu	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13	-0.18	-0.18	-0.18
Delhi	-2.71	-2.71	-2.71	-2.71	-2.71	-2.71	-2.94	-2.94	-2.94
Goa	-3.19	-3.19	-3.19	-3.19	-3.19	-3.19	-13.71	-13.71	-13.71
Gujarat	-7.18	-7.18	-7.18	-7.18	-7.18	-7.18	-3.69	-3.69	-3.69
Haryana	-6.72	-6.72	-6.72	-6.72	-6.72	-6.72	-14.03	-14.03	-14.03
Himachal Pradesh	-7.83	-7.83	-7.83	-7.83	-7.83	-7.83	-35.21	-35.21	-35.21
Jammu and Kashmir	-10.05	-10.05	-10.05	-10.05	-10.05	-10.05	-10.27	-10.27	-10.27
Jharkhand	-7.96	-7.96	-7.96	-7.96	-7.96	-7.96	-8.19	-8.19	-8.19
Karnataka	-2.34	-2.34	-2.34	-2.34	-2.34	-2.34	-2.29	-2.29	-2.29
Kerala	-2.78	-2.78	-2.78	-2.78	-2.78	-2.78	-1.29	-1.29	-1.29
Lakshadweep	-2.81	-2.81	-2.81	-2.81	-2.81	-2.81	1.38	1.38	1.38
Madhya Pradesh	1.06	1.06	1.06	1.06	1.06	1.06	-0.62	-0.62	-0.62
Maharashtra	-14.15	-14.15	-14.15	-14.15	-14.15	-14.15	-7.25	-7.25	-7.25
Manipur	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.24	-0.24	-0.24

<b>Meghalaya</b>	-1.65	-1.65	-1.65	-1.65	-1.65	-1.65	-2.36	-2.36	-2.36
<b>Mizoram</b>	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64
<b>Nagaland</b>	-5.97	-5.97	-5.97	-5.97	-5.97	-5.97	-46.45	-46.45	-46.45
<b>Odisha</b>	0.24	0.24	0.24	0.24	0.24	0.24	-0.18	-0.18	-0.18
<b>Puducherry</b>	-1.84	-1.84	-1.84	-1.84	-1.84	-1.84	-3.55	-3.55	-3.55
<b>Punjab</b>	-4.64	-4.64	-4.64	-4.64	-4.64	-4.64	1.21	1.21	1.21
<b>Rajasthan</b>	-21.58	-21.58	-21.58	-21.58	-21.58	-21.58	-3.04	-3.04	-3.04
<b>Sikkim</b>	-1.99	-1.99	-1.99	-1.99	-1.99	-1.99	-2.78	-2.78	-2.78
<b>Tamil Nadu</b>	0.00	0.00	0.00	0.00	0.00	0.00	-0.09	-0.09	-0.09
<b>Tripura</b>	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	0.07	0.07	0.07
<b>Uttar Pradesh</b>	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.08	-0.08	-0.08
<b>Uttarakhand</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>West Bengal</b>	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.09	-0.09	-0.09

## Annexure VIII

Emission estimates (in million tCO<sub>2</sub>e) from 3B2. Cropland category from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Andhra Pradesh	0.10	0.10	0.10	0.15	0.15	0.15	-0.01	-0.01	-0.01
Arunachal Pradesh	0.11	0.11	0.11	-0.08	-0.08	-0.08	0.01	0.01	0.01
Assam	-1.04	-1.04	-1.04	-1.06	-1.06	-1.06	-1.06	-1.06	-1.06
Bihar	0.34	0.34	0.34	0.22	0.22	0.22	0.28	0.28	0.28
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.34	0.34	0.34	0.39	0.39	0.39	0.16	0.16	0.16
Dadra and Nagar Haveli	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goa	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
Gujarat	0.65	0.65	0.65	0.81	0.81	0.81	0.74	0.74	0.74
Haryana	0.32	0.32	0.32	0.33	0.33	0.33	0.32	0.32	0.32
Himachal Pradesh	-0.10	-0.10	-0.10	-0.09	-0.09	-0.09	-0.07	-0.07	-0.07
Jammu and Kashmir	-0.12	-0.12	-0.12	-0.13	-0.13	-0.13	-0.12	-0.12	-0.12
Jharkhand	0.15	0.15	0.15	0.18	0.18	0.18	0.15	0.15	0.15
Karnataka	-0.47	-0.47	-0.47	-0.36	-0.36	-0.36	-0.45	-0.45	-0.45
Kerala	-1.28	-1.28	-1.28	-1.29	-1.29	-1.29	-1.32	-1.32	-1.32
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	1.06	1.06	1.06	1.12	1.12	1.12	1.39	1.39	1.39
Maharashtra	0.83	0.83	0.83	0.80	0.80	0.80	0.45	0.45	0.45
Manipur	0.12	0.12	0.12	0.14	0.14	0.14	0.14	0.14	0.14

<b>Meghalaya</b>	0.04	0.04	0.04	0.01	0.01	0.01	0.03	0.03	0.03
<b>Mizoram</b>	0.13	0.13	0.13	0.11	0.11	0.11	0.10	0.10	0.10
<b>Nagaland</b>	0.07	0.07	0.07	0.10	0.10	0.10	0.14	0.14	0.14
<b>Odisha</b>	0.38	0.38	0.38	0.36	0.36	0.36	0.28	0.28	0.28
<b>Puducherry</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Punjab</b>	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
<b>Rajasthan</b>	0.72	0.72	0.72	0.75	0.75	0.75	1.06	1.06	1.06
<b>Sikkim</b>	-0.10	-0.10	-0.10	-0.02	-0.02	-0.02	0.01	0.01	0.01
<b>Tamil Nadu</b>	-0.32	-0.32	-0.32	-0.27	-0.27	-0.27	-0.32	-0.32	-0.32
<b>Tripura</b>	0.11	0.11	0.11	0.04	0.04	0.04	0.02	0.02	0.02
<b>Uttar Pradesh</b>	0.25	0.25	0.25	0.93	0.93	0.93	0.60	0.60	0.60
<b>Uttarakhand</b>	0.02	0.02	0.02	0.02	0.02	0.02	0.00	0.00	0.00
<b>West Bengal</b>	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.30	-0.30	-0.30



## Annexure IX

Emission estimates (in million tCO<sub>2</sub>e) from 3B3. Grassland category from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	-	-	-	-	-	-	-	-	-
Andhra Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arunachal Pradesh	0.08	0.08	0.08	0.04	0.04	0.04	0.09	0.09	0.09
Assam	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Bihar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chandigarh	-	-	-	-	-	-	-	-	-
Chhattisgarh	-	-	-	-	-	-	-	-	-
Dadra and Nagar Haveli	-	-	-	-	-	-	-	-	-
Daman and Diu	-	-	-	-	-	-	-	-	-
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gujarat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Haryana	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Himachal Pradesh	0.17	0.17	0.17	0.13	0.13	0.13	0.20	0.20	0.20
Jammu and Kashmir	0.11	0.11	0.11	0.05	0.05	0.05	0.14	0.14	0.14
Jharkhand	-	-	-	-	-	-	-	-	-
Karnataka	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Kerala	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lakshadweep	-	-	-	-	-	-	-	-	-
Madhya Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maharashtra	-	-	-	-	-	-	-	-	-
Manipur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

<b>Meghalaya</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Mizoram</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Nagaland</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Odisha</b>	-	-	-	-	-	-	-	-	-
<b>Puducherry</b>	-	-	-	-	-	-	-	-	-
<b>Punjab</b>	-	-	-	-	-	-	-	-	-
<b>Rajasthan</b>	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
<b>Sikkim</b>	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
<b>Tamil Nadu</b>	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
<b>Tripura</b>	-	-	-	-	-	-	-	-	-
<b>Uttar Pradesh</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Uttarakhand</b>	0.05	0.05	0.05	0.03	0.03	0.03	0.06	0.06	0.06
<b>West Bengal</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

## Annexure X

Emission estimates (in million tCO<sub>2</sub>e) from 3B5. Settlements category from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05
Arunachal Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assam	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Bihar	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Dadra and Nagar Haveli	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gujarat	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Haryana	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Himachal Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jammu and Kashmir	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jharkhand	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Karnataka	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Kerala	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Lakshadweep	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
Madhya Pradesh	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Maharashtra	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Manipur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

<b>Meghalaya</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Mizoram</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Nagaland</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Odisha</b>	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
<b>Puducherry</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Punjab</b>	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
<b>Rajasthan</b>	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
<b>Sikkim</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Tamil Nadu</b>	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
<b>Tripura</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Uttar Pradesh</b>	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06
<b>Uttarakhand</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>West Bengal</b>	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05

## Annexure XI

Emission estimates (in million tCO<sub>2</sub>e) from 3B6. Other Land category from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	0.51	0.51	0.51	0.39	0.39	0.39	0.45	0.45	0.45
Arunachal Pradesh	0.11	0.11	0.11	0.04	0.04	0.04	0.07	0.07	0.07
Assam	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Bihar	0.27	0.27	0.27	0.06	0.06	0.06	0.15	0.15	0.15
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.34	0.34	0.34	0.22	0.22	0.22	0.14	0.14	0.14
Dadra and Nagar Haveli	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goa	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Gujarat	0.36	0.36	0.36	0.40	0.40	0.40	0.50	0.50	0.50
Haryana	0.02	0.02	0.02	0.01	0.01	0.01	0.03	0.03	0.03
Himachal Pradesh	0.17	0.17	0.17	0.16	0.16	0.16	0.21	0.21	0.21
Jammu and Kashmir	1.05	1.05	1.05	0.93	0.93	0.93	1.02	1.02	1.02
Jharkhand	0.26	0.26	0.26	0.16	0.16	0.16	0.27	0.27	0.27
Karnataka	0.23	0.23	0.23	0.22	0.22	0.22	0.23	0.23	0.23
Kerala	0.02	0.02	0.02	0.05	0.05	0.05	0.02	0.02	0.02
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	0.81	0.81	0.81	0.40	0.40	0.40	0.74	0.74	0.74
Maharashtra	0.80	0.80	0.80	0.77	0.77	0.77	0.58	0.58	0.58
Manipur	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00

<b>Meghalaya</b>	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
<b>Mizoram</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Nagaland</b>	0.02	0.02	0.02	0.03	0.03	0.03	0.01	0.01	0.01
<b>Odisha</b>	0.37	0.37	0.37	0.24	0.24	0.24	0.24	0.24	0.24
<b>Puducherry</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Punjab</b>	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.03
<b>Rajasthan</b>	2.17	2.17	2.17	0.96	0.96	0.96	2.10	2.10	2.10
<b>Sikkim</b>	0.03	0.03	0.03	0.01	0.01	0.01	0.04	0.04	0.04
<b>Tamil Nadu</b>	0.13	0.13	0.13	0.11	0.11	0.11	0.11	0.11	0.11
<b>Tripura</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Uttar Pradesh</b>	0.25	0.25	0.25	0.23	0.23	0.23	0.21	0.21	0.21
<b>Uttarakhand</b>	0.11	0.11	0.11	0.09	0.09	0.09	0.14	0.14	0.14
<b>West Bengal</b>	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06

## Annexure XII

Emission estimates (in million tCO<sub>2</sub>e) from 3C. Aggregate Sources and non-CO<sub>2</sub> emissions sources on land sector from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.05	0.05
Andhra Pradesh	11.48	12.03	12.24	13.23	12.11	14.08	14.01	12.64	14.36
Arunachal Pradesh	0.39	0.38	0.37	0.38	0.39	0.41	0.42	0.43	0.44
Assam	5.77	5.41	5.54	5.89	6.02	6.21	6.25	6.14	6.14
Bihar	8.92	9.65	10.14	10.31	9.62	9.00	9.85	10.44	9.91
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	5.91	5.99	6.00	6.01	6.06	6.15	6.23	6.31	6.31
Dadra and Nagar Haveli	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
Goa	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.08	0.08
Gujarat	3.95	4.27	4.70	4.76	4.70	5.22	5.30	4.79	5.03
Haryana	4.13	4.25	4.49	4.66	4.75	4.84	5.00	5.00	4.87
Himachal Pradesh	0.15	0.15	0.15	0.16	0.15	0.15	0.16	0.16	0.16
Jammu and Kashmir	0.35	0.34	0.34	0.37	0.39	0.39	0.38	0.41	0.39
Jharkhand	2.48	2.65	2.69	2.70	2.35	1.98	2.23	2.46	2.43
Karnataka	3.84	3.90	3.97	4.25	4.57	4.91	5.29	4.48	4.39
Kerala	0.77	0.74	0.69	0.69	0.70	0.70	0.69	0.69	0.70

<b>Lakshadweep</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Madhya Pradesh</b>	3.90	4.21	4.43	4.51	4.75	4.91	5.20	5.38	5.80
<b>Maharashtra</b>	5.35	5.86	6.32	6.43	6.71	7.34	7.44	6.80	7.19
<b>Manipur</b>	0.35	0.34	0.35	0.34	0.34	0.38	0.42	0.34	0.40
<b>Meghalaya</b>	0.20	0.20	0.21	0.21	0.20	0.20	0.20	0.13	0.15
<b>Mizoram</b>	0.11	0.10	0.11	0.09	0.08	0.06	0.05	0.04	0.04
<b>Nagaland</b>	0.28	0.30	0.29	0.29	0.29	0.30	0.31	0.31	0.32
<b>Odisha</b>	9.15	9.15	8.94	8.70	8.69	9.16	8.97	8.88	9.12
<b>Puducherry</b>	0.11	0.11	0.10	0.09	0.09	0.09	0.08	0.07	0.07
<b>Punjab</b>	5.85	5.98	6.09	6.21	6.32	6.45	6.52	6.73	6.54
<b>Rajasthan</b>	1.94	2.11	2.26	2.31	2.33	2.70	2.93	3.07	3.03
<b>Sikkim</b>	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.04
<b>Tamil Nadu</b>	5.52	5.60	5.27	5.57	5.50	5.61	5.78	4.98	4.97
<b>Tripura</b>	0.52	0.50	0.50	0.49	0.47	0.49	0.51	0.50	0.48
<b>Uttar Pradesh</b>	17.73	18.16	18.31	18.74	18.46	18.51	19.00	19.40	18.94
<b>Uttarakhand</b>	0.81	0.84	0.88	0.86	0.85	0.88	0.86	0.85	0.86
<b>West Bengal</b>	12.66	13.93	13.96	14.34	14.05	12.81	13.48	13.82	13.64



## Annexure XIII

Emission estimates (in million tCO<sub>2</sub>e) from 3C1. Biomass Burning from Forest Land from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Andhra Pradesh	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Arunachal Pradesh	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Assam	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bihar	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dadra and Nagar Haveli	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Goa	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gujarat	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Haryana	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Himachal Pradesh	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Jammu and Kashmir	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Jharkhand	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Karnataka	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Kerala	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

<b>Lakshadweep</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Madhya Pradesh</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Maharashtra</b>	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
<b>Manipur</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Meghalaya</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Mizoram</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Nagaland</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Odisha</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Puducherry</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Punjab</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Rajasthan</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Sikkim</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Tamil Nadu</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Tripura</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Uttar Pradesh</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Uttarakhand</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>West Bengal</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

## Annexure XIV

Emission estimates (in million tCO<sub>2</sub>e) from 3C2. Biomass Burning from Cropland from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	0.24	0.25	0.28	0.28	0.22	0.26	0.26	0.26	0.27
Arunachal Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assam	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05
Bihar	0.13	0.17	0.17	0.18	0.16	0.17	0.23	0.27	0.25
Chandigarh	-	-	-	-	-	-	-	-	-
Chhattisgarh	0.05	0.05	0.05	0.05	0.04	0.05	0.06	0.06	0.06
Dadra and Nagar Haveli	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daman and Diu	-	-	-	-	-	0.00	0.00	0.00	0.00
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gujarat	0.17	0.17	0.20	0.19	0.16	0.19	0.20	0.17	0.21
Haryana	0.48	0.52	0.55	0.54	0.54	0.56	0.60	0.60	0.61
Himachal Pradesh	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03	0.03
Jammu and Kashmir	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06
Jharkhand	0.03	0.05	0.06	0.07	0.04	0.03	0.06	0.07	0.06
Karnataka	0.18	0.20	0.22	0.20	0.22	0.28	0.28	0.26	0.27
Kerala	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

<b>Lakshadweep</b>	-	-	-	-	-	-	-	-	-
<b>Madhya Pradesh</b>	0.11	0.12	0.11	0.12	0.13	0.13	0.17	0.20	0.20
<b>Maharashtra</b>	0.27	0.44	0.54	0.43	0.41	0.50	0.53	0.46	0.48
<b>Manipur</b>	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
<b>Meghalaya</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Mizoram</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Nagaland</b>	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01
<b>Odisha</b>	0.07	0.07	0.08	0.07	0.07	0.07	0.06	0.07	0.08
<b>Puducherry</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Punjab</b>	1.11	1.11	1.15	1.18	1.19	1.19	1.20	1.23	1.26
<b>Rajasthan</b>	0.11	0.12	0.14	0.15	0.13	0.15	0.17	0.17	0.16
<b>Sikkim</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Tamil Nadu</b>	0.22	0.27	0.26	0.23	0.22	0.23	0.27	0.23	0.23
<b>Tripura</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Uttar Pradesh</b>	1.40	1.47	1.48	1.49	1.47	1.53	1.63	1.67	1.69
<b>Uttarakhand</b>	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
<b>West Bengal</b>	0.21	0.22	0.22	0.22	0.22	0.21	0.22	0.23	0.24

## Annexure XV

Emission estimates (in million tCO<sub>2</sub>e) from 3C3. Direct N<sub>2</sub>O emissions from managed soils from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	3.44	3.55	3.69	4.04	4.11	4.57	4.74	4.39	4.87
Arunachal Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assam	0.22	0.24	0.25	0.27	0.30	0.33	0.36	0.36	0.36
Bihar	1.61	1.87	2.16	2.25	2.17	2.17	2.29	2.58	2.39
Chandigarh	0.00	-	-	-	-	-	-	-	-
Chhattisgarh	0.56	0.63	0.65	0.65	0.73	0.77	0.84	0.89	0.87
Dadra and Nagar Haveli	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Goa	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gujarat	1.96	2.17	2.45	2.56	2.63	2.90	2.88	2.53	2.69
Haryana	2.00	2.06	2.21	2.27	2.30	2.33	2.42	2.46	2.33
Himachal Pradesh	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Jammu and Kashmir	0.14	0.14	0.13	0.16	0.18	0.18	0.16	0.18	0.17
Jharkhand	0.20	0.22	0.22	0.21	0.22	0.20	0.26	0.27	0.22
Karnataka	1.75	1.81	1.88	2.03	2.25	2.41	2.80	2.34	2.24
Kerala	0.20	0.21	0.22	0.26	0.27	0.28	0.31	0.30	0.32

<b>Lakshadweep</b>	-	-	-	-	-	-	-	-	-
<b>Madhya Pradesh</b>	1.38	1.65	1.87	1.92	2.18	2.36	2.51	2.59	2.83
<b>Maharashtra</b>	2.48	2.82	3.00	3.17	3.47	3.87	3.90	3.43	3.68
<b>Manipur</b>	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.02	0.02
<b>Meghalaya</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Mizoram</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
<b>Nagaland</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Odisha</b>	0.57	0.61	0.64	0.70	0.71	0.71	0.76	0.76	0.75
<b>Puducherry</b>	0.05	0.06	0.05	0.04	0.04	0.05	0.04	0.03	0.03
<b>Punjab</b>	2.98	3.09	3.15	3.19	3.25	3.34	3.39	3.53	3.35
<b>Rajasthan</b>	1.44	1.57	1.67	1.70	1.73	2.00	2.17	2.29	2.26
<b>Sikkim</b>	0.00	0.00	0.00	-	-	-	-	-	-
<b>Tamil Nadu</b>	1.30	1.39	1.33	1.49	1.48	1.52	1.62	1.45	1.33
<b>Tripura</b>	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03
<b>Uttar Pradesh</b>	5.83	6.36	6.59	6.84	6.95	7.06	7.30	7.88	7.37
<b>Uttarakhand</b>	0.21	0.25	0.27	0.27	0.27	0.27	0.29	0.29	0.32
<b>West Bengal</b>	1.48	1.59	1.64	1.67	1.74	1.72	1.93	1.98	1.74

## Annexure XVI

Emission estimates (in million tCO<sub>2</sub>e) from 3C4. Indirect N<sub>2</sub>O emissions from managed soils from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	0.87	0.90	0.94	1.02	1.04	1.16	1.20	1.11	1.24
Arunachal Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assam	0.05	0.06	0.06	0.07	0.08	0.08	0.09	0.09	0.09
Bihar	0.41	0.47	0.55	0.57	0.55	0.55	0.58	0.65	0.61
Chandigarh	0.00	-	-	-	-	-	-	-	-
Chhattisgarh	0.14	0.16	0.17	0.16	0.18	0.20	0.21	0.23	0.22
Dadra and Nagar Haveli	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gujarat	0.50	0.55	0.62	0.65	0.67	0.73	0.73	0.64	0.68
Haryana	0.51	0.52	0.56	0.58	0.58	0.59	0.61	0.62	0.59
Himachal Pradesh	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Jammu and Kashmir	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
Jharkhand	0.05	0.06	0.05	0.05	0.06	0.05	0.07	0.07	0.05
Karnataka	0.44	0.46	0.48	0.51	0.57	0.61	0.71	0.59	0.57
Kerala	0.05	0.05	0.06	0.07	0.07	0.07	0.08	0.08	0.08

<b>Lakshadweep</b>	-	-	-	-	-	-	-	-	-
<b>Madhya Pradesh</b>	0.35	0.42	0.47	0.49	0.55	0.60	0.64	0.66	0.72
<b>Maharashtra</b>	0.63	0.71	0.76	0.80	0.88	0.98	0.99	0.87	0.93
<b>Manipur</b>	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01
<b>Meghalaya</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Mizoram</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Nagaland</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Odisha</b>	0.15	0.15	0.16	0.18	0.18	0.18	0.19	0.19	0.19
<b>Puducherry</b>	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
<b>Punjab</b>	0.76	0.78	0.80	0.81	0.82	0.85	0.86	0.89	0.85
<b>Rajasthan</b>	0.37	0.40	0.42	0.43	0.44	0.51	0.55	0.58	0.57
<b>Sikkim</b>	0.00	0.00	0.00	-	-	-	-	-	-
<b>Tamil Nadu</b>	0.33	0.35	0.34	0.38	0.38	0.39	0.41	0.37	0.34
<b>Tripura</b>	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01
<b>Uttar Pradesh</b>	1.48	1.61	1.67	1.74	1.76	1.79	1.85	2.00	1.87
<b>Uttarakhand</b>	0.05	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08
<b>West Bengal</b>	0.38	0.40	0.42	0.42	0.44	0.44	0.49	0.50	0.44



## Annexure XVII

Emission estimates (in million tCO<sub>2</sub>e) from 3C5. Rice Cultivation from 2005 to 13:

States/ Union Territory	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman and Nicobar Island	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03
Andhra Pradesh	6.91	7.29	7.30	7.86	6.71	8.07	7.77	6.84	7.95
Arunachal Pradesh	0.37	0.36	0.35	0.36	0.37	0.40	0.40	0.41	0.43
Assam	5.46	5.07	5.19	5.50	5.60	5.74	5.74	5.63	5.63
Bihar	6.75	7.11	7.24	7.28	6.71	6.08	6.72	6.91	6.65
Chandigarh	-	-	-	-	-	-	-	-	-
Chhattisgarh	5.17	5.15	5.13	5.15	5.10	5.13	5.12	5.13	5.15
Dadra and Nagar Haveli	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goa	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.06
Gujarat	1.31	1.36	1.42	1.36	1.24	1.38	1.48	1.45	1.43
Haryana	1.12	1.12	1.15	1.27	1.31	1.34	1.34	1.31	1.33
Himachal Pradesh	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Jammu and Kashmir	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Jharkhand	2.17	2.30	2.33	2.34	2.00	1.68	1.83	2.02	2.07
Karnataka	1.46	1.42	1.39	1.50	1.52	1.60	1.50	1.29	1.31
Kerala	0.50	0.46	0.40	0.36	0.35	0.33	0.28	0.30	0.29

<b>Lakshadweep</b>	-	-	-	-	-	-	-	-	-
<b>Madhya Pradesh</b>	2.05	2.02	1.96	1.98	1.89	1.81	1.88	1.93	2.04
<b>Maharashtra</b>	1.95	1.87	2.00	2.00	1.93	1.96	2.00	2.02	2.08
<b>Manipur</b>	0.30	0.30	0.30	0.30	0.30	0.36	0.39	0.31	0.37
<b>Meghalaya</b>	0.19	0.18	0.19	0.19	0.19	0.18	0.18	0.11	0.13
<b>Mizoram</b>	0.10	0.10	0.10	0.08	0.07	0.05	0.04	0.03	0.03
<b>Nagaland</b>	0.26	0.28	0.27	0.28	0.27	0.28	0.29	0.29	0.30
<b>Odisha</b>	8.36	8.31	8.06	7.75	7.73	8.20	7.96	7.85	8.09
<b>Puducherry</b>	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
<b>Punjab</b>	0.99	0.99	0.98	1.02	1.05	1.06	1.06	1.07	1.07
<b>Rajasthan</b>	0.02	0.01	0.02	0.03	0.04	0.03	0.03	0.03	0.03
<b>Sikkim</b>	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04
<b>Tamil Nadu</b>	3.68	3.59	3.35	3.47	3.42	3.46	3.48	2.93	3.06
<b>Tripura</b>	0.49	0.47	0.47	0.46	0.44	0.46	0.47	0.45	0.44
<b>Uttar Pradesh</b>	9.03	8.72	8.58	8.67	8.28	8.13	8.23	7.85	8.02
<b>Uttarakhand</b>	0.48	0.45	0.45	0.45	0.43	0.45	0.42	0.40	0.38
<b>West Bengal</b>	10.59	11.72	11.68	12.03	11.66	10.44	10.84	11.11	11.22