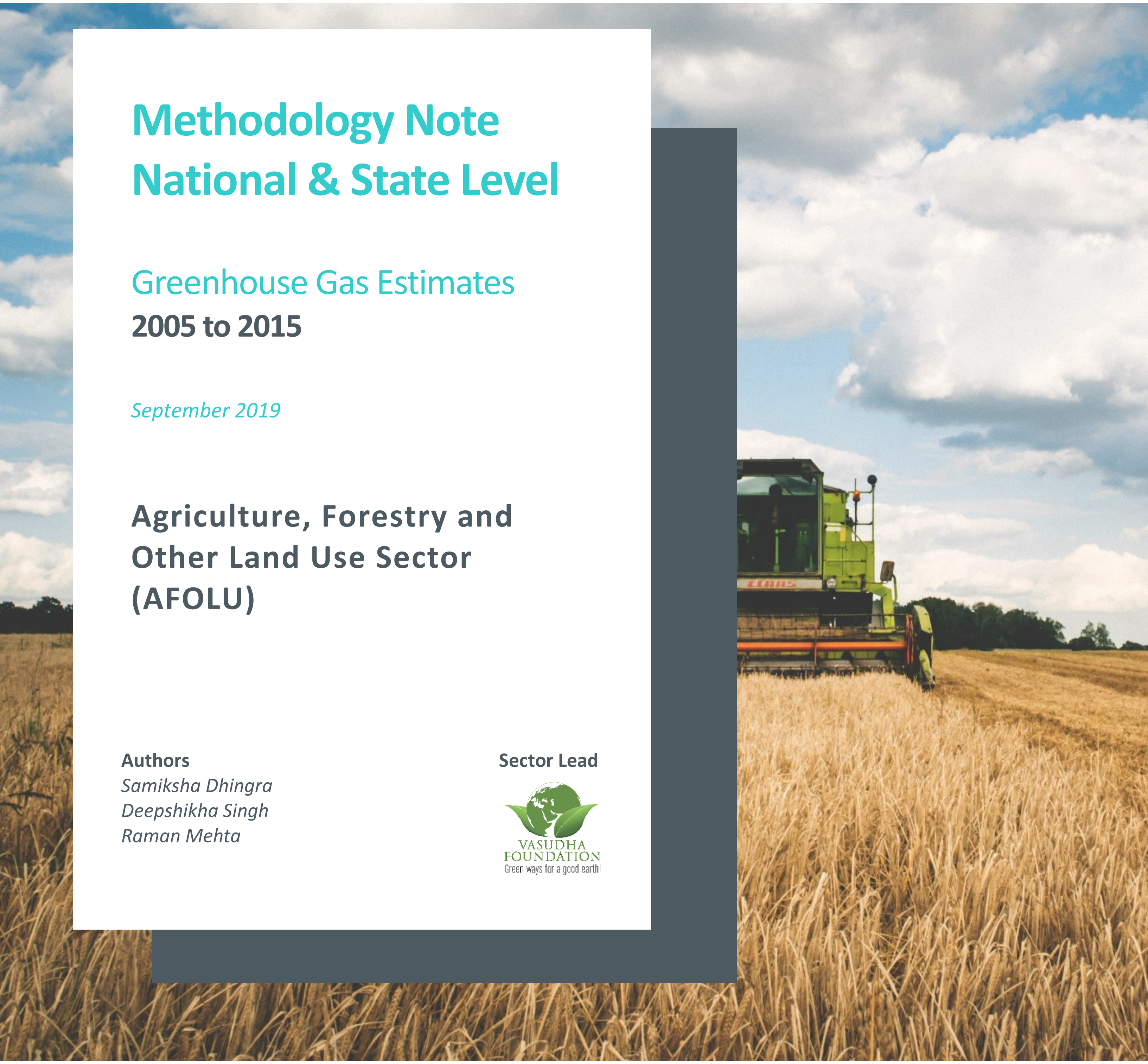
GHG Platform INDIA



Methodology Note
National & State Level

Greenhouse Gas Estimates
2005 to 2015

September 2019

Agriculture, Forestry and Other Land Use Sector (AFOLU)

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VASUDHA FOUNDATION
Green ways for a good earth!

An initiative supported by
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Version Information / Revision history

Version	Date	Brief description on changes from previous version
3.0	25 September 2019	This document contains information on assumptions and the methodology followed to estimate emissions from the energy sector at the national level for the extended time period of 2005-15.
2.0	28 Sep 2017	This document contains information on assumptions and the methodology followed to estimate emissions from the energy sector at the national level for the extended time period of 2005-13.
1.0	15 July 2016	This document contains information on assumptions and the methodology followed to estimate emissions from the energy sector at the national level for the time period of 2007-13.

Foreword

On December 2015, the international community took a significant step towards addressing the global challenge of climate change by endorsing the Paris Agreement at the 21st session of the Conference of Parties (COP) to the United Nations Framework Convention on Climate Change. The milestone Paris Agreement will serve as a foundation for concerted international action to address the threat posed by climate change.

It is now more than clear that climate change is not the responsibility of national government only. It will impact every aspect of the society and therefore, role of non-state actors are more crucial in these testing times. Non-state actors like civil societies and research organizations can inform and help national government in devising robust climate actions and strategies. The first step to devise a robust climate action plan is creating greenhouse gas (GHG) estimates for all relevant economic sectors for recent years.

With the above background, few Indian research organizations came together to form GHG Platform – India, which is a civil society initiative providing independent estimation and analysis of India's GHG emissions. The platform is conceptualized with a noble intention to assist the national government by helping address existing data gaps and data accessibility issues, extending beyond the scope of national inventories, and increasing the volume of analytics and policy dialogue on India's GHG emissions sources, profile, and related policies.

The platform hosted GHG estimates for all key economic sectors for the period of 2005 – 2013 by accounting carbon dioxide, methane and nitrous oxide, both at national and state level. In the present edition, the time series have been extended and the report now presents GHG estimates for the period 2005 – 2015/16 across all key economic sectors. The report also highlights the trend in GHG emissions across the sectors and transparently documents all the assumptions, activity data and emission factors that were used to arrive at GHG estimates.

The GHG estimates presented in the report follows 2006 IPCC guidelines for national GHG inventories and associated good practice guidance. Further, the report went through rigorous peer review and independent technical review process to ensure accuracy, transparency, consistency, completeness and relevance. On behalf of the platform, we hope that the report will be useful to all relevant stakeholders.

Credits

Led and coordinated by

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We also express our deep gratitude to Shakti Sustainable Energy Foundation for the grant support. to the platform for the third year in a row.

We acknowledge with gratitude, WRI India for providing us technical guidance in undertaking the study and conducting a comprehensive review of this report.

We further would like to acknowledge and express our gratitude to the National Remote Sensing Centre, Hyderabad for providing us the Land Use Change Matrix for the period of 2006-2013.

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Executive Summary

Key Highlights

- GHG emissions from this sector are dominated by two key source categories, viz., enteric fermentation and rice cultivation, which together accounts for approx. 76% of the GHG emissions in 2015 (excluding Land sub-sector). However, Land as a whole was a net remover of GHG emissions and removed nearly ~36% of the total emissions in 2015.
- CH_4 contributes maximum to the GHG emissions with contributing percentage of ~80% within the AFOLU sector followed by N_2O (~14%) and CO_2 (~6%) in 2015[1].

ES 1. Background information of GHG emission estimates

The AFOLU sector contributed almost 245.39 $MtCO_2e$[2] to the total GHG emissions of India in 2015. The detailed emissions of each of the key source categories and sub-categories is given in Table 1 below as per the IPCC format.

Table ES 1: Overview of GHG Emission Estimates by Gases and Sector for AFOLU sector[3]

IPCC ID	Key Source category	GHG Emissions (2015)			
		$MtCO_2$	$MtCH_4$	MtN_2O	$MtCO_2e$
3	**AFOLU**	**-117.18**	**14.53**	**0.178**	**243.128**
3A	**Livestock**		**10.86**	**0.002**	**228.75**
3A1	Enteric Fermentation		9.86		206.97
3A2	Manure Management		1.00	0.002	21.78
3B	**Land**	**-117.18**			**-117.18**
3B1	Forest Land	-124.44			-124.44
3B2	Cropland	-1.32			-1.32
3B3	Grasslands	0.66			0.66
3B5	Settlements	0.49			0.49
3B6	Other Lands	7.43			7.43
3C	**Aggregate Sources and non-CO_2 emission sources on land**		**3.67**	**0.176**	**131.56**
3C1a	Emissions from biomass burning in forest lands		0.21	0.003	5.27
3C1b	Emissions from biomass burning in croplands		0.21	0.005	6.16
3C4	Direct N_2O emissions from managed soils			0.134	41.46
3C5	Indirect N_2O emissions from managed soils			0.034	10.52
3C7	Rice Cultivation		3.24		68.14

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

[2] Million tCO_2 equivalent

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

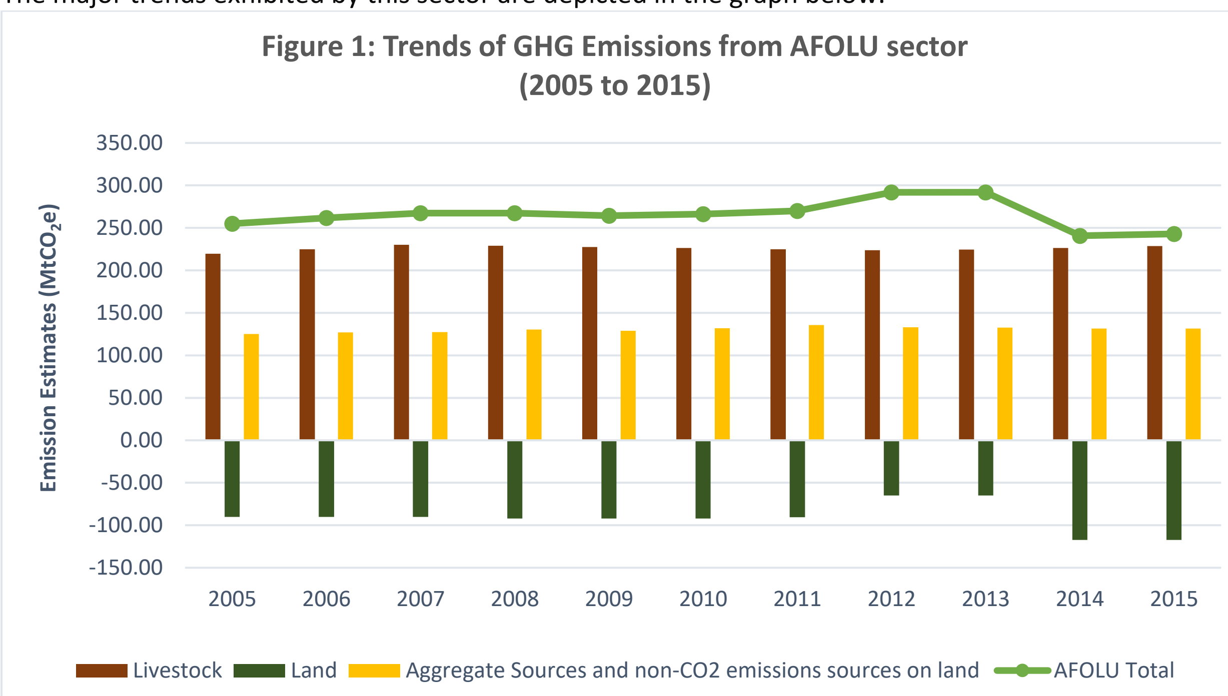
ES 2. Summary of GHG sources and sinks

GHG emissions from the AFOLU sector mainly arises from three sub-sectors namely, Livestock, Land and Aggregate sources and non-CO_2 emissions sources on land. Notably, the Land sub-sector was a net remover of GHGs while the other two sub-sectors were net emitter. If the emissions were considered excluding the removals from the Land sub-sector, Livestock had the major contribution of 63% while Aggregate sources and non-CO_2 emissions sources on land represented 37% of the remaining AFOLU emissions from 2005 to 2015. Livestock sub-sector is the major contributor because India has the highest cattle population in terms of density and absolute numbers. Notably, in 2015 the Land sub-sector removed nearly 36% of the GHG emissions of the AFOLU sector in India from the atmosphere.

ES 3. Summary of GHG trend

In general, during the period of estimation, the GHG emissions from AFOLU sector have decreased, primarily due to increased removals of CO_2 from the forests. However, a bump in the overall emissions was registered from 2012 to 2013 owing to decreased removals from the land sub-sector[4]. The India specific GHG emissions value has been attained by adding up the state values for all the sub-sectors.

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



[4] GHG Platform India observes a dip in removals from 2012 to 2013 however, the BUR2 observes an increment from the same years in consideration. Commenting on the rationale for such increment is not possible as data and its source is unknown.

1. Introduction and Background

1.1 Context

The GHG estimates for the AFOLU sector being presented in this document are a part of a collaborative effort by GHG Platform India[5] to build year on year estimates by collating and interpreting data that is available in the public domain. This can hopefully lead to greater discussion and debate on climate change policies and practises in India. The platform seeks to add value to various ongoing GHG estimation efforts by helping address existing data gaps and data accessibility issues, extending beyond the scope of national inventories, and by increasing the volume of analytics and policy dialogue on India's Greenhouse Gas emissions sources, profile, and related policies.

1.2 GHG Coverage

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

Table 1.2: Global warming potential as per IPCC assessment reports

Name of the gas	Formula	Global Warming Potential (GWP)	
		SAR	AR5
Carbon dioxide	CO_2	1	1
Methane	CH_4	21	28
Nitrous oxide	N_2O	310	265

Source: SAR Values from (IPCC 2006); AR5 Values from (IPCC, 2014)

1.3 Key economic sectors covered

Vasudha Foundation has estimated the GHG emissions for the AFOLU Sector based on the 2006 IPCC Guidelines for National GHG Inventories with all relevant calculation approaches. As indicated previously, specific source sub-categories included in the emission estimates are:

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

[5] http://www.ghgplatform-india.org/

- 3C4. Direct N_2O emissions from managed soils
- 3C5. Indirect N_2O emissions from managed soils
- 3C7. Rice Cultivation

The emissions for all these categories have been estimated for the period 2005-2015. The emission estimates are based primarily on aggregated secondary data collected by Vasudha Foundation from nationally acceptable published documents and reports of relevant government departments, nodal agencies and research institutions in the AFOLU sector. Interactions were held with external experts and representatives to seek inputs on data availability and the emission estimation approach where required.

1.4 Boundary of GHG estimates

In this study, GHG emissions have been estimated at state level and then aggregated to national level for the AFOLU sector. The greenhouse gases covered under this analysis are namely Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) with total carbon dioxide equivalent (CO_2e). Section 1.3 of the present report provides the details of key source categories covered under the AFOLU sector.

1.5 Reporting Period

Emissions are estimated from 2005 to 2015 in this study. The base year for these emission estimates is 2005. From the perspective of data availability and India's NDC, which chooses 2005 as the base year for its pledges, the year 2005 is of historical and administrative importance and hence, has been considered as the base year for these calculations.

1.6 Outline of GHG estimates

This exercise entails a time-series emission estimate for sectors mentioned in section 1.3 at the state (sub-national) level, for the period 2005 to 2015. The estimations were based on literature review and followed the 2006 IPCC Guidelines for National GHG Inventories and other internationally acceptable guidance. Emissions were estimated based on fuel sources, sub-sectoral activities, and emission factors. Chapter 2 provides the trends in GHG emissions and the key drivers of emission trends in various sectors. Chapter 3 provides the overview of the AFOLU sector, detailed analysis of the sectoral emissions, methodology involved, source of activity data, and emission factors. Chapter 4 broadly compares the emissions estimated for 2007, 2010, and 2014 with the emissions reported by MoEFCC.

1.7 Institutional Information

Vasudha Foundation, New Delhi is involved in preparation of emission estimates from the AFOLU sector for GHG Platform India. Given below is the technical competence of the staff involved in this exercise:

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1.8 Data collection process and Storage

To ensure estimates from the emission source categories represent the AFOLU sector in India, state and country-specific data has been used in the assessment to the extent possible. The data has been primarily collected through an extensive secondary research. The data collection exercise focussed on gathering reliable information from peer-reviewed published documents and reports of relevant government departments, nodal agencies and research institutions including Ministry of Agriculture and Farmers Welfare (MoAFW), Ministry of Statistics and Programme Implementation (MOSPI), Forest Survey of India (FSI) and National Remote Sensing Centre (NRSC) among others. The data collected was in various forms and units and has been assessed to ensure its applicability within the emission estimation boundaries and subsequently processed for further use. All the data collected for emission estimation was in the form of a soft copy, no data was obtained in its hard form.

The emission estimation method, reporting period, boundaries, year-wise activity data, emission factors and relevant parameters along with data sources and any assumptions to address gaps, and national-level emission results have been transparently recorded in this reporting document and in excel spreadsheets to provide clear understanding and to enable reconstruction of the emission estimations as required. All information collected and compiled for the emission estimates has been archived electronically in separate folders for future use as needed along with copies of relevant references or data sources. The final emission estimates and reporting documents are published and available on the GHG Platform India website (www.ghgplatform-india.org).

1.9 Quality Control (QC) and Quality Assurance (QA)

To prepare the expanded national-level emission estimates, secondary data research was undertaken for the years 2005 to 2015 for all sub-sectors with regards to parameters such as agricultural production, livestock population, land use change matrix etc. Interactions have been held with relevant experts as needed. The aggregate sources emission estimates for 2005 to 2013 have been revisited and have been refined based on updated information on activity data and related parameters. The emission estimation process involved regular discussions and reporting of progress between the project partners. Reporting formats were also developed for clear and transparent documentation and reporting of the methodology and results of the emission estimation.

Quality controls applied to the emission estimates include generic quality checks in terms of the calculations, processing, consistency, and clear recording and documentation as follows:

- The input activity data for each emission source sub-category has been selected from that available in different datasets by duly factoring in its relative time-series consistency and temporal and spatial applicability;
- The input data in the calculation sheets has been checked internally for transcription errors on a sample basis for all the 3 key source categories;
- The calculation spreadsheets have been checked for correct application of formulae, activity and factors and to ensure that calculations are correct. Manual calculations have been carried out for a part of the emission estimates in all 3 key source categories to verify the spreadsheets results;
- Appropriate recording, conversions, processing and consistency of measurement units for parameters and emission has been checked across the reporting period;
- The emission estimates of each year of the reporting period have been compared on a year on year basis and with the published GoI inventory to check for consistency in trends and detect any major deviations which cannot be correlated with corresponding changes in activity data and/or emission factors;
- The emission calculation equations, relevant data and parameter values used, intermediate formulae and cells wherein these are linked, and emission results are clearly depicted in the calculation spreadsheets for all 3 key source categories;
- The reporting document has been checked to confirm all relevant references and secondary sources for activity data and emission factors have been included and documented;
- Emission source categories and sub-categories included and excluded in the emission estimates have been transparently reported. Any known gaps in the emission estimates along with rationale of assumptions used to address data gaps have been clearly indicated in the reporting document;

1.10 General assessment of completeness

Table 1.10: Details of key source categories excluded from present GHG estimates

Sector	IPCC ID	Category description	Reason for exclusion
AFOLU	3B4	Wetlands	Lack of availability of activity data
	3C1c	Emissions from Biomass Burning in Grassland	Lack of availability of activity data
	3C1d	Emissions from Biomass Burning in Other Land	Negligible incidences of biomass burning in other land
	3C2	Liming	Lack of availability of activity data
	3C3	Urea Fertilization	Lack of availability of activity data
	3C6	Indirect N_2O emissions from Manure Management	Lack of availability of activity data

Emissions from the source categories mentioned above are not included in the estimates due to the lack of reliable data for these sources 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.

Due to lack of availability of activity data and emission factors specific to IPCC 2006 methodology guidance, emissions from biomass burning in forestland and cropland are limited to the methodology available in NATCOM II[6] in this assessment.

1.11 Recommended Improvements

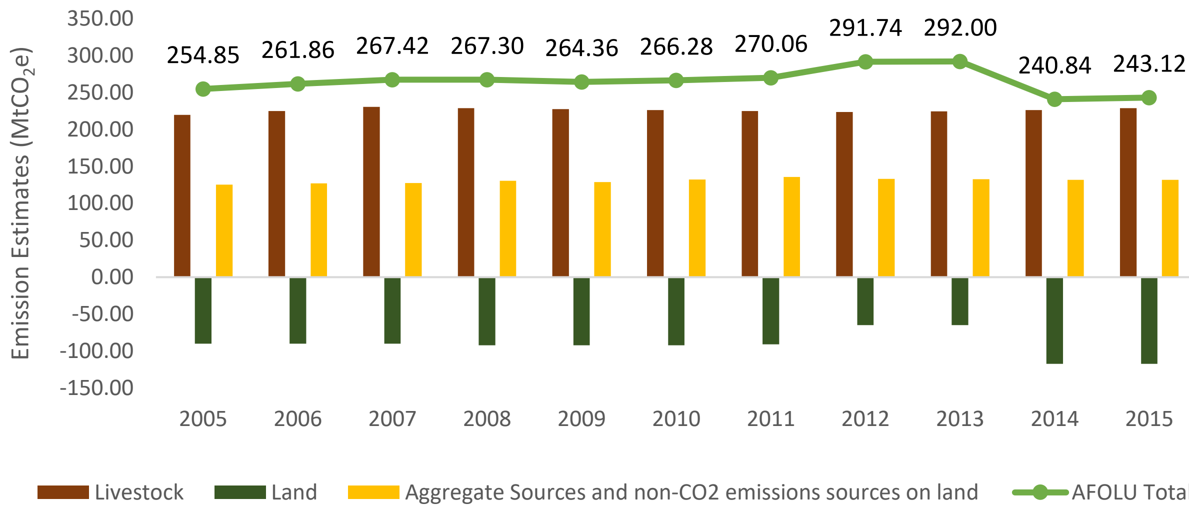
The major recommendations that emanate from this exercise are as follows:

- While it is difficult for the platform to address the gap on its own, there is a need to engage with more relevant authorities to begin doing the apt surveys to collect the required data regarding the AFOLU subsectors.
- More specific emission factors, disaggregated at the state level if possible, need to be developed to make more precise calculations for AFOLU sector as a whole.

2. Trends in GHG emissions

2.1 Trend in aggregated GHG emissions

Figure 2: Trends of GHG Emissions from AFOLU sector (2005 to 2015)



The above graph shows that the total emissions from AFOLU sector followed a linear trend from 254.85 $MtCO_2e$ in 2005 to 243.12 $MtCO_2e$ in 2015. A slight rise in the overall emissions was registered in 2012 and 2013 which can be attributed to slight decrease in absorption of GHGs from India's forests due to reduction in net carbon stock from 2011 to 2013.

Table 2.1: AFOLU Sector trend of GHG Emission estimates by source categories

Key source Category	Emissions in million tCO_2e				%change		
	2005	2007	2010	2015	2005-2007	2005-2010	2005-2015

[6] http://www.environmentportal.in/files/NATCOM.pdf

Livestock	219.79	230.28	226.29	228.75	4.78%	2.96%	4.08%
Land	-90.20	-90.20	-92.07	-117.18	0.00%	2.03%	29.92%
Aggregate Sources and non-CO_2 emission sources on land	125.26	127.34	132.06	131.56	1.66%	5.43%	5.03%

Emissions from the livestock sub-sector i.e. enteric fermentation and manure management contribute a major share in the AFOLU sector. The emissions from this sector saw an insignificant rise in 2007 after which they were found to decrease due to decline in the livestock population from 2007 onwards. However, emissions from the livestock sub-sector grew at a nominal CAGR of 0.43% from 219.05 MtCO^{2}e in 2005 to 228.73 MtCO_2e in 2015 and were mostly flat.

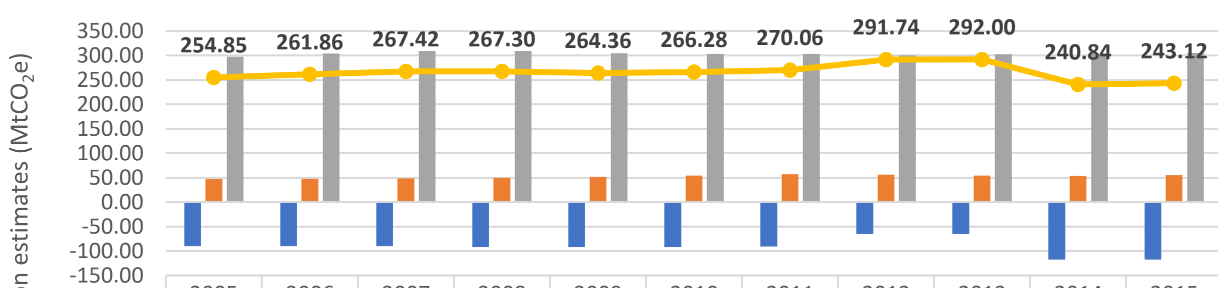
As seen in the graph above, CO_2 removals from the Land sub-sector followed a linear trend from 2005 to 2011 and saw a dip in 2012 and 2013. This deterioration in emission removals from -90.71 MtCO_2e in 2011 to -65.09 MtCO_2e in 2012 can be attributed to decrease in carbon stock in forest lands. However, a significant rise in the overall CO_2removals was observed from 2014 (-117.18 MtCO_2e) onwards.

Emissions from the category (3C) Aggregate sources and non-carbon dioxide emission sources on land were found to increase marginally over the years with a CAGR of 0.41% from 124.77 MtCO_2e in 2005 to 129.99 MtCO_2e in 2015. Rice cultivation had the major share of ~51% in the total emissions of this sub-sector followed by emissions from the Agricultural Soils (~40%).

2.2 Trend in GHG emissions by type of GHG

The Trend of GHG emissions by the type of GHG is given below. CH_4 remained the maximum contributor to the emissions of the AFOLU sector across all the years. Significant emissions are also registered from N_2O gas. Notably, CO_2 gas was a net remover of GHG emissions throughout the reference period.

Figure 3: Trend of GHG Emissions by type of GHG in the AFOLU sector (2005 to 2015)

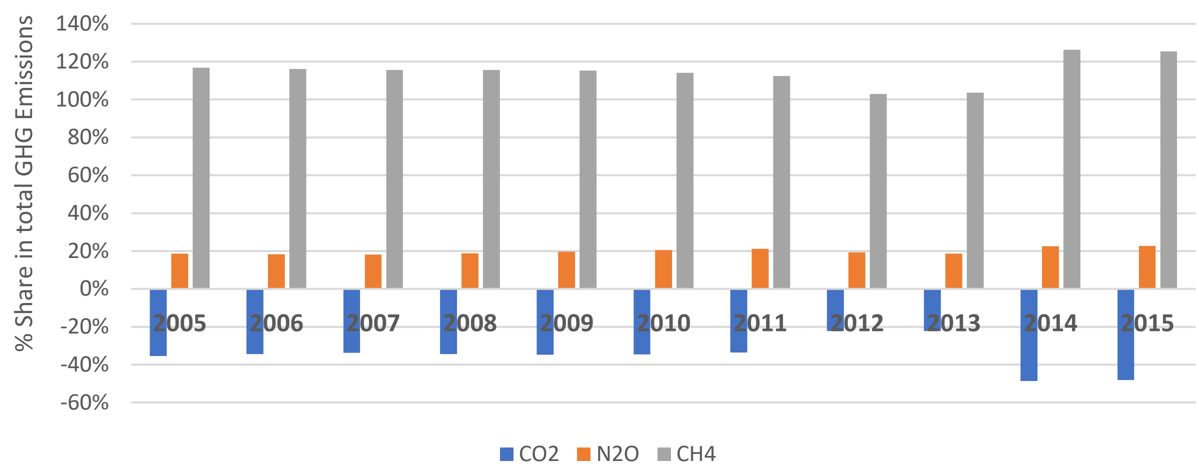


	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
CO2	-90.20	-90.20	-90.20	-92.07	-92.07	-92.07	-90.71	-65.09	-65.09	-117.18	-117.18
N2O	47.34	47.86	48.37	50.15	51.76	54.71	57.35	56.49	54.28	54.05	55.19
CH4	297.71	304.20	309.25	309.23	304.67	303.64	303.42	300.34	302.82	303.97	305.12
Total	254.85	261.86	267.42	267.30	264.36	266.28	270.06	291.74	292.00	240.84	243.12

CO2 N2O CH4 Total

The overall share of each greenhouse gas (GHG) in the total AFOLU emissions is illustrated below.

Figure 4: Overall Contribution of each Gas in the AFOLU sector Emissions (2005 to 2015)



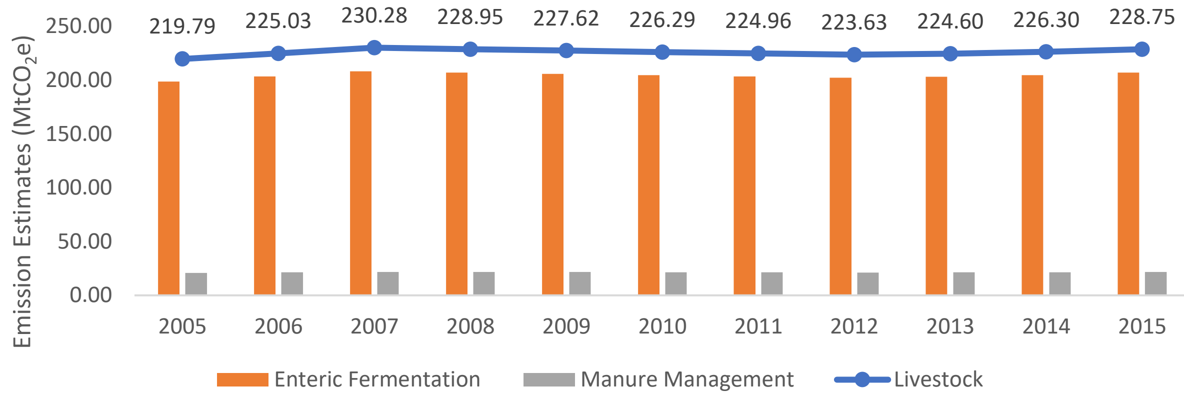
Distribution of emissions from different key source categories is given in the table 2.2 below.

Table 2.2: AFOLU Sector distribution of emission contribution by sector for 2015				
IPCC ID	**Key source category**	**%CO_2**	**%CH_4**	**%N_2O**
3A	Livestock		74.74%	1.26%
3B	Land	100% (Removals)	-	-
3C	Aggregate Sources and non-CO_2 emission sources on land		25.26%	98.74%

2.3 Key drivers of the emission trends in AFOLU sector

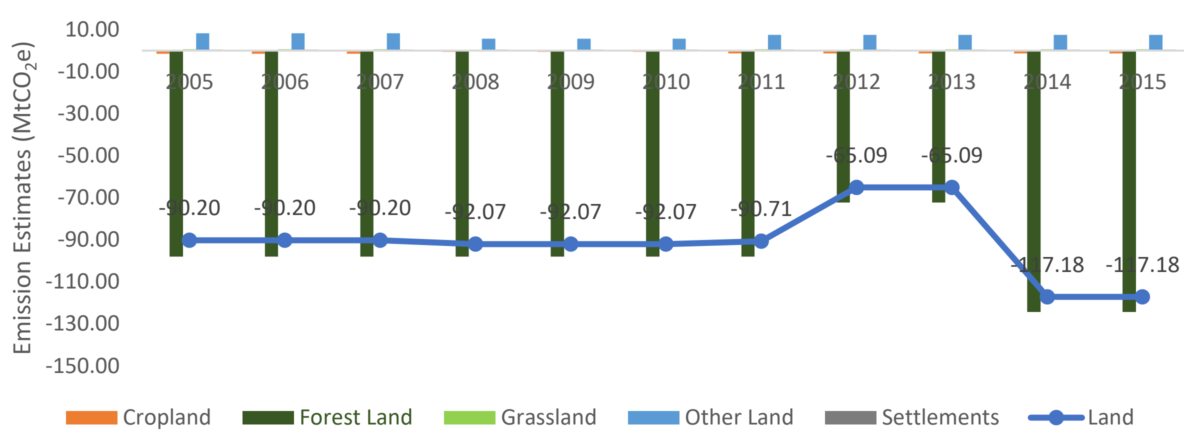
The key drivers of emissions from the AFOLU sector are livestock population, forests, rice cultivation and fertilizer use. Since these drivers are either stagnant or declining, the overall emissions of the AFOLU sector have remained stagnant. The emission estimates from each of the key category sources is elaborated below.

Figure 5: Trends of GHG Emissions from (3A) Livestock Sub-sector (2005 to 2015)



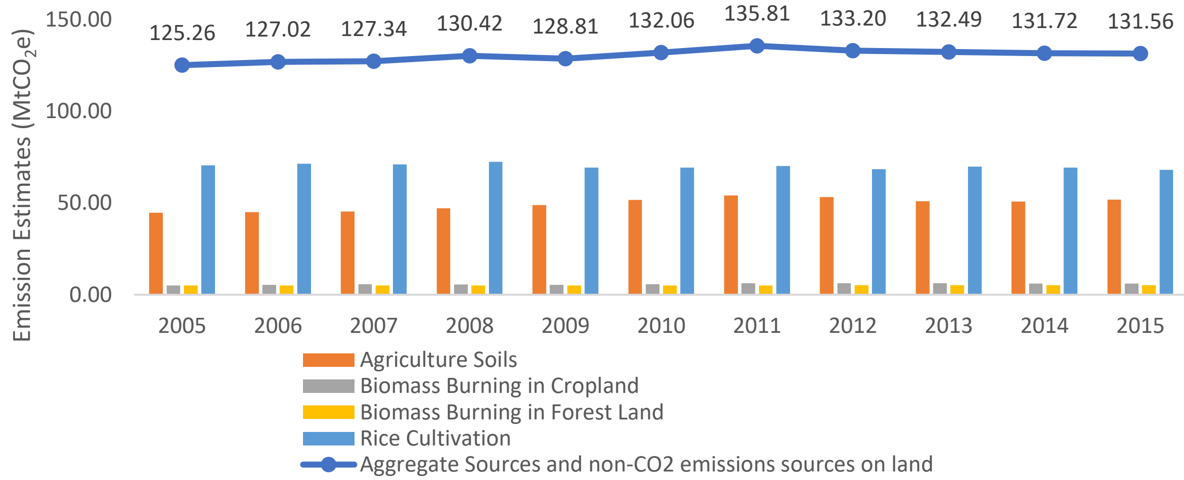
Emissions from the livestock category i.e. enteric fermentation and manure management contribute a major share in the AFOLU sector. The emissions from this sector saw an insignificant rise in 2007 after which they were found to decrease due to decline in the livestock population from 2007 onwards. However, emissions from the livestock category grew at a nominal CAGR of 0.40% from 219.79 $MtCO^2e$ in 2005 to 228.75 $MtCO_2e$ in 2015 and were mostly flat (Figure 5).

Figure 6: Trends of GHG Emissions from the (3B) Land Sub-sector (2005 to 2015)



As seen in the figure 6 above, CO_2 removals from the Land sub-sector followed a linear trend from 2005 to 2011 and saw a dip in 2012 and 2013. This deterioration in emission removals from 90.71 $MtCO_2e$ to -65.09 $MtCO_2e$ from 2011 to 2012 can be attributed to decrease in carbon stock in forest lands. However, a significant rise in the overall CO_2removals was observed from 2014 (-117.18 $MtCO_2e$) onwards.

Figure 7: Trends of GHG Emissions from (3C) Aggregate Sources and non-CO_2 Emissions Sources on Land (2005 to 2015)



Emissions from the category (3C) Aggregate sources and non-carbon dioxide emission sources on land were found to increase marginally over the years with a CAGR of 0.41% from 124.77 $MtCO_2e$ in 2005 to 129.99 $MtCO_2e$ in 2015 (Figure 7). Rice cultivation had the major share of ~54% in the total emissions of this category followed by emissions from the Agricultural Soils (~38%).

From the above discussion it can be concluded that the most important contribution of GHG emissions in the AFOLU sector are from CH_4 emissions of livestock and rice cultivation.

3. AFOLU

3.1 Overview of the sector

Emission estimates for the AFOLU sector have been provided as under for the base year (2005) and the reporting year (2015):

Table 3.1: GHG estimates for base year and current year

IPCC ID	Source Category	GWP – SAR			GWP – AR5		
		2005	**2015**	**% change**	**2005**	**2015**	**% change**
3A	**Livestock**	219.79	228.75	4.08%	292.80	304.66	4.05%
3B	**Land**	-90.20	-117.18	29.92 % (Removals)	-90.20	-117.18	29.91% (Removals)
3C	**Aggregate Sources and non-CO_2 emission sources on land**	125.26	131.56	5.03%	129.94	135.01	3.89%

Between 2005 and 2015, there has been a decrease of approximately 0.48% compounded annually in the CO_2 equivalent emissions from this sector for India. This is primarily due to increase of carbon dioxide removals from the atmosphere by the forests.

3.2 Analysis of sectoral emissions

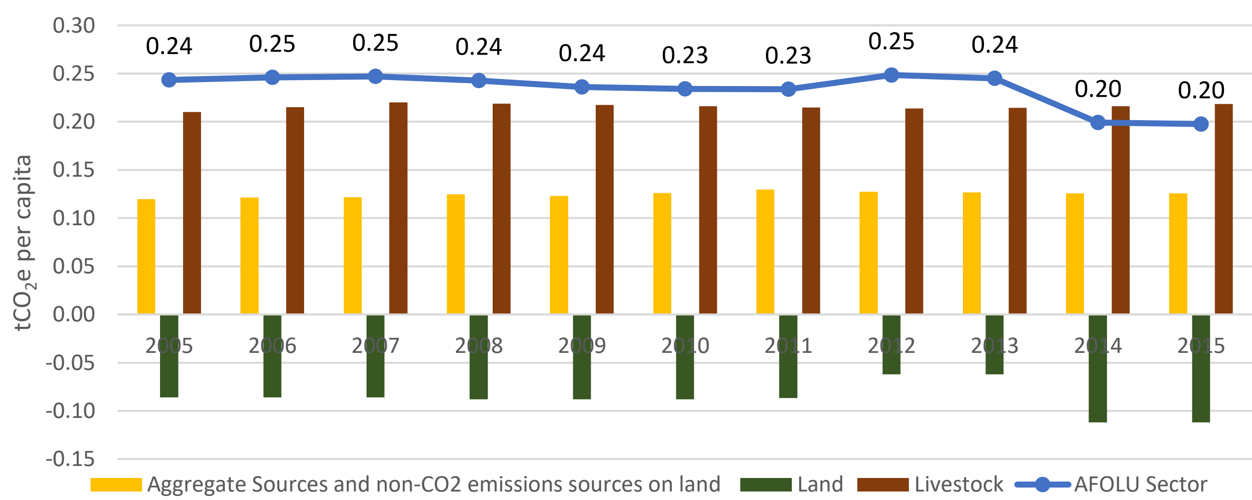
Category wise analysis of sectoral emissions is as follows:

Table 3.2: Category wise Analysis of GHG Emissions Estimates (2005-2015) in million tCO_2e

IPCC ID	Category description	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
3A	Livestock	219.79	225.03	230.28	228.95	227.62	226.29	224.96	223.63	224.60	226.30	228.75
3B	Land	-90.20	-90.20	-90.20	-92.07	-92.07	-92.07	-90.71	-65.09	-65.09	-117.18	-117.18
3C	Aggregate Sources and non-CO2 emissions sources on land	125.26	127.02	127.34	130.42	128.81	132.06	135.81	133.20	132.49	131.72	131.56

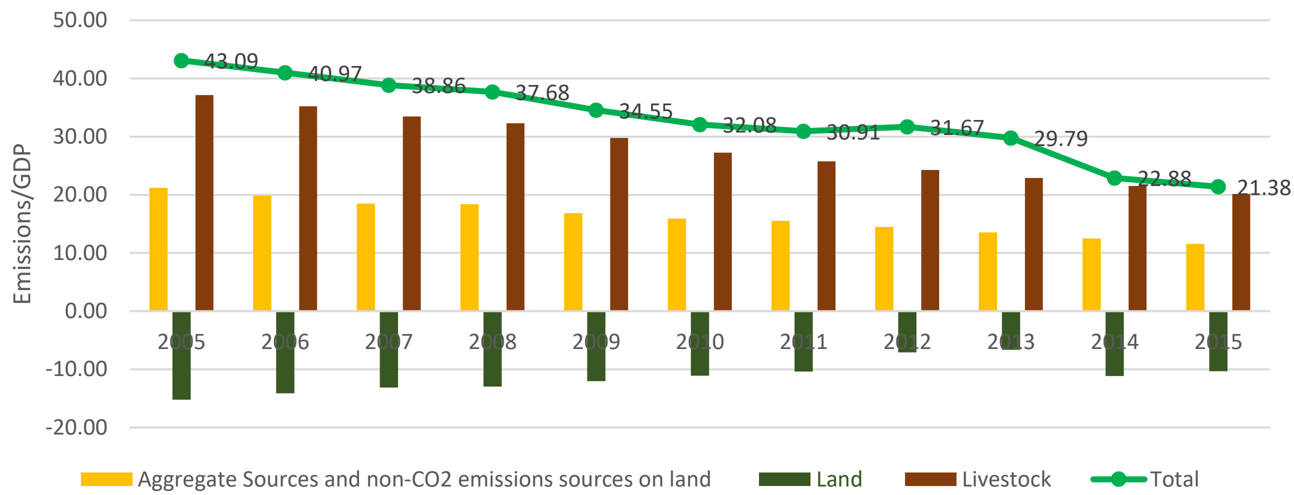
GHG emissions from the AFOLU sector mainly arises from three sub-sectors namely, Livestock, Land and Aggregate sources and non-CO_2 emissions sources on land. Notably, the Land sub-sector was a net remover of GHGs while the other two sub-sectors were net emitter. In 2015, if the emissions were considered excluding the removals from the Forest Land sub-sector, Livestock had the major contribution of 59.98% while Aggregate sources and non-CO_2 emissions sources on land contributed to 34.49% of the total AFOLU emissions followed by very minor contribution of 5.53% by the Land sector. Notably, Forest land sequestered 36.26% of the GHG emissions from the atmosphere.

Figure 8: Per Capita GHG Emissions from the AFOLU sector (2005 to 2015)



The per capita GHG emissions of the AFOLU sector in the country were found to be decreasing at a compounded rate of 2.06% from 0.19 tCO_2e in 2005 to 0.20 tCO_2e in 2015. This decline in the per capita emissions can be attributed to the increase in removals from Indian forests and also an increase in the population of India coupled with an overall stagnation of the positive emissions from this sector.

Figure 9: Emission Intensity of AFOLU Sector (tCO_2e per Crore)



The emissions intensity (emissions per unit of GDP PPP) of India from AFOLU sector witnessed a downward trend at a compounded rate of 6.77% due to a slight fall in emissions from this sector and a significant rise in India's GDP contributions from sectors other than AFOLU (using GDP values from Ministry of Statistics Planning and Implementation[7])

3.3 State-wise analysis of emissions

States with maximum emissions from the AFOLU sector in year 2005 and 2015 are as follows.

Table 3.3: State-wise GHG estimates 2005 - 2015(in $MtCO_2e$)

Name of the State	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Andaman and Nicobar Island	-7.11	-7.11	-7.10	-7.11	-7.11	-7.11	-7.13	-1.17	-1.17	0.36	0.36
Andhra Pradesh	5.35	5.84	6.13	6.42	5.47	6.55	6.23	-8.25	-9.63	-18.96	-19.72
Arunachal Pradesh	-20.64	-20.66	-20.66	-20.95	-20.94	-20.92	-20.75	5.47	5.49	6.42	6.28

[7] For 2004-05 to 2011-12: http://pibphoto.nic.in/documents/rlink/2018/nov/p2018112801.pdf
Fore 2011-12 to 2015-16:
http://www.mospi.nic.in/sites/default/files/press_release/FRE%20of%20National%20Income%2C%20Consumption%20Expenditure%2C%20Saving%20and%20Capital%20Formation%20For%202017-18_0.pdf

Assam	8.95	8.84	9.24	9.62	9.80	10.03	10.08	13.92	13.84	5.81	5.91
Bihar	24.26	25.23	25.92	25.80	25.24	24.74	25.86	26.02	25.83	25.18	26.29
Chandigarh	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-0.06	-0.06	0.02	0.02
Chhattisgarh	9.92	10.06	10.19	10.11	10.14	10.20	9.96	15.80	15.82	15.00	14.91
Dadra and Nagar Haveli	0.12	0.13	0.13	0.13	0.12	0.12	0.12	0.14	0.14	0.03	0.03
Daman and Diu	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.08	-0.08	0.00	0.00
Delhi	0.23	0.25	0.26	0.24	0.23	0.21	0.19	0.13	0.12	0.18	0.18
Goa	-1.01	-1.01	-1.02	-1.02	-1.03	-1.03	-1.03	0.27	0.26	-0.18	-0.18
Gujarat	19.05	19.45	19.88	20.51	20.92	21.91	22.50	20.23	21.05	22.04	22.40
Haryana	10.56	10.59	10.64	10.80	10.92	11.05	11.25	11.14	11.09	11.08	11.36
Himachal Pradesh	-0.60	-0.60	-0.59	-0.65	-0.69	-0.72	-0.59	2.20	2.18	-5.70	-5.70
Jammu and Kashmir	-0.19	-0.10	-0.02	-0.33	-0.47	-0.62	-0.61	-5.41	-5.54	-1.39	-1.47
Jharkhand	6.55	6.93	7.20	7.09	6.68	6.26	6.54	9.48	9.43	9.68	10.57
Karnataka	11.94	12.33	12.72	12.78	12.81	12.85	12.87	7.49	7.23	-10.90	-11.28
Kerala	-1.34	-1.42	-1.52	-1.57	-1.63	-1.70	-1.84	-30.84	-30.85	-23.74	-23.79
Lakshadweep	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Madhya Pradesh	27.03	27.83	28.61	27.74	27.40	26.97	27.30	27.73	27.74	26.08	26.05
Maharashtra	34.40	34.52	34.77	34.58	34.63	35.03	34.36	22.82	23.05	24.47	24.02
Manipur	-0.61	-0.63	-0.66	-0.65	-0.66	-0.63	-0.61	-0.47	-0.42	-2.95	-3.00
Meghalaya	-2.29	-2.28	-2.25	-2.28	-2.28	-2.27	-2.25	1.33	1.34	2.85	2.86
Mizoram	-0.76	-0.76	-0.76	-0.80	-0.81	-0.83	-0.85	3.47	3.47	5.32	5.34
Nagaland	0.23	0.25	0.24	0.24	0.20	0.18	0.17	2.71	2.70	9.02	8.99
Odisha	11.55	11.27	10.80	10.18	9.95	10.22	9.73	16.83	17.03	4.17	3.88
Puducherry	0.15	0.14	0.14	0.12	0.12	0.12	0.10	0.01	0.01	0.15	0.15

Punjab	11.81	11.64	11.51	11.71	11.90	12.13	12.29	12.95	12.92	11.84	12.28
Rajasthan	25.02	25.47	25.92	25.13	25.48	26.20	28.21	26.93	27.39	23.54	24.43
Sikkim	-4.01	-4.02	-4.02	-3.94	-3.95	-3.95	-3.89	0.34	0.35	0.47	0.50
Tamil Nadu	18.53	19.05	19.35	19.14	18.49	18.01	17.57	-24.70	-25.09	11.50	11.78
Telangana	16.25	16.75	17.11	17.15	16.41	16.94	16.57	46.14	46.88	4.87	3.88
Tripura	-1.58	-1.57	-1.53	-1.62	-1.64	-1.62	-1.62	0.89	0.89	3.73	3.77
Uttar Pradesh	46.05	45.96	45.97	48.15	48.96	50.11	51.35	55.63	56.65	54.74	55.99
Uttarakhand	2.78	2.92	3.09	2.97	2.90	2.84	2.85	8.32	8.30	2.71	2.77
West Bengal	4.24	6.55	7.73	7.59	6.78	5.02	5.14	24.31	23.66	23.39	23.24
India	**254.85**	**261.86**	**267.42**	**267.30**	**264.36**	**266.28**	**270.06**	**291.74**	**292.00**	**240.84**	**243.12**

As seen above, maximum GHG emissions arise 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 are only around 4.34 $MtCO_2e$, which is low compared to the other states.

3.4 Sectoral Quality Control (QC) and Quality Assurance (QA)

A summary of the key source category-wise description of the quality assessment and quality control processes undertaken is given below.

<table>
<tr><th colspan="6">Table 3.4: Summary of Quality Assessment and Quality Control Processes</th></tr>
<tr><th>IPCC Category</th><th>Activity Data Source</th><th>Type of Source</th><th>Emission Factor</th><th>Data Processing Strategy</th><th>Bifurcation of data for Andhra Pradesh and Telangana from Unified Andhra Pradesh before 2012</th></tr>
<tr><td>3A1Enteric Fermentation</td><td rowspan="2">Livestock Census of India for 2007 and 2012</td><td rowspan="2">Official, Publicly Available</td><td rowspan="2">NATCOM-II: Indigenous cattle, Cross bred Cattle and Buffalo
IPCC 2006: Rest of the Categories</td><td rowspan="2">Data has been interpolated and extrapolated for the years where the data was unavailable</td><td rowspan="2">District -wise proportion of the Livestock population was taken and apportioned to the total population of livestock before bifurcation to attain the new values.</td></tr>
<tr><td>3A2 Manure Management</td></tr>
<tr><td>3B1 Forest Land</td><td>Forest Survey of India</td><td>Official, Publicly Available</td><td>2005-2009: FSI, Carbon Report[8]
2010-2015: FSI, State of Forest Report,2017[9]</td><td rowspan="6">Data has been interpolated and extrapolated for the years where the data was unavailable</td><td>Actual District-wise forest area has been taken for the calculations.</td></tr>
<tr><td>3B2 Cropland</td><td rowspan="5">National Remote Sensing Centre (available on request)</td><td rowspan="5">Official, Available on Request</td><td rowspan="5">Biomass: Forest Survey of India, State of Forest report
SOC: Sreenivas et.al
SOC (Cropland): Expert Literature[10]</td><td rowspan="5">The Proportion of the new Andhra Pradesh and Telangana area were assigned to gain the land use change.</td></tr>
<tr><td>3B3 Grassland</td></tr>
<tr><td>3B4 Wetlands</td></tr>
<tr><td>3B5 Settlements</td></tr>
<tr><td>3B6 Other Lands</td></tr>
<tr><td>3C1a Biomass Burning in Forest Land</td><td>Forest Survey of India</td><td>Official, Publicly Available</td><td>NATCOM-II</td><td>No Data Extrapolation/ Interpolation</td><td>Proportion of the forest area burnt in Andhra Pradesh and Telangana was available in Reddy et.al.</td></tr>
</table>

[8] http://fsi.nic.in/carbon_stock/chapter-4.pdf
[9] http://fsi.nic.in/isfr2017/isfr-carbon-stock-in-india-forest-2017.pdf
[10] The values have been taken from various literatures the links to which can be found in the bibliography.

3C1b Biomass Burning in Cropland	2005-2008: Planning Commission 2009 to 2015: Statistical year Book	Official, Publicly Available	NATCOM-II (Andreae and Merlet 2001)	No Data Extrapolation/ Interpolation	The average of the proportions of Andhra Pradesh and Telangana for the latest years i.e. 2013-14 and 2014-15 was apportioned to the previous year values (2005 to 2012) of Andhra Pradesh
3C4 Direct N_2O emissions from Managed Soils	Indian Fertilizer Scenario, Department of Fertilizers, Ministry of Chemicals and Fertilizers Government of India Statistical Year Book, Ministry of Statistics and Programme Implementation	Official, Publicly Available	NATCOM-II Bhatia e. al. 2004	No Data Extrapolation or Interpolation	The average of the proportions of Andhra Pradesh and Telangana for the latest years i.e. 2013-14 and 2014-15 was apportioned to the previous year values (2005 to 2012) of Andhra Pradesh
3C5 Indirect N_2O emissions from Managed Soils			NATCOM-II (Bhatia et al 2013)		
3C7 Rice Cultivation	Directorate of Economics and Statistics Department of Agriculture, Cooperation and Farmer’s Welfare, Government of India	Official, Publicly Available	NATCOM-II (Gupta et al., 2009 and Pathak et al.,2010)	No Data Extrapolation or Interpolation	The average of the proportions of Andhra Pradesh and Telangana for the latest years i.e. 2013-14 and 2014-15 was apportioned to the previous year values (2005 to 2012) of Andhra Pradesh

Given below is a detailed explanation of the quality assessment and quality control processes undertaken:

- 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.
- 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 draft estimates are peer reviewed by WRI India. WRI India reviewed the data points (including but not limited to AD, EF, etc.) on sample basis and ensured consistency of methodology with internationally acceptable standards and guidelines like IPCC, etc.

3.5 3A Livestock

3A1. Enteric Fermentation

3.5.1 Category description

Enteric Fermentation resulting in emissions of CH_4 arises out of the process of ingesting and digesting of food eaten by herbivores, primarily bovines and ovine. However, other animals such as camels, horses and mules etc. also emit small amounts of CH_4.

The activity data has been sourced from the Livestock Census of India and the type and quality of data is given below. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.5A: Source category wise details on type of data, quality and source

IPCC ID	GHG Source & Sink Categories	Type	Quality	Source
3.	AFOLU			
3A	Livestock			
3A1	Enteric Fermentation			
3A1a	Cattle	Secondary	High	18th Livestock Census 19th Livestock Census
3A1ai	Dairy cows (Indigenous and Cross Bred)	Secondary	High	
3A1aii	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	Secondary	High	

3A1b	Buffalo (dairy and non-dairy)	Secondary	High	http://dahd.nic.in/documents/statistics/livestock-census
3A1c	Sheep	Secondary	High	
3A1d	Goats	Secondary	High	
3A1e	Camels	Secondary	High	
3A1f	Horses and ponies	Secondary	High	
3A1g	Donkeys	Secondary	High	
3A1h	Pigs	Secondary	High	

3.5.2 Methodology

Methane emissions from Enteric Fermentation have been calculated using methodology prescribed in 2006 IPCC guidelines for national GHG inventories. To ensure consistency with India's National Communication Reports and the Biennial Update Report 2010, the emission inventory for all sub-sectors has been prepared on a calendar year basis. Activity datasets for emission estimations available on financial year basis have been converted to calendar year datasets for a given calendar year by considering 3/4th of the value from the previous financial year (corresponding to 9 months from April to December out of 12 months in a year) and 1/4th from the next financial year (corresponding to 3 months from January to March out of 12 months in a year)[11].

CO_2 emissions from livestock are not estimated because annual net CO_2 emissions are assumed to be zero – the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2. (Chapter 10, Volume 4, IPCC 2006). Similarly, as no nitrogen is released during the process of digestion in livestock, no nitrous oxide (N_2O) emissions are reported. The methodological details for estimation of GHG emissions for enteric fermentation are as follows:

Table 3.5B: Source category wise details on tier approach and type of emission factor used

IPCC ID	GHG source & sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
3A1	Enteric Fermentation	Not Applicable				Not Applicable	
3A1a	Cattle			T2	CS		
3A1ai	Dairy cows (Indigenous and Cross Bred)			T2	CS		
3A1aii	Other cattle or Non-dairy cows (Indigenous and Cross Bred)			T2	CS		
3A1b	Buffalo (dairy and non-dairy)			T2	CS		
3A1c	Sheep			T2	CS		
3A1d	Goats			T2	CS		
3A1e	Camels			T1	D		
3A1f	Horses and ponies			T1	D		
3A1g	Donkeys			T1	D		
3A1h	Pigs			T1	D		

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

[11] This has been applied to the data sets of all key source categories unless otherwise mentioned.

The activity data i.e. the livestock population is sourced from the Livestock Census of India published every five years by the Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers Welfare. The Livestock census have been used for the years 2002, 2007 and 2012. Emission factors for bovines[12], sheep and goats have been sourced from the NATCOM II and for the remaining other animals IPCC Default emission factors have been used.

Therefore, a Tier II methodology has been used for major methane emitting categories (i.e. bovines, sheep and goats) and Tier I methodology has been used where country specific emission factors were not available.

The following steps were performed for emission estimation from enteric fermentation:

Step 1. Livestock Population Estimation

As a first step, the average annual population of animals was taken from the Census of Livestock. Categorization was done as per available categories in the emission factors 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 their population is miniscule and the relative emissions are negligible. The details regarding categorisation are given in the table 3.5C below:

Table 3.5C: Categorization of livestock for derivation of methane emission factors

Category	**Sub category**
a) Mature dairy cows (Mature cows that have calved at least once and used principally for milk production)	"Cross-bred" dairy cows "Indigenous cows" (non-descript or desi) dairy cows. "Buffaloes"
b) Non-dairy cattle	Young cattle (cross bred cows, indigenous cows and buffaloes): • Below 1 year[13] • 1-3 years[14] Others (cross bred cows, indigenous cows and buffaloes): • Male (Breeding, Working and Others) • 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

[12] Bovines refers to Cattles and Buffaloes (both Dairy and Non-Dairy)

[13] 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.

[14] 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.

Livestock populations for the intermediate years between the livestock census years were 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:

$$AIR = \frac{Population\ in\ Y2 - Population\ in\ Y1}{n}$$

$$Population\ in\ Y3 = Population\ in\ \ Y2 + AIR$$

Where,
AIR = Annual Increment Ratio
Population in Y = Population in Year 1, 2, 3… etc
n = Number of Years
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:

$$CAGR = \left(\frac{FV}{BV}\right)^{1/n} - 1$$

Where,
CAGR = Compounded Annual Growth Rate
FV = Future Value
BV = Beginning Value
n = Number of Years

Step 2: Emission Factor Estimation

Methane emission factors for the livestock categories have been sourced from NATCOM II and IPCC 2006. Table 3.5D below provides emission factors for each sub-group:

Table 3.5D: Emission factor of each sub-group in terms of kilograms of methane per animal per year				
Category	**Sub-category**	**Age group**	**Methane emission factor ($kgCH_4$/head/year)**	**Source**
Indigenous Cattle	Dairy cattle	Indigenous	28.00	NATCOM II, 2012
	Non-dairy cattle (indigenous)	0-1 year	9.00	NATCOM II, 2012
		1-3 year	23.00	NATCOM II, 2012
		Adult	32.00	NATCOM II, 2012
Cross-bred cattle	Dairy cattle	Cross-bred	43.00	NATCOM II, 2012
	Non-dairy cattle (cross-bred)	0-1 year	11.00	NATCOM II, 2012
		1-3 year	26.00	NATCOM II, 2012
		Adult	33.00	NATCOM II, 2012
Buffalo	Dairy buffalo		50.00	NATCOM II, 2012
	Non-dairy buffalo	0-1 year	8.00	NATCOM II, 2012
		1-3 year	22.00	NATCOM II, 2012
		Adult	44.00	NATCOM II, 2012
Sheep			5.00	IPCC 2006
Goat			5.00	IPCC 2006

Horses & Ponies			18.00	IPCC 2006
Donkeys			10.00	IPCC 2006
Camels			46.00	IPCC 2006
Pigs			1.00	IPCC 2006
Poultry			0.00	IPCC 2006

Step 3: Emission Estimation

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 1 for sample calculation) and summed using IPCC equation 10.20 (Refer Annex 1 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_4 yr^{-1}
$EF_{(T)}$ = emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}
$N_{(T)}$ = the number of head of livestock species/category T in the country
T = species/category of livestock

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

Where,

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

3.5.3 Recalculation

There is no change in the activity data and emission factors for the period 2005 to 2013, when compared with phase 2. All activity data pertaining to Enteric Fermentation are complete and high quality in nature. Therefore, the scope for recalculation in national level estimates is nil, compared to the previous phase.

3.5.4 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, emission factor estimation due to feed intake of livestock varies from region to region from enteric fermentation.

Table 3.5E: Source category wise description of Qualitative uncertainty			
IPCC ID	Source Category	Qualitative Uncertainty	
		Activity Data	Emission Factor
3A1	Enteric Fermentation	Lack of availability of yearly livestock population data	There are significant variations in body weight and size of livestock across India, along with variations of feed intake that are not fully captured.

3.5.5 Recommended 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.

3.6 3A2. Manure Management

3.6.1 Category description

Manure management emissions arise from the process of animal's manure decomposition. In general, emissions vary depending on the type of decomposition – aerobic or anaerobic. If manure is decomposed naturally i.e. aerobically, little or no emissions are produced. However, if manure is treated anaerobically, higher emissions are observed.

Manure management results in CH_4 and N_2O emissions. CO_2 emissions from livestock are not estimated because annual net CO_2 emissions are assumed to be zero – the CO_2 photosynthesized by plants is returned to the atmosphere as respired CO_2 (Chapter 10, Volume 4, IPCC 2006).

Methane emissions from manure management tend to be smaller than enteric emissions, with the most substantial emissions associated with confined animal management operations where manure is handled in liquid-based systems. Nitrous oxide emissions from manure management vary significantly between the types of management system used and can also result in indirect emissions due to other forms of nitrogen loss from the system (Chapter 10, Volume 4, IPCC 2006).

The activity data has been sourced from the Livestock Census of India and the type and quality of data is given below. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.6A: Source category wise details on type of data, quality and source

IPCC ID	GHG Source & Sink Categories	Type	Quality	Source
3.	**AFOLU**			
3A	**Livestock**			
3A2	**Manure Management**			
3A2a	Cattle	Secondary	High	18th Livestock Census 19th Livestock Census http://dahd.nic.in/documents/statistics/livestock-census
3A2ai	Dairy cows (Indigenous and Cross Bred)	Secondary	High	
3A2aii	Other cattle or Non-dairy cows (Indigenous and Cross Bred)	Secondary	High	
3A2b	Buffalo (dairy and non-dairy)	Secondary	High	
3A2c	Sheep	Secondary	High	
3A2d	Goats	Secondary	High	
3A2e	Camels	Secondary	High	
3A2f	Horses and ponies	Secondary	High	
3A2g	Donkeys	Secondary	High	
3A2h	Pigs	Secondary	High	

3.6.2 Methodology

Methane emissions from manure management have been calculated using the methodology provided in 2006 IPCC guidelines for national GHG inventories. The methodological details (Tier approach) for estimation of GHG emissions for manure management are as follows:

Table 3.6B: Source category wise details on tier approach and type of emission factor used

IPCC ID	GHG source & sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
3A2a	Manure Management	Not Applicable					
3A2ai	Cattle			T2	CS	T1	D
3A2aii	Dairy cows (Indigenous and Cross Bred)			T2	CS	T1	D
3A2b	Other cattle or Non-dairy cows (Indigenous and Cross Bred)			T2	CS	T1	D
3A2c	Buffalo (dairy and non-dairy)			T2	CS	T1	D
3A2d	Sheep			T2	CS	T1	D
3A2e	Goats			T2	CS	T1	D
3A2f	Camels			T1	D	T1	D
3A2g	Horses and ponies			T1	D	T1	D
3A2h	Donkeys			T1	D	T1	D
3A2a	Pigs			T1	D	T1	D

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

The activity data i.e. the livestock population is sourced from the 18th and 19th Livestock Census of India, published every five years by the Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers Welfare. The Livestock census has been used for the years 2002, 2007 and 2012. Methane emission factors for bovines[15], sheep and goats have been sourced from the NATCOM II and for the other remaining animals IPCC default emission factors have been used. IPCC default emission factors[16] have been used for estimating N_2O emissions for all the categories.

Therefore, for CH_4 emissions, a Tier II methodology has been used for major methane emitting categories (i.e. bovines, sheep and goats) and Tier I methodology has been used where country specific emission factors were not available. For N_2O emissions, a Tier I methodology has been adopted.

The following steps were performed for **CH_4 emission estimation** from manure management:

Step 1. Livestock Population Estimation

[15] Bovines refers to Cattles and Buffaloes (both Dairy and Non-Dairy)

[16] Most expert literatures available in the public domain state that they are using IPCC, 2006 N2O for emissions factors but they still use the IPCC 1996 N2O emissions factors for calculations. The same has been done in the present study.

As a first step, the average annual population of animals was taken from the Census of Livestock. 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 3.6C below:

Table 3.6C: Categorization of livestock for derivation of methane emission factors	
Category	**Sub category**
a) Mature dairy cows (Mature cows that have calved at least once and used principally for milk production)	"Cross-bred" dairy cows "Indigenous cows" (non-descript or desi) dairy cows. "Buffaloes"
b) Non-dairy cattle	Young cattle (cross bred cows, indigenous cows and buffaloes): • Below 1 year[17] • 1-3 years[18] Others (cross bred cows, indigenous cows and buffaloes): • Male (Breeding, Working and Others) • 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 were 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:

$$AIR = \frac{Population\ in\ Y2 - Population\ in\ Y1}{n}$$

$$Population\ in\ Y3 = Population\ in\ \ Y2 + AIR$$

where,
AIR = Annual Increment Ratio
Population in Y = Population in Year 1, 2, 3… etc
n = Number of Years

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[17] 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.
[18] 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.

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:

$$CAGR = \left(\frac{FV}{BV}\right)^{1/n} - 1$$

Where,
CAGR = Compounded Annual Growth Rate
FV = Future Value
BV = Beginning Value
n = Number of Years

Step 2: Emission Factor Estimation

Methane emission factors for the livestock categories have been sourced from NATCOM II and IPCC 2006. The table 3.6D mentioned below provides emission factors for each sub-group:

Table 3.6D: Emission factor of each sub-group in terms of kilograms of methane per animal per year

Category	**Sub-category**	**Age group**	**Methane emission factor ($kgCH_4$/head/year)**	**Source**
Indigenous Cattle	Dairy cattle	Indigenous	3.50	NATCOM II, 2012
	Non-dairy cattle (indigenous)	0-2 year	1.20	NATCOM II, 2012
		1-3 year	2.80	NATCOM II, 2012
		Adult	2.90	NATCOM II, 2012
Cross-bred cattle	Dairy cattle	Cross-bred	3.80	NATCOM II, 2012
	Non-dairy cattle (cross-bred)	0-1 year	1.10	NATCOM II, 2012
		1-3 year	2.30	NATCOM II, 2012
		Adult	2.50	NATCOM II, 2012
Buffalo	Dairy buffalo		4.40	NATCOM II, 2012
	Non-dairy buffalo	0-1 year	1.80	NATCOM II, 2012
		1-3 year	3.40	NATCOM II, 2012
		Adult	4.00	NATCOM II, 2012
Sheep			0.20	IPCC 2006
Goat			0.22	IPCC 2006
Horses & Ponies			2.19	IPCC 2006
Donkeys			0.90	IPCC 2006
Camels			2.56	IPCC 2006
Pigs			4.00	IPCC 2006
Poultry			0.00	IPCC 2006

Step 3: Emission Estimation

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

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

Where,

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

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

The following steps were performed for **<u>N_2O emission estimation</u>** from manure management:

Step 1. Livestock Population Estimation

As a first step, the average annual population of animals was taken from the Census of Livestock. 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 3.6E below:

Table 3.6E: Categorization of livestock for derivation of methane emission factors	
Category	**Sub category**
a) Mature dairy cows (Mature cows that have calved at least once and used principally for milk production)	▪ "Cross-bred" dairy cows ▪ "Indigenous cows" (non-descript or desi) dairy cows. ▪ "Buffaloes"
b) Non-dairy cattle	▪ Young cattle (cross bred cows, indigenous cows and buffaloes): a) Below 1 year[19] b) 1-3 years[20] ▪ 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)

[19] 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.

[20] 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.

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:

$$AIR = \frac{Population\ in\ Y2 - Population\ in\ Y1}{n}$$

$$Population\ in\ Y3 = Population\ in\ \ Y2 + AIR$$

where,
AIR = Annual Increment Ratio
Population in Y = Population in Year 1, 2, 3… etc
n = Number of Years

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:

$$CAGR = \left(\frac{FV}{BV}\right)^{1/n} - 1$$

Where,
CAGR = Compounded Annual Growth Rate
FV = Future Value
BV = Beginning Value
n = Number of Years

Step 2: Emission Factor Estimation

For calculating nitrogen excretion, IPCC values[21] 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
The following nitrogen emission factors were used as per 2006 IPCC Guidelines:

Table 3.6F: Nitrogen Emission Factors	
Category of Livestock	**Nitrogen emissions per animal (kgN_2O/head/year)**
Dairy cattle	0.0006
Non-dairy cattle	0.0004
Pigs	0.0074
Poultry	0.0025

[21] 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

Step 3 & 4: Emission Estimation

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

N_2O emissions were calculated in the following manner:

IPCC equation 10.25[22] (Refer Annex I for sample calculations) that was used was the following:

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

where,

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

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.

3.6.3 Recalculation

No recalculation was performed for estimating emissions from this category because the activity data, emissions factor and methodology was the same as used for Phase II estimates. There was no new data source used, no error was observed and no new methodology was used.

3.6.4 Uncertainties

Uncertainty in emission estimation from manure management arises 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.

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

Table 3.6G: Source category wise description of Qualitative uncertainty			
IPCC ID	**Source Category**	**Qualitative Uncertainty**	
		Activity Data	**Emission Factor**
3A2	Manure Management	Lack of availability of yearly livestock population data	Precise data on manure yields and their end uses is not fully known under Indian conditions.

3.6.5 Recommended 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.

3.7 3B Land

3B1 Forestland

3.7.1 Category description

This section provides details of emission estimates from Forestland due to changes in biomass, dead organic matter and soil organic matter on Forest Land and Land converted to Forest Land.

For this study, Land Use Matrix for forestland remaining forestland and land converted to forestland 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 Linear Imaging and Self Scanning Sensor (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. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.7A: An overview of source categories of Forest Land				
IPCC ID	**GHG source & sink categories**	**Type**	**Quality**	**Source**
3B	**Land**			
3B1	Forest Land[23]	Secondary Data	High	State of Forest Reports: 2017 2015

[23] 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

				2013 2011 2009 2005

3.7.2 Methodology

For GHG estimation from forestland 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[24], it can be used where carbon stocks in relevant pools are measured at two points in time to assess carbon stock changes, as represented in equation given below (Refer Annex I for sample calculations):

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

where,
ΔC is Annual Carbon stock change in pool (tonnes C yr-1)
C_{t_2} is Carbon stock in the pool at time t2
C_{t_1} is Carbon stock in the pool at time t1

The following steps were performed for emission estimation from Forestland:

Step 1. Estimation of Area

Area under Forest Land Remaining Forestland and Land converted to Forestland is estimated. Table 3.7B below provides details of the tier approach and types of emission factors used for forest land:

Table 3.7B: An overview of emission factors used for forestland			
IPCC ID	**GHG source & sink categories**	**CO_2**	
		Method Applied	**Emission Factor**
3B1	Forest Land	T2	CS

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

The area is sourced from the State of Forest Reports (SFR) for India published biannually by Forest Survey of India (FSI). The reports used in this study are SFR 2009, SFR 2011, SFR 2013, SFR 2015 and SFR 2017. The FSI provides Forestland remaining Forestland and Land converted to Forestland in these reports. For the years that FSI does not publish the data, the area is interpolated using a linear trend.

Step 2: Emission Factor Estimation

Emission factor estimation, i.e. the change in the carbon stock and biomass in case of forestland is registered from the Forest Survey of India's Report on Carbon Stock in India. FSI's Carbon Stock Report, 2011[25] gives the carbon stock density under five different pools for the forests in year 2009 for all states and UTs. The five pools mentioned in this report are Above Ground Biomass, Below Ground Biomass,

[24] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_02_Ch2_Generic.pdf
[25] See table 4.4 available at http://fsi.nic.in/carbon_stock/chapter-4.pdf

Deadwood, Litter and Soil Organic Carbon. The carbon stock density under these pools is updated and is provided in the SFR 2017 for all Indian states and UTs.

Carbon stock for each year in consideration is estimated by multiplying the carbon stock density under different pools with the area under forestland for that year. From 2005 to 2010, the carbon stock density from the Carbon Stock Report is considered and is multiplied with the Forest area till 2010. From 2011 onwards, the carbon stock density is used from the SFR 2017 report.

Step 3: Emission Estimation

In cases where forestland remains as forestland, 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.

IPCC's Stock Exchange Methodology has been used with Equation 2.5 (Refer the methodology section on Page 42, Section 3.6.2 for equation).

A bottom up approach has been used for estimating emissions from forestland. 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).

3.7.3 Recalculation

Table 3.7C: Source category wise details on the difference between GHG estimates

Year	Key source category	GHG Emission Estimates ($MtCO_2e$)		% Difference
		Phase-II	Phase-III	
2005	Forest Land	-145.62	-97.97	-33%
2006	Forest Land	-145.62	-97.97	-33%
2007	Forest Land	-145.62	-97.97	-33%
2008	Forest Land	-145.62	-97.97	-33%
2009	Forest Land	-145.62	-97.97	-33%
2010	Forest Land	-145.62	-97.97	-33%
2011	Forest Land	-188.83	-97.97	-48%
2012	Forest Land	-188.83	-72.35	-62%
2013	Forest Land	-188.83	-72.35	-62%

As decided amongst platform partners, a significance threshold of 5% is considered. Recalculation have been reported where the deviation between Phase III and Phase II results is higher than the threshold.

As seen in table 3.7C above, some deviation in Phase -3 and Phase-2 emissions were observed in Forest land category. This deviation can be attributed to the usage of updated carbon stock values used from SFR 2017 as compared to the carbon stock values published in carbon stock report 2011. Under this method, we have assumed three time periods i.e. 2004-11, 2011-13, 2013-15 for which FSI has provided the actual carbon stock in India. Also, in this phase, the India value has been derived by totaling up the state emissions unlike phase-2, where the national data was used to derive the India emission values.

3.7.4 Uncertainty

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 (FSI 2011) and hence not considered significant.

Table 3.7D: Source category wise description of Qualitative uncertainty

IPCC ID	**Source Category**	**Qualitative Uncertainty**	
		Activity Data	**Emission Factor**
3B1	Forestland	Lack of availability of year-on-year data on Forestland	Lack of data on underlying assumptions for carbon stock calculations such as stand age, species composition, etc.

3.7.5 Recommended 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.

3.8 3B2 Cropland

3.8.1 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 for national GHG inventories).

Given below is an overview of the source categories. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.8A: An overview of source categories of Cropland				
IPCC ID	**GHG source & sink categories**	**Type**	**Quality**	**Source**
3B	**Land**			
3B2	Cropland	Secondary Data	High	National Remote Sensing Centre (available on request)
3B2a	Cropland Remaining Cropland	Secondary Data	High	
3B2bi	Forestland converted to Cropland	Secondary Data	High	
3B2bv	Other Land converted to Cropland	Secondary Data	High	

3.8.2 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 for national GHG inventories).

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 *(No Land use change observed by NRSC)*
(e) Settlements converted to Cropland *(No Land use change observed by NRSC)*
(f) Other lands converted to Cropland
(g) Forest Land converted to Agriculture Plantations *(No Land use change observed by NRSC)*
(h) Cropland converted to Agriculture Plantations *(No Land use change observed by NRSC)*
(i) Settlements converted to Agriculture Plantations *(No Land use change 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.

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 the methodology approach used for emission estimation from cropland:

Table 3.8B: An overview of emission factors used for cropland			
IPCC ID	GHG source & sink categories	CO_2	
		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 by NRSC 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, 2013, 2014 and 2015, land use pattern for 2005 has been assumed same as for the year 2006. Similarly, land use pattern for 2013, 2014 & 2015 has been assumed to be same as for 2012. 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 3.8C 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 3.8C: Biomass carbon stock in Croplands

Category	2004[a]	2013[b]
Growing Stock in TOF (million cum)	1616.25	1573.34
Total stock in above ground biomass[26] (Mt)	1035.11	1007.63

[26] Above Ground Biomass = Growing Stock x density (0.7116) x Biomass Expansion Factor ** (**Source: http://www.envfor.nic.in/mef/Technical_Paper.pdf)
Biomass Expansion Factor is 0.9 for India – Source: Page 75, BUR II
https://unfccc.int/sites/default/files/resource/INDIA%20SECOND%20BUR%20High%20Res.pdf

Total stock in below ground biomass[27] (Mt)	279.48	272.06
Total biomass (Mt)	1314.59	1279.69
Total biomass Carbon[28] (MtC)	657.29	639.84
Rate of Change of Biomass Carbon (MtC/yr)	-1.94	
Rate of Change of Biomass Carbon (tC/ha/yr)	-0.008	

Source: a – Table 6.1, Page 40, SFR 2005 & b – Table 5.2, Page 81, SFR 2015

Step 5:

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

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, chapter 2, Vol. 04 of {IPCC 2006 Guidelines} (Refer Annex I for sample calculations) given below:

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

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

where,

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

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

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

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

D = Time Dependence, 20 years

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

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

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

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[27] Please See Table 1, Page 9 of https://www.academia.edu/26244255/Indias_Forest_and_Tree_Cover_Contribution_as_a_Carbon_Sink_Technical_Paper – Root Shoot Ratio is 0.27

[28] Carbon Fraction is 0.49 (Default Value sourced from IPCC 2006 Guidelines. Please see table 4.3 (Tropical, Woody – Carbon Fraction value from https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf)

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 biomass and soil organic carbon content for each sub-category is calculated by multiplying the area within that sub-category with the respective change in biomass and soil organic carbon for that particular sub-category. The total change in carbon stocks is calculated by adding up all values of the sub-categories estimates.

3.8.3 Recalculation

Table 3.8D: Source category wise details on the difference between GHG estimates

Year	Key source category	GHG Emission Estimates ($MtCO_2e$)		% Difference
		Phase-II	Phase-III	
2005	Cropland	2.30	-1.46	-164%
2006	Cropland	2.30	-1.46	-164%
2007	Cropland	2.30	-1.46	-164%
2008	Cropland	3.14	-0.62	-120%
2009	Cropland	3.14	-0.62	-120%
2010	Cropland	3.14	-0.62	-120%
2011	Cropland	2.47	-1.32	-154%
2012	Cropland	2.47	-1.32	-154%
2013	Cropland	2.47	-1.32	-154%

As decided amongst platform partners, a significance threshold of 5% is considered. Recalculation have been reported where the deviation between Phase III and Phase II results is higher than the threshold.
As seen in table 3.8D above, high deviation was observed in phase-3 and phase-2 emissions from cropland. This is mainly because the emission factors used to calculate the emissions are now sourced from BUR II.

3.8.4 Uncertainty

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

The classification outputs were subjected to post classification accuracy assessment. The error matrix of accuracy assessment for different states was done. The overall classification accuracy is found to be 88.82% with a range of 83.05% to 95.31% in different states (NRSC 2007).

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 (NRSC 2010), (NRSC 2012), (NRSC 2013) [29]. 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 K. Sreenivas et al 2016 from National Remote Sensing Centre (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 agroecological regions. Using Random forests (RF) based spatial prediction procedure with climatic, land cover, rock type, soil type, multi-year Normalized Difference Vegetation Index (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 3.8E: Source category wise description of Qualitative uncertainty

IPCC ID	**Source Category**	**Qualitative Uncertainty**	
		Activity Data	**Emission Factor**
3B2	Cropland	Lack of access to finer resolution data to map land use changes	Lack of data on underlying assumptions for carbon stock calculations such as stand age, species composition, etc. Lack of availability of region-specific carbon stock data based on topography and climatic regions.

3.8.5 Recommended 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.

3.9 3B3 Grassland

3.9.1 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 for national GHG inventories).

In India, grasslands include many categories other than forest land and cropland.

Given below are details of activity data used in Grasslands. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.9A: An overview of source categories of Grassland

IPCC ID	GHG source & sink categories	Type	Quality	Source
3B	**Land**			
3B3	Grassland	Secondary Data	High	National Remote Sensing Centre (available on request)
3B3a	Grassland Remaining Grassland	Secondary Data	High	
3b3bv	Other Land converted to Grassland	Secondary Data	High	

3.9.2 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 for national GHG inventories) 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 for national GHG inventories 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 are estimated using the *Stock Difference Method* from the following categories:
(a) Grassland remaining Grassland
(b) Forest Land converted to Grassland *(No Land use change observed by NRSC)*
(c) Cropland converted to Grassland *(No Land use change observed by NRSC)*
(d) Settlements converted to Grassland *(No Land use change observed by NRSC)*

(e) Other Land converted to Grassland

Given below are details of the methodology used for grasslands:

Table 3.9B: An overview of emission factors used for grasslands			
IPCC ID	**GHG source & sink categories**	**CO_2**	
		Method Applied	**Emission Factor**
3B3	Grassland	T2	CS
3B3a	Grassland Remaining Grassland	T2	CS
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

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).

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, 2014 and 2015, land use pattern for 2005 has been assumed same as for the year 2006. Similarly, land use pattern for 2013, 2014 & 2015 has been assumed to be same as for 2012. 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 3.9C 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 3.9C: Biomass Carbon Stock in Grassland		
Category	**2004[a]**	**2013[b]**
Growing Stock in TOF (million cum)	1616.25	1573.34

Total stock in above ground biomass[30] (Mt)	1035.11	1007.63
Total stock in below ground biomass[31] (Mt)	279.48	272.06
Total biomass (Mt)	1314.59	1279.69
Total biomass Carbon[32] (MtC)	657.29	639.84
Rate of Change of Biomass Carbon (MtC/yr)	-1.94	
Rate of Change of Biomass Carbon (tC/ha/yr)	-0.008	

Source: : a – Table 6.1, Page 40, SFR 2005 & b – Table 5.2, Page 81, SFR 2015

Step 5:

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

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

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

where,

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

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

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

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

D = Time Dependence, yr

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

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

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

[30] Above Ground Biomass = Growing Stock x density (0.7116) x Biomass Expansion Factor** (**Source: http://www.envfor.nic.in/mef/Technical_Paper.pdf)
Biomass Expansion Factor is 0.9 for India – Source: Page 75, BUR II
https://unfccc.int/sites/default/files/resource/INDIA%20SECOND%20BUR%20High%20Res.pdf

[31] Please See Table 1, Page 9 of https://www.academia.edu/26244255/Indias_Forest_and_Tree_Cover_Contribution_as_a_Carbon_Sink_Technical_Paper – Root Shoot Ratio is 0.27

[32] Carbon Fraction is 0.49 (Default Value sourced from IPCC 2006 Guidelines. Please see table 4.3 (Tropical, Woody – Carbon Fraction value from https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf

change factors (F_{LU}, F_{MG}, F_I) as given by the 2006 IPCC guidelines (Vol 04, Chapter 06, Table 6.2, Page 6.16). 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 (Vol 04, Chapter 06, Table 6.2, Page 6.16)). 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 biomass and soil organic carbon content for each sub-category is calculated by multiplying the area within that sub-category with the respective change in biomass and soil organic carbon for that particular sub-category. The total change in carbon stocks is calculated by adding up all values of the sub-categories estimates.

3.9.3 Recalculation

Table 3.9D: Source category wise details on the difference between GHG estimates

Year	Key source category	GHG Emission Estimates ($MtCO_2e$)		% Difference
		Phase-II	Phase-III	
2005	Grassland	0.63	0.58	-8%
2006	Grassland	0.63	0.58	-8%
2007	Grassland	0.63	0.58	-8%
2008	Grassland	0.47	0.42	-11%
2009	Grassland	0.47	0.42	-11%
2010	Grassland	0.47	0.42	-11%
2011	Grassland	0.71	0.66	-7%
2012	Grassland	0.71	0.66	-7%
2013	Grassland	0.71	0.66	-7%

As decided amongst platform partners, a significance threshold of 5% is considered. Recalculation have been reported where the deviation between Phase III and Phase II results is higher than the threshold. As seen in table 3.9D above, slight deviation was observed in phase-3 and phase-2 emissions from grassland. This is mainly because the biomass factor has been updated using the BUR II report.

3.9.4 Uncertainty

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

The classification outputs were subjected to post classification accuracy assessment. The error matrix of accuracy assessment for different states was done. The overall classification accuracy is found to be 88.82% with a range of 83.05% to 95.31% in different states for 2006 to 2007.[33]

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[34]. During 2013-14 it was <1 pixel in plains[35].

The standing stock or biomass stock outside forest area is which includes grassland is taken from the State of Forest Report (*SFR 2015*). 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 K. Sreenivas et al 2016 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 agroecological 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 3.9E: Source category wise description of Qualitative uncertainty

IPCC ID	**Source Category**	**Qualitative Uncertainty**	
		Activity Data	**Emission Factor**
3B3	Grassland	Lack of access to finer resolution data to map land use changes	Lack of data on underlying assumptions for carbon stock calculations such as stand age, species composition, etc. Lack of availability of region-specific carbon stock data based on topography and climatic regions.

[33] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/0607.pdf (refer section 3.5)
[34] 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)
[35] http://bhuvan.nrsc.gov.in/gis/thematic/tools/document/LULC250/1314.pdf

3.9.5 Recommended 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.

3.10 3B5 Settlements

3.10.1 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 for national GHG inventories).

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.

Given below are details of activity data used in Settlements. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.10A: An overview of source categories of Settlements

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

3.10.2 Methodology

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

In this study, GHG emissions from settlements are estimated using the *Stock Difference Method*[36] 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 sub-categories of land converted to Settlements:

Table 3.10B: An overview of emission factors used for settlements			
IPCC ID	**GHG source & sink categories**	**CO_2**	
		Method Applied	**Emission Factor**
3B5	**Settlements**		
3B5a	Settlements Remaining Settlements	T2	CS
3B5bii	Cropland 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, 2014 and 2015, land use pattern for 2005 has been assumed same as for the year 2006. Similarly, land use pattern for 2013, 2014 & 2015 has been assumed to be same as for 2012. This is because these changes in land use tend to be almost the same when looked at year on year.

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

Step 4:
The annual change in organic C stocks in mineral soils is estimated using the equation given below of the {IPCC 2006 Guidelines } (Equation 2.25, chapter 2, Vol. 04 (Refer Annex I for sample calculations)):

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

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

where,

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

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

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

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

Due to lack of data during two points of time, the rate of change in SOC for settlements was determined from the country-specific reference soil organic C stocks from K. Sreenivas et al. 2016 and default stock change factors (F_{LU}, F_{MG}, F_I) as given by the {IPCC 2006 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 0.8, 1.22 and 1 was considered respectively for the land transition from settlements to cropland (Section 8.3.3.2, Chapter 8, Vol. 04 IPCC 2006 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 biomass and soil organic carbon content for each sub-category is calculated by multiplying the area within that sub-category with the respective change in biomass and soil organic carbon for that particular sub-category. The total change in carbon stocks is calculated by adding up all values of the sub-category estimates.

3.10.3 Recalculation

No recalculation was performed for estimating emissions from this category because the activity data, emissions factor and methodology was the same as used for Phase II estimates. There was no new data source used, no error was observed and no new methodology was used.

3.10.4 Uncertainty

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

The classification outputs were subjected to post classification accuracy assessment. The error matrix of accuracy assessment for different states was done. The overall classification accuracy is found to be 88.82% with a range of 83.05% to 95.31% in different states (NRSC 2007).

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 (NRSC 2010) (NRSC 2012) (NRSC 2013)[37]. 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 K. Sreenivas *et al* 2016 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 agroecological 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 3.10C: Source category wise description of Qualitative uncertainty

IPCC ID	Source Category	Qualitative Uncertainty	
		Activity Data	**Emission Factor**
3B5	Settlements	Lack of access to finer resolution data to map land use changes	Lack of data on underlying assumptions for carbon stock calculations such as stand age, species composition, etc. Lack of availability of region-specific carbon stock data based on topography and climatic regions.

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3.10.5 Recommended Improvements

For the estimation of GHG emissions/removals from land, we will be looking at generating change matrices for selected states to$_2$ validate the change matrices that we have been able to obtain from official sources. In addition, we will continue to scan relevant literature for improvements in tools and methodologies, as well as more precise data in the future.

3.11 3B6 Other Land

3.11.1 Category description

For the sub-category 'other lands', it includes wasteland, snow covered area, rocky surfaces, water bodies, etc. For this category, Land Use Change Matrix for Other Land has been derived from National Remote Sensing Centre (NRSC), Hyderabad. NRSC is a national organization hosted under Indian Space Research Organization (ISRO). Given below are details of activity data used in the sub-category. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.11A: An overview of source categories of Other Land

IPCC ID	GHG source & sink categories	Type	Quality	Source
3B	**Land**			
3B6	Other Land	Secondary Data	High	National Remote Sensing Centre (available on request)
3B6a	Other Land Remaining Other Land	Secondary Data	High	
3b6bii	Cropland converted to Other Land	Secondary Data	High	
3b6biii	Grassland converted to Other Land	Secondary Data	High	
3b6biv	Settlements converted to Other Land	Secondary Data	High	

3.11.2 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 Other Land 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 3.11B: An overview of Emission Factors used for Other Land

IPCC ID	GHG source & sink categories	CO_2	
		Method Applied	**Emission Factor**
3B5	**Other land**		
3B6a	Other Land Remaining 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, 2014 and 2015, land use pattern for 2005 has been assumed same as for the year 2006. Similarly, land use pattern for 2013, 2014 & 2015 has been assumed to be same as for 2012. 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 for national GHG inventories). Since, there is no land conversion from Forest Land to Other Land, no calculations have been performed for the same.

Step 5:
The total biomass and soil organic carbon content for each sub-category is calculated by multiplying the area within that sub-category with the respective change in biomass and soil organic carbon for that particular sub-category. The total change in carbon stocks is calculated by adding up all values of the sub-category estimates.

3.11.3 Recalculation

No deviation was observed in phase-3 and phase-2 emissions from Other Lands. This is mainly because the activity data and methodology used to calculate the emissions remained invariant.

3.11.4 Uncertainty

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

The classification outputs were subjected to post classification accuracy assessment. The error matrix of accuracy assessment for different states was done. The overall classification accuracy is found to be 88.82% with a range of 83.05% to 95.31% in different states(NRSC 2007)

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 (NRSC 2010) (NRSC 2012) (NRSC 2013). During 2013-14 it was <1 pixel in plains.

The standing stock or biomass stock outside forest area is which includes Other Land 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 K. Sreenivas *et al* 2016 from NRSA, wherein the SOC was spatially mapping at 250 m resolution and an estimate of their pool size in India was undertaken using many remote sensing derived data layers and data mining approach. The SOC densities were estimated for 1198 soil samples located across India using a stratified random sampling that integrated land use, soil, topography and agroecological regions. Using 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 3.11C: Source category wise description of Qualitative uncertainty

IPCC ID	**Source Category**	**Qualitative Uncertainty**	
		Activity Data	**Emission Factor**
3B6	Other Land	Lack of access to finer resolution data to map land use changes	Lack of data on underlying assumptions for carbon stock calculations such as stand age, species composition, etc. Lack of availability of region-specific carbon stock data based on topography and climatic regions.

3.11.5 Recommended 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.

3.12 3C Aggregate Sources and Non-CO_2 Emission Sources on Land

3C1a Biomass Burning in Forestland

3.12.1 Category description

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

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. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.12A: An overview of source categories of Forestland

IPCC ID	**GHG source & sink categories**	**Type**	**Quality**	**Source**
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**			
3C1a	Biomass Burning in Forestland	Secondary Data	High	Forest Survey of India State of Forest Reports: 2017 2015 2013 2011 2009 2005

3.12.2 Methodology

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

Table 3.12B: An overview of Emission factors used for Biomass burning in Forest Land

IPCC ID	**GHG source & sink categories**	**CH_4**		**N_2O**	
		Method Applied	**Emission Factor**	**Method Applied**	**Emission Factor**
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**				
3C1a	Biomass burning in Forestland	T2	CS	T2	CS

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

2006 IPCC guidelines for national GHG inventories is adopted for estimating the GHG emissions from forest fire. The following equation (Equation 2.27, Chapter 2, Vol. 04 {IPCC 2006 Guidelines}, (Refer Annex 1 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_4, N_2O, etc.

A = area burnt, ha

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

C_f = combustion factor, dimensionless

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

Steps followed:

Step 1:

Non-CO_2 GHG emissions are estimated for the forestland subjected to biomass burning. The state-wise activity data for the area of the forest burnt was derived by (Reddy, 2017 n.d.)which gives the forest area burnt of each state it could further be apportioned to get the actual Area burnt by using the forest area of the particular state from FSI report.

Step 2:

Mass of fuel available for combustion (M_B) is used from (NATCOM 2 n.d., p. 70)(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 [38] 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 (Value – 0.36 referred from Table 2. 6 (*V4_02_Ch2_Generic.pdf*, n.d.)

Step 5:

Country specific emission factors (G_{ef}) for methane and nitrous oxide gas were adopted from NATCOM 2 "indnc2.pdf," n.d., p. 70

Step 6:

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

[38] Section 4.2.4.3, P-4.28, Chapter 4, Volume 4, 2006 IPCC Guidelines for National GHG Inventories. Values selected from Table 2.6, Chapter 2, Volume 4, 2006 IPCC Guidelines for National GHG Inventories.

3.12.3 Recalculation

Table 3.12C: Source category wise details on the difference between GHG estimates				
Year	Key source category	GHG Emission Estimates ($MtCO_2e$)		% Difference
		Phase-II	Phase-III	
2005	Biomass burning in forest land	0.32	5.02	1488%
2006	Biomass burning in forest land	0.32	5.04	1490%
2007	Biomass burning in forest land	0.32	5.06	1497%
2008	Biomass burning in forest land	0.32	5.08	1504%
2009	Biomass burning in forest land	0.32	5.10	1506%
2010	Biomass burning in forest land	0.32	5.12	1508%
2011	Biomass burning in forest land	0.32	5.14	1510%
2012	Biomass burning in forest land	0.32	5.16	1512%
2013	Biomass burning in forest land	0.32	5.18	1514%

As decided amongst platform partners, a significance threshold of 5% is considered. Recalculation have been reported where the deviation between Phase III and Phase II results is higher than the threshold.

As seen in table 3.12C, a substantial deviation is observed in phase-3 and phase-2 emissions from the biomass burning in forest land. It is mainly because, in the present phase, we were able to get the state wise proportion of the forest area burnt unlike the previous phase where the total burnt area in year 2000 was taken from NATCOM II which was used to derive the Burnt area factor.

3.12.4 Uncertainty

The activity data for the area under forests at the state level is from Forest Survey of India reports. The area burnt is derived using appropriate proportions from (Reddy, et al. 2017)in activity data arises due to non-availability of data on forest burnt every year India.

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 3.12D: Source category wise description of Qualitative uncertainty			
IPCC ID	Source Category	Qualitative Uncertainty	
		Activity Data	Emission Factor
3C1a	Biomass burning in Forestland	Uncertainty arise due to various variables used in the assessment such as fraction of forest burnt, area estimation.	Uncertainty arise due to various variables used in the assessment such as climatic conditions, soil type, water etc. Various biological, chemical and physical properties of soil and forest type influence the emissions from soil to the atmosphere

3.12.5 Recommended Improvements

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

3.13 3C1b Biomass Burning in Cropland

3.13.1 Category description

From a climate change perspective, burning of crop residues causes emissions of N_2O and CH_4. CO_2 emissions do not count since it is an offset by the absorption of CO_2 in the process of photosynthesis that caused the biomass growth at the outset. Given below are details of the data used for estimation. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.13A: An overview of source categories of Cropland

IPCC ID	GHG source & sink categories	Years	Type	Quality	Source
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**				
3C1a	Biomass Burning in Cropland	2005 to 2008	Secondary Data	High	Planning Commission of India (See table titled-"Production of principal crops - State-wise")
		2009 to 2015	Secondary Data	High	Agriculture chapter in Statistical Year Book (See table 8.3 under chapter 8 for every year)

3.13.2 Methodology

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

Table 3.13C: An overview of emission factors used for biomass burning in cropland

IPCC ID	GHG source & sink categories	CH_4		N_2O	
		Method Applied	**Emission Factor**	**Method Applied**	**Emission Factor**
3.	**AFOLU**				
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**				
3C1b	Biomass Burning in Cropland	T1	CS	T1	CS

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

Steps followed:

Step 1:

Crop residue is burnt in many Indian states particularly in Punjab, Haryana and Western Uttar Pradesh leading to greenhouse gas emissions Jain et al. (2013)[39]. The crop considered for biomass burning in cropland in India for this study is rice, wheat, cotton, maize, millets, sugarcane, jute, mustard and groundnut). Emissions from crop residue burning was calculated using the following equation[40]:

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

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[41]
E is the fraction oxidized,
F is the emission factor for CH_4 and N_2O
(Refer Annex I for sample calculations)

Step 2:

State-wise crop production data for above mentioned crops were obtained from Planning Commission of India (from 2004-05 to 2007-08) and Statistical Year Books (2008-09 to 2015-16) and a ratio of residue to crop ratio was taken from Jain et. al. 2014.

The production data is provided in fiscal years which was converted to calendar year values by considering 3/4th of the value from the previous financial year (corresponding to 9 months from April to December out of 12 months in a year) and 1/4th from the next financial year (corresponding to 3 months from January to March out of 12 months in a year).

From years 2013-14 onwards, crop production data for only major states is provided by the government. Therefore, the data is apportioned by calculating an average from the corresponding previous years using a linear trend analysis.

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). Since, direct value for groundnut and rapeseed-mustard combustion efficiency wasn't available; we have used value of other nuts as a proxy for groundnut from Turn et al (1997) The emission factors for different pollutants emitted from residue burning were taken from Andreae and Merlet (2001).

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[39] http://www.aaqr.org/files/article/619/40_AAQR-13-01-OA-0031_422-430.pdf

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

[41] 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

3.13.3 Recalculation

As decided amongst platform partners, a significance threshold of 5% is considered. Recalculation have been reported where the deviation between Phase III and Phase II results is higher than the threshold.
Less than 5% deviation is observed in phase-3 and phase-2 emissions from the biomass burning in Cropland. This is primarily because of the fact that, in phase-3 there is a slight variation in the activity data of crop production which is now sourced from more reliable and publicly available sources unlike phase 2. Also, in this phase the national value has been obtained by totaling the state values.

3.13.4 Uncertainty

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 Andrea and Merlet 2001[42]. 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 3.13D: Source category wise description of Qualitative uncertainty

IPCC ID	**Source Category**	**Qualitative Uncertainty**	
		Activity Data	**Emission Factor**
3C1a	Biomass burning in cropland	No specific activity data on crop burning available. Therefore, assumptions have been made to estimate the proportion of crop residues burnt every year	Uncertainty arise due to various variables used in the assessment such as fraction of residue burnt, area estimation, climatic conditions, soil type, water usage etc. Various biological, chemical and physical properties of soil influence the emissions from soil to the atmosphere, etc.

3.13.5 Recommended Improvements

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

3.13 Estimation of Emissions from Agricultural Soils, including from:

3C4 Direct N_2O emissions from managed soils and

3C5 Indirect N_2O emissions from Managed Soils

3.14.1 Category description

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

[42] https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2000GB001382

N_2O through volatilization losses, leaching and runoffs. Given below are the details of data used. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.14A: An overview of source categories of Aggregate sources and non-CO2 Emissions Sources on Land				
IPCC ID	**GHG source & sink categories**	**Type**	**Quality**	**Source**
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**			
3C4	Direct N_2O emissions from managed soils	Secondary	High	
3C5	Indirect N_2O emissions from managed soils	Secondary	High	
		Urea		Indian Fertilizer Scenario, Department of Fertilizers, Ministry of Chemicals and Fertilizers Government of India http://fert.nic.in/sites/default/files/Fertilizers%20Scenario%202017.pdf http://fert.nic.in/sites/default/files/Full%20Book.pdf http://fert.nic.in/sites/default/files/Indian%20Fertilizer%20SCENARIO-2014.pdf
		Nitrogen Consumption		Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare Ministry of Agriculture and Farmers Welfare, Govt of India https://eands.dacnet.nic.in/latest_2006.htm https://eands.dacnet.nic.in/Previous_AT_Glance.htm

3.14.2 Methodology

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

Table3.14B: An overview of emission factors used for N_2O emissions from Managed Soils					
IPCC ID	**GHG source & sink categories**	**CH_4**		**N_2O**	
		Method Applied	**Emission Factor**	**Method Applied**	**Emission Factor**
3.	**AFOLU**				
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**				
3C4	Direct N_2O emissions from Managed Soils			T2	CS
3C5	Indirect N_2O emissions from Managed Soils			T2	CS

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

Step 1:
As already mentioned above, the data on total N consumption for years 2007-08 to 2014-15 was taken from Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare Ministry of Agriculture and Farmers Welfare, Govt of India. For year 2004-05 to 2006-07 and 2015-16 the interpolation and extrapolation techniques were used using the CAGR of the above-mentioned period. The month wise data on the actual sale[43] of urea was obtained from the annual report 'Indian Fertilizer Scenario' published by the Department of Fertilizers, Ministry of Chemicals and Fertilizers Government of India which was then added up to obtain the annual sales. For years 2009-10 to 2015-16 the sales data was available for all the states. However, for years 2004-05 to 2008-09 the data some minor selling states was combined and provided as 'Others'. So, the average proportion of the sales throughout 2009-10 to 2015-16 was utilised to estimate the state wise sales for the previous years. For calculating the quantity of Nitrogen in Urea, the total urea consumption was multiplied by 46 percent as urea contains 46% Nitrogen[44]. So, N consumed by other fertilizers was found by subtracting the N consumed in urea from the total N consumption.

Step 2:
For the calculation of the nitrogen loss from volatilization of NH_3 and NO_x, a magnitude of 15 percent per kg of urea and other fertilizers was considered instead of IPCC fraction of 10 percent as most Indian soils are low in acidity and high in average temperature therefore resulting in more volatilization losses. The fraction of N lost through leaching is 10 percent of N applied to the soil. It should be noted that the above-mentioned factors have been sourced from BUR-II[45].

Step 3:
The default IPCC emission factor for N_2O emission for atmospheric NH_3 and NO_x is 1 percent; however, considering characteristics of Indian soils, 0.5 percent emission factor was used for N_2O from volatilized N. Similarly, emission factor used for deposited N from leaching and runoff was 0.5 percent as stated in BUR-II[46] .

[43] It was assumed that the sales were equal to the consumption of urea.
[44] Refer Table 5 http://fert.nic.in/sites/default/files/Full%20Book.pdf
[45] Refer Table 2.11 https://unfccc.int/sites/default/files/resource/INDIA%20SECOND%20BUR%20High%20Res.pdf
[46]Refer Table 2.11 https://unfccc.int/sites/default/files/resource/INDIA%20SECOND%20BUR%20High%20Res.pdf `

3.14.3 Recalculation

Table 3.14C: Source category wise details on the difference between GHG estimates				
Year	Key source category	GHG Emission Estimates ($MtCO_2e$)		% Difference
		Phase-II	Phase-III	
2005	Agricultural Soils	37.54	44.66	19%
2006	Agricultural Soils	40.68	45.03	11%
2007	Agricultural Soils	42.92	45.43	6%
2008	Agricultural Soils	44.93	47.22	5%
2009	Agricultural Soils	46.54	48.87	5%
2010	Agricultural Soils	49.11	51.71	5%
2011	Agricultural Soils	51.52	54.22	5%
2012	Agricultural Soils	51.00	53.34	5%
2013	Agricultural Soils	50.48	51.07	1%

As decided amongst platform partners, a significance threshold of 5% is considered. Recalculation have been reported where the deviation between Phase III and Phase II results is higher than the threshold. As seen in table 3.14C above, a significant deviation is observed in phase-3 and phase-2 emissions from Agricultural soils. This deviation can be attributed to the change in the activity data which is now sourced from more reliable publicly available sources, unlike the previous phase where the data was made available on request.

3.14.4 Uncertainty

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 3.14D: Source category wise description of Qualitative uncertainty			
IPCC ID	Source Category	Qualitative Uncertainty	
		Activity Data	Emission Factor
3C4 & 3C5	Agriculture Soils	Lack of coverage of measurements, spatial aggregation, and lack of information on specific on-farm practices.	According to 2006 IPCC guidelines (Chapter 11, Volume 04)60, uncertainties in estimates of emissions from managed soils are caused by uncertainties related to the emission factors that arise from natural variability, partitioning fractions.

3.14.5 Recommended Improvements

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

3.15 3C7 Rice Cultivation

3.15.1 Category description

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. Given below are the details of data used. The data quality is considered high because the activity data has been obtained from credible and relevant Government of India sources that have been engaged in collecting such data every five years for several decades. Further, the credibility of the data is acknowledged by all the relevant stakeholders both within and outside the Government.

Table 3.15A: An overview of source categories of Rice Cultivation

IPCC ID	**GHG source & sink categories**	**Type**	**Quality**	**Source**
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**			
3C7	Rice Cultivation	Secondary	High	Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmer's Welfare, Government of India Source: For years 2004-05 to 2012-13: Table 3.1, State-wise Area under Crops (Detailed Tables - State wise(2003-04 to 2012-13) available at: http://eands.dacnet.nic.in/LUS_2012-13.htm) For years 2013-14 to 2015-16: Table 3.1, State-wise Area under Crops (All India Summary Tables available at : http://eands.dacnet.nic.in/LUS_1999_2004.htm)

3.15.2 Methodology

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

Table 3.15B: An *overview of Emission Factors used for Rice Cultivation*

IPCC ID	**GHG source & sink categories**	**CH_4**		**N_2O**	
		Method Applied	**Emission Factor**	**Method Applied**	**Emission Factor**
3.	**AFOLU**				
3C	**Aggregate sources and non-CO_2 Emissions Sources on Land**				
3C7	Rice Cultivation	T3	CS		

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

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

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

Where,

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

Step1:
We first calculated the percentage of area under rice under respective water management regime for each state by multiplying the harvested area obtained by percentage area covered under a particular water management regime. The water management regimes in each state were assumed to be the same as that available in Pathak et al 2010, Bhatia et al 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 BUR-II) used were as follows:

Table 3.15C: Emission Factor for different water regime for Rice Cultivation	
Emission from different water regime for rice cultivation	**Emission (kg CH_4/ha)**
Continuous Flooding	159.74
Single Aeration	66.2
Multiple Aeration	19.3
Flood Prone	189
Drought Prone	66.84
Deep Water	190
Upland	0

Source: (Table 2.10, “BUR Report,” n.d.)

3.15.3 Recalculation

As decided amongst platform partners, a significance threshold of 5% is considered. Recalculation have been reported where the deviation between Phase III and Phase II results is higher than the threshold.
A very minute deviation is observed in phase 3 and phase 2 emissions from rice cultivation. This slight variation due to a slight change in emission factors which has been sourced from published EF in BUR 2 ("BUR Report," n.d.) unlike phase 2.

3.15.4 Uncertainty

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 BUR 2 ("BUR Report," n.d.). According to it, there is an underlying uncertainty of 8.0% in emission factors. 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 3.15D: Source category wise description of Qualitative uncertainty

IPCC ID	Source Category	Qualitative Uncertainty	
		Activity Data	Emission Factor
3C7	Rice Cultivation	Precise and disaggregated data on water regimes for rice cultivation in different parts of the country is not available.	8.0%

3.15.5 Recommended Improvements

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

4 Comparison with national inventories

Table 4: AFOLU Source category wise details of deviation in GHG estimates between GHGPI and official inventories published by Government of India ($MtCO_2e$)

Key Source Category	2007			2010			2014		
	INCCA	GHGPI	% Deviation	BUR	GHGPI	% Deviation	BUR2	GHGPI	% Deviation
3A1 Enteric Fermentation	212.1	208.42	-2%	227.03	204.79	-10%	227.16	204.76	-10%
3A2 Manure Management	2.44	21.86	796%	2.77	21.49	676%	28.10	21.52	-23%
3B1 Forest Land	-67.8	-97.97	45%	-203.83	-97.97	-52%	-69.67	-124.44	79%
3B2 Cropland	-207.52	-1.46	-99%	-110.76	-0.62	-99%	-248.61	-1.32	-99%
3B3 Grasslands	10.49	0.58	-94%	55.65	0.42	-99%	17.22	0.66	-96%
3B5 Settlements	-0.04	0.45	-1214%	2.62	0.47	-82%	-1.58	0.49	-131%
3B6 Other Land	-	-	-	-	-	-	-	-	-
3C1a Biomass burning in forest land	-	-	-	3.79	5.23	38%	157.47	5.12	-97%
3C1b Biomass burning in cropland	6.61	5.75	-12.96%	7.92	6.17	-22%	8.59	5.84	-32%
3C4&3C5 Direct and Indirect emissions from managed soils	43.4	45.43	4.68%	81.08	50.87	-37%	80.53	51.71	-36%
3C7 Rice Cultivation	69.87	71.10	1.13%	71.37	69.44	-3%	72.84	69.4	-5%

3A1 Enteric Fermentation

All the necessary and required data from 18th and 19th Livestock Census of India for years 2007 and 2012 respectively[47] have been used. The calculations are consistent with the requirements of best practice as per 2006 IPCC guidelines

INCCA: GHGPI values deviated only by a slight magnitude of 2% from the INCCA estimates which can be attributed to the bottom's up approach taken up by the platform to attain the National values.

BUR-I and BUR-II: During both the years for which data is reported a deviation of 10% is observed which is mainly due to lack of 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

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

unpacking the BUR inventory is challenging for further analysis. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

3A2 Manure Management

All the necessary and required data from Livestock Census of India for 2007 and 2012[48] have been used. The calculations are consistent with the requirements of best practice as per 2006 IPCC guidelines.

<u>INCCA:</u> A huge deviation of 796% was observed from the INCCA values 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.

<u>BUR-I and BUR-II:</u> In 2010 and 2014 a deviation of 676% and -23% respectively was observed which is mainly due to lack of 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. In the absence of such details unpacking the BUR inventory is challenging for further analysis.

3B1 Forest Land

All the necessary and required data from Forest Survey of India[49] have been used. The calculations are consistent with the requirements of best practice as per 2006 IPCC guidelines.

<u>INCCA:</u> A deviation of 45% was noted 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 are not available in the INCCA report. Our analysis uses FSI reports on carbon stock and forest area, therefore, the variation in results.

<u>BUR-I and BUR-II:</u> A deviation of 52% and 79% was observed in 2010 and 2014 respectively due to lack of 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.

3B2 Cropland

All the available data sources from National Remote Sensing Centre have been used. The calculations are consistent with the requirements of best practice as per 2006 IPCC guidelines.

<u>INCCA:</u> A deviation of -99% was observed from the INCAA values because the 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

[48] http://dahd.nic.in/documents/statistics/livestock-census
[49] http://fsi.nic.in/

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.

BUR-I and BUR-II: A deviation of -99% was also observed from the BUR values in both the years for which the inventories have been reported i.e. 2010 and 2014. This is due to lack of 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.

3B3 Grasslands

All the available data sources from National Remote Sensing Centre have been used. The calculations are consistent with the requirements of best practice as per 2006 IPCC guidelines.

INCCA: A deviation of -94% from the INCCA values was observed because the 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.
BUR-I and BUR-II: A deviation of -99% and -96% was observed in 2010 and 2014 respectively due to lack of 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.

3B5 Settlements

All the available data sources from National Remote Sensing Centre have been used. The calculations are consistent with the requirements of best practice as per 2006 IPCC guidelines.

INCCA: A deviation of -1214% from the INCCA values was observed because INCCA report does not estimate emissions from the category 'Land converted to Settlement'. It only estimates 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.

BUR-I and BUR-II: A deviation of -82% and -131% was observed in 2010 and 2014 respectively due to lack of 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.

3B6 Other Land

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

3C1a. Biomass burning in Forest Land
All the available data sources from Forest Survey of India[50] have been used. The calculations are consistent with the requirements of best practice as per 2006 IPCC guidelines.

INCCA: This category is not considered under emission estimation in the INCCA report.

BUR-I and BUR-II: A deviation of 38% and -97% was observed in 2010 and 2014 respectively due to lack of 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.

3C1b. Biomass Burning in Cropland
The data that have been used for this estimation are calculated from Ministry of Agriculture and peer reviewed literature mentioned above in the methodology section.

INCCA: A deviation of 12.96% from the INCCA values was observed because the INCCA report does not give detailed activity data in terms of residue burnt in Indian states. Hence, it is difficult to analyze the variation without comparing the base data.

BUR-I and BUR-II: A deviation of -22% and -32% was observed in 2010 and 2014 respectively due to lack of 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.

3C4&3C5 Direct and Indirect emissions from managed soils
The calculations are consistent with the requirements of best practice as per 2006 IPCC Guidelines.

INCCA: A slight deviation of 4.68% from the INCCA values was observed which can be attributed to rounding-off factors and adding up of the state values to get the national value.

BUR-I and BUR-II: A deviation of -37% and -36% was observed in 2010 and 2014 respectively due to lack of 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.

3C7 Rice Cultivation
The calculations are consistent with the NATCOM 2 and BUR 2.
INCCA: A very minute deviation of 1.13% from the INCCA values was observed which may be due to rounding off calculations adding up of the state values to get the national value.

BUR-I and BUR-II: A deviation of -3% and -5% was observed in 2010 and 2014 respectively which may be due to rounding off calculations adding up of the state values to get the national value.

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

Additional Information

To the extent possible, we have tried to adhere to the 2006 IPCC guidelines for national GHG inventories for estimations of emissions from the AFOLU sector for India. Exceptions, however, arise due to lack of availability of data that is required to adhere to IPCC 2006 guidelines. In these cases, we have tried to estimate emissions on the basis of the information obtained during the unpacking of official inventories that are available in the public domain. Specifically, the deviations are for the following sub-sectors:

- 3C1b Biomass Burning in Cropland: For this sub-sector, we have used the methodology that has been followed in NATCOM-II
- 3C4 Direct N_2O emissions from Managed Soils: For this sub-sector, we have used the methodology that has been followed in NATCOM-II.
- 3C5 Indirect N_2O emissions from Managed Soils: For this sub-sector, we have used the methodology that has been followed in NATCOM-II.
- 3C7 Rice Cultivation: For this sub-sector, we have used the methodology that has been followed in NATCOM-II.

Appendix

Annexure I

1. **IPCC equation 10.19, Emission Estimation from Enteric Fermentation**

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

Where,

$Emissions$ = *methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}*

$EF_{(T)}$ = *emission factor for the defined livestock population, kg CH_4 $head^{-1}$ yr^{-1}*

$N_{(T)}$ = *the number of head of livestock species/category T in the country*

T = *species/category of livestock*

Sample Calculation:

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

T = Indigenous Dairy Cattle

$EF^{51}_{(Indigenous\ Dairy\ Cattle)}$ = 24 kg CH_4 $head^{-1}$ yr^{-1}

$N_{(Indigenous\ Dairy\ Cattle)}$ = 4,81,41,000[52]

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

2. **IPCC equation 10.20, Emission Estimation from Enteric Fermentation**

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

Where,

$Total\ CH_{4Enteric}$ = *total methane emissions from Enteric Fermentation, Gg CH_4 yr^{-1}*

E_i = *Emissions for the i^{th} livestock categories and subcategories*

Sample Calculation:

Total CH_4 emissions from enteric fermentation from Indigenous Cattle are:

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[51] Source: India's Second National Communications to the UNFCCC, 2004

[52] Using CAGR, livestock derived using 19th Livestock Census of India

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

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

3. <u>IPCC equation 10.21, Emission Factor for Enteric Fermentation</u>

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

Where,

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

GE = *Gross energy intake (MJ[53] / animal / year),*

Y_m = *Methane conversion rate which is the fraction of gross energy feed converted to methane*

<u>Sample Calculation:</u>

For indigenous dairy cattle in India, dry matter intake is approximately 2%[54]. Average body weight of indigenous dairy cattle is 175 kg. The conversion factor (CF) used for arriving at GE is 18.45 MJ/kg feed. These factors are used to calculate Gross Energy Intake.

Now,

GE = 60.99 MJ/animal/year

Y_m = 6%[55]

Therefore,

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

4. IPCC equation 10.22, <u>Emission Estimation from Manure Management</u>

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

Where,

$CH_{4_{Manure}}$ = *methane emissions from Manure Management, Gg $CH_4\ yr^{-1}$*

$EF_{(T)}$ = *emission factor for the defined livestock population, kg $CH_4\ head^{-1}\ yr^{-1}$*

$N_{(T)}$ = *the number of head of livestock species/category T in the country*

T = *species/category of livestock*

<u>Sample Calculation:</u>

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

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[53] Assumed to be 18.45

[54] Swamy and Bhattacharya (2006)

[55] Swamy and Bhattacharya (2006)

T = Indigenous Dairy Cattle

$EF^{56}{}_{(Indigenous\ Dairy\ Cattle)}$ = 3.50 kg CH_4 head^{-1} yr^{-1}

$N_{(Indigenous\ Dairy\ Cattle)}$ = 4,81,41,000[57]

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

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

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

5. IPCC equation 10.25[58], Emission Estimation from Manure Management

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

Where,

$N_2O_{animals}$ = N_2O emissions from animal production in a country (kg N/ yr)

N_2O_{AWMS} = N_2O emissions from Animal Waste Management System in the country (kg N/ yr);

N_T = number of animals of type T in the country

$N_{ex(T)}$ = N excretion of animals of type T in the country (kg N/animal/yr)

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

$EF_{3(AWMS)}$ = N_2O emission factor for an AWMS (kg N_2O -N/ kg of N_{ex} in AWMS)

T = type of animal category

Sample Calculation:

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

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

Emission Factor = 0.0006 kgN_2O/head/year

Population = N_T = 4,81,41,000[59]

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[56] Source: India's Second National Communications to the UNFCCC, 2004

[57] Using CAGR, livestock derived using 19th Livestock Census of India

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

[59] Using CAGR, livestock derived using 19th Livestock Census of India

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

6. IPCC Equation 2.5, Emission Estimation from Land

Stock Difference Method

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

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

Sample Calculation:
Assuming: t_2 = 2013
t_1 = 2011

C_{t_2} = 7044[60] MtC…………………………………………………………………………………………………(5)
C_{t_1} = 6941[61] MtC …………………………………………………………………………………………………(6)

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

7. IPCC Equation 2.25 , Emission Estimation from Land

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

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

where,

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

[60] State of Forest Report 2015
[61] State of Forest Report 2013

$S0C_0$ *and* $S0C_{(0-T)}$ *are calculated using the SOC equation in the box where the reference carbon stocks and stock change factors are assigned according to the land-use and management activities and corresponding areas at each of the points in time (time = 0 and time = 0-T)*

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

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

$S0C_{(0-T)}$[62] = 38 tC/ha…………………………………………………………………………………………(7)
F_{LU}[63] = 1
F_{MG}[64] = 0.97
F_I[65] = 1

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

$S0C_{(0)}$ = $\sum_{C,S,I} SOC_{REF_{C,S,I}} \cdot F_{LU_{C,S,I}} \cdot F_{MG_{C,S,I}} \cdot F_{I_{C,S,I}} \cdot A_{C,S,I}$
- ⇨ $S0C_{(0)}$ = 38 x 1 x 0.97 x 1 x 1
- ⇨ $S0C_{(0)}$ = 36.86 tC/ha……………………………………………………………………………….(8)

Now,

$$\Delta C_{mineral} = \frac{\left(S0C_0 - S0C_{(0-T)}\right)}{D}$$

Therefore, from (7) & (8)

$\Delta C_{mineral}$ = {(8) – (7)}/20
- ⇨ $\Delta C_{mineral}$ = {36.86 – 38}/20
- ⇨ $\Delta C_{mineral}$ = -0.06 tC/ha/year

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62 0 = Grassland; Source: Rao S. (2016)
63 Considering Level = All as per IPCC 2006 Guidelines, Volume 4, Chapter 6
64 Considering Level = Moderately degraded as per IPCC 2006 Guidelines, Volume 4, Chapter 6; FMG for tropical = 0.97, FMG for tropical montane = 0.96
65 Considering Level of Input = Medium as per IPCC 2006 Guidelines, Volume 4, Chapter 6

8. **IPCC Equation 2.27, Emission Estimation from Biomass Burning**

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

Where,

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

A *= area burnt, ha*

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

C_f *= combustion factor, dimensionless*

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

<u>Sample Calculation:</u>

Consider biomass burning[66] in Indian Forests in year 2013.
Area burnt in year 2013 (in ha) = A = 3,04,679
Mass of fuel available for combustion (in t/ha) = 13.12
Combustion Factor = 0.36
Emission factor for methane gas (g/kg dry matter burnt) = 9
Emission factor for nitrous dioxide gas (g/kg dry matter burnt) = 0.11
Therefore,
Methane emissions from biomass burning can be calculated as:

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

⇨ L_{fire} = 12,760 tonnes of methane

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

9. **Equation used for Biomass Burning in cropland**[67]

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

Where,
FBCR is the emissions from residue burning,
A is the crop production,
B is the residue to crop ratio,
C is the dry matter fraction,
D is the fraction burnt
E is the fraction oxidized,
F is the emission factor for CH_4 and N_2O

<u>Sample Calculation:</u>

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[68] = B = 1.50

[66] Note: Source for all the data in this calculation is from India's Second National Communications.
[67] Bhatia et al. (2013)
[68] Jain et al. (2014)

Dry Matter Fraction[69] = C = 0.86
Fraction Burnt[70] = D = 0.80
Combustion Factor[71] = E = 0.89
Emission Factor for CH_4[72] = F = 2.70 g/kg

Therefore,

Emissions from Residue Burning in Punjab's Rice fields =

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

10. <u>Equation used for emission estimation from Rice Cultivation</u>[73]

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

Where,

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

<u>Sample Calculation</u>
Consider rice cultivation in Punjab in year 2013 and intermittent multiple aeration water management is used in Punjab.
Area under intermittent multiple aeration water management is estimated by multiplying the total harvested area by the percentage of area falling under the said water management system based on various studies.
So, in this sample calculation

Area of Rice Cultivation under intermittent multiple aeration management= (2849 ha* 99.6)/100

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[74] = EF_W = 18 kg CH_4/ha
Hence,

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

[69] Jain et al. (2014)
[70] Calculations based on data from Gadde et al. (2009)
[71] Turn et al. (1997)
[72] Andrea and Merlot (2001)
[73] Gupta et al. (2009) and Pathak et al. (2010)
[74] India's Second National Communications to the UNFCCC

Annexure II

Emission estimates (in $MtCO_2e$) from 3A. Livestock sector from 2005 to 15:

State/UT	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Andaman and Nicobar Island	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
Andhra Pradesh	10.13	10.61	11.09	10.76	10.44	10.11	9.79	9.47	9.21	8.98	8.77
Arunachal Pradesh	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.34	0.35	0.36
Assam	6.48	6.74	7.01	7.05	7.09	7.12	7.16	7.20	7.29	7.39	7.50
Bihar	13.08	13.57	14.05	14.17	14.28	14.40	14.52	14.63	14.96	15.37	15.89
Chandigarh	0.02	0.02	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	7.65	7.71
Dadra and Nagar Haveli	0.04	0.04	0.04	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	0.00	0.00
Delhi	0.26	0.28	0.29	0.27	0.25	0.24	0.22	0.20	0.19	0.19	0.19
Goa	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.06
Gujarat	12.12	12.45	12.78	13.26	13.73	14.20	14.67	15.14	15.71	16.32	16.98
Haryana	5.67	5.63	5.59	5.63	5.66	5.69	5.72	5.76	5.82	5.90	6.00
Himachal Pradesh	2.37	2.38	2.38	2.35	2.33	2.30	2.27	2.24	2.23	2.22	2.21
Jammu and Kashmir	3.62	3.70	3.78	3.62	3.47	3.31	3.16	3.00	2.88	2.77	2.66
Jharkhand	7.11	7.33	7.54	7.49	7.44	7.38	7.33	7.28	7.26	7.26	7.26
Karnataka	11.39	11.73	12.08	11.78	11.49	11.20	10.90	10.61	10.40	10.23	10.08
Kerala	1.54	1.50	1.46	1.39	1.31	1.24	1.17	1.10	1.05	1.01	0.98
Lakshadweep	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Madhya Pradesh	20.03	20.76	21.48	20.91	20.33	19.75	19.17	18.59	18.25	17.96	17.72
Maharashtra	17.23	17.19	17.16	16.93	16.71	16.48	16.26	16.03	15.88	15.75	15.63
Manipur	0.33	0.31	0.29	0.28	0.27	0.26	0.25	0.24	0.24	0.23	0.23
Meghalaya	0.61	0.63	0.65	0.65	0.66	0.66	0.67	0.67	0.69	0.70	0.72
Mizoram	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nagaland	0.41	0.41	0.41	0.38	0.34	0.31	0.27	0.24	0.22	0.20	0.19
Odisha	10.13	9.88	9.64	9.41	9.19	8.97	8.74	8.52	8.46	8.44	8.45
Puducherry	0.06	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.04

Punjab	5.90	5.69	5.48	5.57	5.65	5.74	5.82	5.90	6.04	6.19	6.36
Rajasthan	18.74	19.09	19.44	19.78	20.12	20.46	20.80	21.14	21.62	22.16	22.76
Sikkim	0.11	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.12	0.14	0.16
Tamil Nadu	9.89	10.40	10.91	10.33	9.75	9.17	8.59	8.00	7.62	7.28	6.98
Telangana	9.37	9.81	10.25	9.95	9.65	9.35	9.05	8.76	8.52	8.31	8.11
Tripura	0.60	0.63	0.66	0.66	0.66	0.66	0.66	0.66	0.67	0.68	0.69
Uttar Pradesh	30.86	30.96	31.05	32.15	33.24	34.33	35.43	36.52	38.04	39.72	41.57
Uttarakhand	2.24	2.39	2.55	2.48	2.42	2.36	2.30	2.24	2.20	2.17	2.14
West Bengal	11.46	12.63	13.80	13.27	12.75	12.23	11.71	11.18	10.81	10.48	10.18
India	**219.79**	**225.03**	**230.28**	**228.95**	**227.62**	**226.29**	**224.96**	**223.63**	**224.60**	**226.30**	**228.75**

Annexure III

Emission estimates (in $MtCO_2e$) from 3A1. Enteric Fermentation sector from 2005 to 15:

State/UT	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Andaman and Nicobar Island	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Andhra Pradesh	9.22	9.66	10.10	9.80	9.51	9.21	8.91	8.62	8.39	8.18	7.98
Arunachal Pradesh	0.29	0.29	0.29	0.29	0.28	0.28	0.28	0.28	0.28	0.29	0.30
Assam	5.72	5.95	6.18	6.22	6.27	6.31	6.35	6.40	6.48	6.58	6.69
Bihar	11.83	12.27	12.72	12.83	12.94	13.05	13.16	13.27	13.57	13.95	14.43
Chandigarh	0.02	0.02	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	6.89	6.95
Dadra and Nagar Haveli	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	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	0.00	0.00
Delhi	0.24	0.25	0.26	0.25	0.23	0.21	0.19	0.17	0.17	0.16	0.16
Goa	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05
Gujarat	10.99	11.30	11.60	12.03	12.45	12.88	13.30	13.73	14.25	14.80	15.39
Haryana	5.11	5.07	5.03	5.06	5.09	5.11	5.14	5.17	5.23	5.30	5.38
Himachal Pradesh	2.17	2.17	2.17	2.15	2.12	2.10	2.08	2.05	2.04	2.03	2.02
Jammu and Kashmir	3.32	3.39	3.46	3.32	3.18	3.04	2.90	2.75	2.64	2.54	2.44
Jharkhand	6.40	6.60	6.81	6.76	6.71	6.66	6.61	6.56	6.54	6.53	6.53
Karnataka	10.36	10.67	10.99	10.72	10.45	10.19	9.92	9.65	9.46	9.30	9.17
Kerala	1.40	1.37	1.33	1.26	1.19	1.12	1.06	0.99	0.95	0.91	0.87
Lakshadweep	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Madhya Pradesh	18.13	18.80	19.46	18.93	18.41	17.88	17.35	16.82	16.51	16.24	16.02
Maharashtra	15.66	15.62	15.58	15.38	15.17	14.96	14.76	14.55	14.41	14.29	14.18
Manipur	0.27	0.25	0.23	0.23	0.22	0.21	0.21	0.20	0.19	0.19	0.19
Meghalaya	0.52	0.53	0.54	0.55	0.55	0.56	0.56	0.57	0.58	0.59	0.61
Mizoram	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Nagaland	0.32	0.32	0.32	0.29	0.26	0.24	0.21	0.18	0.16	0.15	0.14
Odisha	9.16	8.95	8.73	8.53	8.33	8.13	7.93	7.73	7.68	7.66	7.68
Puducherry	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04

Punjab	5.35	5.16	4.97	5.05	5.13	5.20	5.28	5.35	5.47	5.61	5.76
Rajasthan	17.08	17.41	17.73	18.04	18.34	18.65	18.95	19.26	19.69	20.18	20.72
Sikkim	0.10	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.11	0.12	0.14
Tamil Nadu	8.99	9.46	9.93	9.40	8.87	8.34	7.81	7.28	6.93	6.61	6.34
Telangana	8.52	8.93	9.33	9.06	8.79	8.51	8.24	7.97	7.75	7.56	7.38
Tripura	0.52	0.55	0.58	0.57	0.57	0.57	0.57	0.57	0.57	0.58	0.59
Uttar Pradesh	27.84	27.94	28.04	29.03	30.02	31.01	32.00	32.99	34.36	35.88	37.56
Uttarakhand	2.04	2.18	2.31	2.26	2.20	2.15	2.09	2.04	2.00	1.97	1.95
West Bengal	10.35	11.39	12.42	11.96	11.49	11.02	10.55	10.08	9.75	9.45	9.19
India	**198.84**	**203.63**	**208.42**	**207.21**	**206.00**	**204.79**	**203.58**	**202.37**	**203.24**	**204.76**	**206.97**

Annexure IV

Emission estimates (in $MtCO_2e$) from 3A2. Manure Management sector from 2005 to 15:

State/UT	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015

Andaman and Nicobar Island	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Andhra Pradesh	0.91	0.95	0.99	0.96	0.93	0.91	0.88	0.85	0.83	0.81	0.79
Arunachal Pradesh	0.06	0.06	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	0.81	0.81
Bihar	1.25	1.29	1.33	1.34	1.35	1.35	1.36	1.36	1.39	1.42	1.46
Chandigarh	0.00	0.00	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	0.75	0.76
Dadra and Nagar Haveli	0.00	0.00	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	0.00	0.00
Delhi	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.03	0.03	0.03
Goa	0.01	0.01	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	1.52	1.59
Haryana	0.56	0.56	0.56	0.57	0.57	0.58	0.58	0.59	0.59	0.60	0.61
Himachal Pradesh	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.19	0.19	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	0.23	0.22
Jharkhand	0.71	0.73	0.74	0.73	0.73	0.73	0.73	0.72	0.73	0.73	0.73
Karnataka	1.03	1.06	1.09	1.06	1.03	1.01	0.98	0.96	0.94	0.92	0.91
Kerala	0.14	0.13	0.13	0.13	0.12	0.12	0.11	0.11	0.11	0.11	0.11
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	1.90	1.96	2.02	1.97	1.92	1.87	1.82	1.77	1.74	1.72	1.70
Maharashtra	1.58	1.58	1.57	1.56	1.54	1.52	1.50	1.48	1.47	1.46	1.45
Manipur	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04
Meghalaya	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Mizoram	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
Nagaland	0.09	0.09	0.09	0.09	0.08	0.07	0.07	0.06	0.06	0.05	0.05
Odisha	0.97	0.94	0.91	0.88	0.86	0.83	0.81	0.79	0.78	0.78	0.78
Puducherry	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Punjab	0.55	0.53	0.51	0.52	0.53	0.53	0.54	0.55	0.56	0.58	0.59
Rajasthan	1.66	1.68	1.71	1.74	1.78	1.81	1.85	1.88	1.93	1.98	2.04
Sikkim	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02

Tamil Nadu	0.90	0.94	0.98	0.93	0.88	0.83	0.78	0.73	0.69	0.66	0.64
Telangana	0.85	0.88	0.92	0.89	0.87	0.84	0.82	0.79	0.77	0.75	0.74
Tripura	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10
Uttar Pradesh	3.02	3.02	3.01	3.12	3.22	3.32	3.43	3.53	3.68	3.84	4.01
Uttarakhand	0.20	0.22	0.24	0.23	0.22	0.22	0.21	0.20	0.20	0.20	0.19
West Bengal	1.11	1.24	1.37	1.32	1.26	1.21	1.15	1.10	1.06	1.02	0.99
India	**20.94**	**21.40**	**21.86**	**21.74**	**21.62**	**21.50**	**21.38**	**21.26**	**21.36**	**21.53**	**21.78**

Annexure V

Emission estimates (in $MtCO_2e$) from 3B. Land sector from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**

Andaman and Nicobar Island	-7.20	-7.20	-7.20	-7.20	-7.20	-7.20	-7.21	-1.25	-1.25	0.28	0.28
Andhra Pradesh	-14.86	-14.86	-14.86	-14.90	-14.90	-14.90	-14.95	-28.13	-28.13	-36.55	-36.55
Arunachal Pradesh	-21.38	-21.38	-21.38	-21.67	-21.67	-21.67	-21.50	4.70	4.70	5.33	5.33
Assam	-3.44	-3.44	-3.44	-3.46	-3.46	-3.46	-3.47	0.43	0.43	-7.64	-7.64
Bihar	1.52	1.52	1.52	1.18	1.18	1.18	1.33	0.81	0.81	-0.33	-0.33
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.08	-0.08	0.00	0.00
Chhattisgarh	-4.07	-4.07	-4.07	-4.15	-4.15	-4.15	-4.45	1.34	1.34	0.41	0.41
Dadra and Nagar Haveli	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.09	0.09	-0.01	-0.01
Daman and Diu	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.09	-0.09	-0.01	-0.01
Delhi	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.08	-0.08	-0.03	-0.03
Goa	-1.19	-1.19	-1.19	-1.18	-1.18	-1.18	-1.18	0.12	0.12	-0.32	-0.32
Gujarat	2.24	2.24	2.24	2.43	2.43	2.43	2.48	0.26	0.26	0.39	0.39
Haryana	0.50	0.50	0.50	0.51	0.51	0.51	0.52	0.39	0.39	0.19	0.19
Himachal Pradesh	-3.12	-3.12	-3.12	-3.16	-3.16	-3.16	-3.01	-0.20	-0.20	-8.07	-8.07
Jammu and Kashmir	-4.11	-4.11	-4.11	-4.30	-4.30	-4.30	-4.12	-8.79	-8.79	-4.50	-4.50
Jharkhand	-3.31	-3.31	-3.31	-3.39	-3.39	-3.39	-3.31	-0.54	-0.54	-0.16	-0.16
Karnataka	-3.56	-3.56	-3.56	-3.47	-3.47	-3.47	-3.54	-7.82	-7.82	-26.01	-26.01
Kerala	-3.67	-3.67	-3.67	-3.65	-3.65	-3.65	-3.70	-32.63	-32.63	-25.40	-25.40
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	2.25	2.25	2.25	1.90	1.90	1.90	2.51	3.35	3.35	1.97	1.97
Maharashtra	10.72	10.72	10.72	10.67	10.67	10.67	10.12	-0.57	-0.57	0.93	0.93
Manipur	-1.51	-1.51	-1.51	-1.48	-1.48	-1.48	-1.49	-1.27	-1.27	-3.84	-3.84
Meghalaya	-3.15	-3.15	-3.15	-3.18	-3.18	-3.18	-3.16	0.48	0.48	1.98	1.98
Mizoram	-0.97	-0.97	-0.97	-0.99	-0.99	-0.99	-1.00	3.33	3.33	5.19	5.19
Nagaland	-0.56	-0.56	-0.56	-0.53	-0.53	-0.53	-0.51	2.07	2.07	8.41	8.41
Odisha	-8.64	-8.64	-8.64	-8.79	-8.79	-8.79	-8.87	-1.46	-1.46	-13.94	-13.94
Puducherry	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.02	-0.10	-0.10	0.05	0.05
Punjab	-0.12	-0.12	-0.12	-0.13	-0.13	-0.13	-0.12	0.28	0.28	-0.80	-0.80
Rajasthan	4.13	4.13	4.13	2.95	2.95	2.95	4.40	2.65	2.65	-1.78	-1.78
Sikkim	-4.18	-4.18	-4.18	-4.10	-4.10	-4.10	-4.04	0.19	0.19	0.30	0.30
Tamil Nadu	2.77	2.77	2.77	2.80	2.80	2.80	2.75	-38.16	-38.16	-1.51	-1.51

Telangana	1.31	1.31	1.31	1.28	1.28	1.28	1.24	31.70	31.70	-9.32	-9.32
Tripura	-2.78	-2.78	-2.78	-2.85	-2.85	-2.85	-2.87	-0.35	-0.35	2.48	2.48
Uttar Pradesh	-3.50	-3.50	-3.50	-2.83	-2.83	-2.83	-3.18	-0.35	-0.35	-3.88	-3.88
Uttarakhand	-0.32	-0.32	-0.32	-0.36	-0.36	-0.36	-0.30	5.25	5.25	-0.31	-0.31
West Bengal	-20.00	-20.00	-20.00	-20.02	-20.02	-20.02	-20.04	-0.68	-0.68	-0.68	-0.68
India	**-90.20**	**-90.20**	**-90.20**	**-92.07**	**-92.07**	**-92.07**	**-90.71**	**-65.09**	**-65.09**	**-117.18**	**-117.18**

Annexure VI

Emission estimates (in $MtCO_2e$) from 3B1. Forest Land category from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**

Andaman and Nicobar Island	-7.21	-7.21	-7.21	-7.21	-7.21	-7.21	-7.21	-1.25	-1.25	0.28	0.28
Andhra Pradesh	-15.04	-15.04	-15.04	-15.04	-15.04	-15.04	-15.04	-28.22	-28.22	-36.63	-36.63
Arunachal Pradesh	-21.66	-21.66	-21.66	-21.66	-21.66	-21.66	-21.66	4.55	4.55	5.17	5.17
Assam	-2.37	-2.37	-2.37	-2.37	-2.37	-2.37	-2.37	1.53	1.53	-6.54	-6.54
Bihar	1.04	1.04	1.04	1.04	1.04	1.04	1.04	0.51	0.51	-0.63	-0.63
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.07	-0.07	0.00	0.00
Chhattisgarh	-4.64	-4.64	-4.64	-4.64	-4.64	-4.64	-4.64	1.15	1.15	0.22	0.22
Dadra and Nagar Haveli	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.09	0.09	-0.01	-0.01
Daman and Diu	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.09	-0.09	-0.01	-0.01
Delhi	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.04	-0.08	-0.08	-0.03	-0.03
Goa	-1.16	-1.16	-1.16	-1.16	-1.16	-1.16	-1.16	0.14	0.14	-0.30	-0.30
Gujarat	1.44	1.44	1.44	1.44	1.44	1.44	1.44	-0.78	-0.78	-0.65	-0.65
Haryana	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.09	0.09	-0.11	-0.11
Himachal Pradesh	-3.33	-3.33	-3.33	-3.33	-3.33	-3.33	-3.33	-0.51	-0.51	-8.39	-8.39
Jammu and Kashmir	-5.12	-5.12	-5.12	-5.12	-5.12	-5.12	-5.12	-9.79	-9.79	-5.51	-5.51
Jharkhand	-3.65	-3.65	-3.65	-3.65	-3.65	-3.65	-3.65	-0.88	-0.88	-0.50	-0.50
Karnataka	-3.08	-3.08	-3.08	-3.08	-3.08	-3.08	-3.08	-7.35	-7.35	-25.54	-25.54
Kerala	-2.38	-2.38	-2.38	-2.38	-2.38	-2.38	-2.38	-31.30	-31.30	-24.08	-24.08
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	0.74	0.74	0.74	0.74	0.74	0.74	0.74	1.58	1.58	0.20	0.20
Maharashtra	9.49	9.49	9.49	9.49	9.49	9.49	9.49	-1.19	-1.19	0.30	0.30
Manipur	-1.63	-1.63	-1.63	-1.63	-1.63	-1.63	-1.63	-1.41	-1.41	-3.98	-3.98
Meghalaya	-3.22	-3.22	-3.22	-3.22	-3.22	-3.22	-3.22	0.43	0.43	1.93	1.93
Mizoram	-1.10	-1.10	-1.10	-1.10	-1.10	-1.10	-1.10	3.23	3.23	5.09	5.09
Nagaland	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	-0.65	1.93	1.93	8.26	8.26
Odisha	-9.25	-9.25	-9.25	-9.25	-9.25	-9.25	-9.25	-1.83	-1.83	-14.31	-14.31
Puducherry	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.11	-0.11	0.05	0.05
Punjab	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38	0.02	0.02	-1.06	-1.06
Rajasthan	1.55	1.55	1.55	1.55	1.55	1.55	1.55	-0.20	-0.20	-4.62	-4.62
Sikkim	-4.10	-4.10	-4.10	-4.10	-4.10	-4.10	-4.10	0.13	0.13	0.24	0.24

Tamil Nadu	3.09	3.09	3.09	3.09	3.09	3.09	3.09	-37.82	-37.82	-1.17	-1.17
Telangana	1.18	1.18	1.18	1.18	1.18	1.18	1.18	31.64	31.64	-9.38	-9.38
Tripura	-2.88	-2.88	-2.88	-2.88	-2.88	-2.88	-2.88	-0.36	-0.36	2.47	2.47
Uttar Pradesh	-3.64	-3.64	-3.64	-3.64	-3.64	-3.64	-3.64	-0.81	-0.81	-4.34	-4.34
Uttarakhand	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	-0.48	5.07	5.07	-0.49	-0.49
West Bengal	-19.73	-19.73	-19.73	-19.73	-19.73	-19.73	-19.73	-0.37	-0.37	-0.37	-0.37
India	-97.97	-97.97	-97.97	-97.97	-97.97	-97.97	-97.97	-72.35	-72.35	-124.44	-124.44

ANNEXURE VII

Emission estimates (in $MtCO_2e$) from 3B2. Cropland category from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**

Andaman and Nicobar Island	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	-0.14	-0.14	-0.14	-0.11	-0.11	-0.11	-0.20	-0.20	-0.20	-0.20	-0.20
Arunachal Pradesh	0.10	0.10	0.10	-0.09	-0.09	-0.09	0.00	0.00	0.00	0.00	0.00
Assam	-1.12	-1.12	-1.12	-1.14	-1.14	-1.14	-1.15	-1.15	-1.15	-1.15	-1.15
Bihar	0.18	0.18	0.18	0.06	0.06	0.06	0.12	0.12	0.12	0.12	0.12
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.20	0.20	0.20	0.25	0.25	0.25	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	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	0.00	0.00
Delhi	0.00	0.00	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	-0.03	-0.03
Gujarat	0.42	0.42	0.42	0.58	0.58	0.58	0.52	0.52	0.52	0.52	0.52
Haryana	0.23	0.23	0.23	0.25	0.25	0.25	0.23	0.23	0.23	0.23	0.23
Himachal Pradesh	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.08	-0.08	-0.08	-0.08	-0.08
Jammu and Kashmir	-0.14	-0.14	-0.14	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
Jharkhand	0.06	0.06	0.06	0.09	0.09	0.09	0.06	0.06	0.06	0.06	0.06
Karnataka	-0.75	-0.75	-0.75	-0.65	-0.65	-0.65	-0.73	-0.73	-0.73	-0.73	-0.73
Kerala	-1.32	-1.32	-1.32	-1.33	-1.33	-1.33	-1.36	-1.36	-1.36	-1.36	-1.36
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	0.68	0.68	0.68	0.74	0.74	0.74	1.01	1.01	1.01	1.01	1.01
Maharashtra	0.40	0.40	0.40	0.37	0.37	0.37	0.01	0.01	0.01	0.01	0.01
Manipur	0.11	0.11	0.11	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Meghalaya	0.03	0.03	0.03	0.01	0.01	0.01	0.03	0.03	0.03	0.03	0.03
Mizoram	0.13	0.13	0.13	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Nagaland	0.06	0.06	0.06	0.09	0.09	0.09	0.13	0.13	0.13	0.13	0.13
Odisha	0.21	0.21	0.21	0.19	0.19	0.19	0.11	0.11	0.11	0.11	0.11
Puducherry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Punjab	0.21	0.21	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.20
Rajasthan	0.26	0.26	0.26	0.28	0.28	0.28	0.59	0.59	0.59	0.59	0.59
Sikkim	-0.11	-0.11	-0.11	-0.02	-0.02	-0.02	0.01	0.01	0.01	0.01	0.01
Tamil Nadu	-0.50	-0.50	-0.50	-0.45	-0.45	-0.45	-0.50	-0.50	-0.50	-0.50	-0.50

Telangana	-0.10	-0.10	-0.10	-0.08	-0.08	-0.08	-0.15	-0.15	-0.15	-0.15	-0.15
Tripura	0.11	0.11	0.11	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01
Uttar Pradesh	-0.16	-0.16	-0.16	0.52	0.52	0.52	0.19	0.19	0.19	0.19	0.19
Uttarakhand	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	-0.02	-0.02	-0.02	-0.02
West Bengal	-0.39	-0.39	-0.39	-0.39	-0.39	-0.39	-0.42	-0.42	-0.42	-0.42	-0.42
India	**-1.46**	**-1.46**	**-1.46**	**-0.62**	**-0.62**	**-0.62**	**-1.32**	**-1.32**	**-1.32**	**-1.32**	**-1.32**

Annexure VIII

Emission estimates (in $MtCO_2e$) from 3B3. Grassland category from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Andhra Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arunachal Pradesh	0.07	0.07	0.07	0.03	0.03	0.03	0.08	0.08	0.08	0.08	0.08
Assam	0.03	0.03	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	0.00	0.00
Chandigarh	0.00	0.00	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	0.00	0.00
Dadra and Nagar Haveli	0.00	0.00	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	0.00	0.00
Delhi	0.00	0.00	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	0.00	0.00
Gujarat	0.00	0.00	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	0.02	0.02
Himachal Pradesh	0.16	0.16	0.16	0.11	0.11	0.11	0.18	0.18	0.18	0.18	0.18
Jammu and Kashmir	0.10	0.10	0.10	0.04	0.04	0.04	0.13	0.13	0.13	0.13	0.13
Jharkhand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Karnataka	0.01	0.01	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	0.00	0.00
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maharashtra	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manipur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Meghalaya	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mizoram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nagaland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odisha	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Puducherry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Punjab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rajasthan	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Sikkim	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Tamil Nadu	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Telangana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tripura	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uttar Pradesh	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Uttarakhand	0.05	0.05	0.05	0.03	0.03	0.03	0.06	0.06	0.06	0.06	0.06
West Bengal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
India	**0.58**	**0.58**	**0.58**	**0.42**	**0.42**	**0.42**	**0.66**	**0.66**	**0.66**	**0.66**	**0.66**

Annexure IX

Emission estimates (in $MtCO_2e$) from 3B5. Settlements category from 2005 to 15:

State/UT	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015

Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Arunachal Pradesh	0.00	0.00	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	0.01	0.01
Bihar	0.03	0.03	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	0.00	0.00
Chhattisgarh	0.02	0.02	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	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	0.00	0.00
Delhi	0.00	0.00	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	0.00	0.00
Gujarat	0.02	0.02	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	0.01	0.01
Himachal Pradesh	0.00	0.00	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	0.00	0.00
Jharkhand	0.02	0.02	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	0.03	0.03
Kerala	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	0.02	0.02	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	0.04	0.04
Manipur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Meghalaya	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mizoram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nagaland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odisha	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Puducherry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Punjab	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Rajasthan	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Sikkim	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Tamil Nadu	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Telangana	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Tripura	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uttar Pradesh	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Uttarakhand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
West Bengal	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
India	**0.45**	**0.45**	**0.45**	**0.47**	**0.47**	**0.47**	**0.49**	**0.49**	**0.49**	**0.49**	**0.49**

Annexure X

Emission estimates (in $MtCO_2e$) from 3B6. Other Land category from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Andhra Pradesh	0.30	0.30	0.30	0.23	0.23	0.23	0.26	0.26	0.26	0.26	0.26
Arunachal Pradesh	0.11	0.11	0.11	0.04	0.04	0.04	0.07	0.07	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	0.02	0.02
Bihar	0.27	0.27	0.27	0.06	0.06	0.06	0.15	0.15	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	0.00	0.00
Chhattisgarh	0.34	0.34	0.34	0.22	0.22	0.22	0.14	0.14	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	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	0.00	0.00
Delhi	0.00	0.00	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	0.01	0.01
Gujarat	0.36	0.36	0.36	0.40	0.40	0.40	0.50	0.50	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	0.03	0.03
Himachal Pradesh	0.17	0.17	0.17	0.16	0.16	0.16	0.21	0.21	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	1.02	1.02
Jharkhand	0.26	0.26	0.26	0.16	0.16	0.16	0.27	0.27	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	0.23	0.23
Kerala	0.02	0.02	0.02	0.05	0.05	0.05	0.02	0.02	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	0.00	0.00
Madhya Pradesh	0.81	0.81	0.81	0.40	0.40	0.40	0.74	0.74	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	0.58	0.58
Manipur	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Meghalaya	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Mizoram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nagaland	0.02	0.02	0.02	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01
Odisha	0.37	0.37	0.37	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Puducherry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Punjab	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
Rajasthan	2.17	2.17	2.17	0.96	0.96	0.96	2.10	2.10	2.10	2.10	2.10
Sikkim	0.03	0.03	0.03	0.01	0.01	0.01	0.04	0.04	0.04	0.04	0.04
Tamil Nadu	0.13	0.13	0.13	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11

Telangana	0.21	0.21	0.21	0.16	0.16	0.16	0.19	0.19	0.19	0.19	0.19
Tripura	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Uttar Pradesh	0.25	0.25	0.25	0.23	0.23	0.23	0.21	0.21	0.21	0.21	0.21
Uttarakhand	0.11	0.11	0.11	0.09	0.09	0.09	0.14	0.14	0.14	0.14	0.14
West Bengal	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
India	**8.21**	**8.21**	**8.21**	**5.63**	**5.63**	**5.63**	**7.43**	**7.43**	**7.43**	**7.43**	**7.43**

Annexure XI

Emission estimates (in $MtCO_2e$) from 3C. Aggregate Sources and non-CO_2 emissions sources on land sector from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Andaman and Nicobar Island	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Andhra Pradesh	10.08	10.09	9.91	10.56	9.93	11.33	11.39	10.42	9.28	8.61	8.06

Arunachal Pradesh	0.39	0.37	0.37	0.38	0.38	0.41	0.41	0.43	0.44	0.75	0.59
Assam	5.92	5.54	5.68	6.03	6.17	6.36	6.39	6.29	6.12	6.07	6.06
Bihar	9.66	10.14	10.35	10.45	9.78	9.16	10.01	10.57	10.06	10.14	10.73
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	6.57	6.58	6.59	6.61	6.66	6.75	6.83	6.90	6.89	6.95	6.79
Dadra and Nagar Haveli	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	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	0.00	0.00
Delhi	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.03	0.02
Goa	0.09	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.07	0.07	0.08
Gujarat	4.69	4.75	4.85	4.82	4.76	5.28	5.36	4.84	5.09	5.33	5.03
Haryana	4.39	4.46	4.55	4.67	4.76	4.85	5.01	5.00	4.88	4.99	5.17
Himachal Pradesh	0.14	0.14	0.15	0.15	0.14	0.14	0.15	0.15	0.15	0.15	0.16
Jammu and Kashmir	0.30	0.30	0.31	0.34	0.36	0.36	0.35	0.38	0.37	0.35	0.37
Jharkhand	2.75	2.91	2.97	2.98	2.63	2.26	2.51	2.74	2.71	2.58	3.47
Karnataka	4.12	4.16	4.21	4.47	4.79	5.13	5.51	4.70	4.64	4.88	4.65
Kerala	0.79	0.76	0.69	0.69	0.70	0.70	0.70	0.69	0.72	0.65	0.64
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	4.74	4.82	4.87	4.93	5.17	5.33	5.62	5.79	6.14	6.15	6.36
Maharashtra	6.45	6.60	6.89	6.98	7.26	7.88	7.98	7.35	7.74	7.79	7.45
Manipur	0.57	0.56	0.56	0.55	0.55	0.59	0.63	0.56	0.61	0.65	0.61
Meghalaya	0.24	0.24	0.25	0.25	0.24	0.24	0.24	0.18	0.17	0.16	0.16
Mizoram	0.15	0.15	0.15	0.13	0.12	0.10	0.09	0.08	0.08	0.08	0.09
Nagaland	0.38	0.40	0.39	0.39	0.38	0.40	0.40	0.40	0.41	0.41	0.39
Odisha	10.06	10.03	9.80	9.55	9.55	10.04	9.86	9.76	10.02	9.67	9.37
Puducherry	0.11	0.10	0.09	0.08	0.09	0.09	0.07	0.06	0.06	0.05	0.05
Punjab	6.04	6.08	6.15	6.27	6.38	6.52	6.59	6.78	6.60	6.45	6.72
Rajasthan	2.15	2.24	2.34	2.40	2.42	2.79	3.01	3.14	3.12	3.16	3.44
Sikkim	0.05	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04
Tamil Nadu	5.87	5.88	5.67	6.01	5.94	6.05	6.24	5.45	5.45	5.72	6.31
Telangana	5.58	5.63	5.55	5.91	5.48	6.30	6.27	5.69	6.66	5.88	5.09

Tripura	0.60	0.58	0.58	0.57	0.55	0.57	0.59	0.58	0.57	0.57	0.59
Uttar Pradesh	18.69	18.50	18.42	18.84	18.55	18.61	19.10	19.46	18.96	18.90	18.30
Uttarakhand	0.85	0.85	0.86	0.85	0.83	0.83	0.85	0.83	0.84	0.85	0.94
West Bengal	12.78	13.92	13.94	14.33	14.04	12.80	13.47	13.81	13.53	13.60	13.74
India	**125.26**	**127.02**	**127.34**	**130.42**	**128.81**	**132.06**	**135.81**	**133.20**	**132.49**	**131.72**	**131.56**

Annexure XII

Emission estimates (in $MtCO_2e$) from 3C1. Biomass Burning from Forest Land from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Andhra Pradesh	0.60	0.61	0.63	0.65	0.65	0.65	0.67	0.68	0.70	0.73	0.75
Arunachal Pradesh	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Assam	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Bihar	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.19
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.48	0.48	0.48	0.48
Dadra and Nagar Haveli	0.00	0.00	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	0.00	0.00
Delhi	0.00	0.00	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	0.00	0.00
Gujarat	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Haryana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Himachal Pradesh	0.00	0.00	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	0.00	0.00
Jharkhand	0.26	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
Karnataka	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.21	0.21
Kerala	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Maharashtra	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
Manipur	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21
Meghalaya	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Mizoram	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Nagaland	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Odisha	0.84	0.84	0.84	0.84	0.85	0.86	0.86	0.86	0.86	0.87	0.88
Puducherry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Punjab	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rajasthan	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Sikkim	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamil Nadu	0.44	0.44	0.45	0.45	0.45	0.45	0.47	0.48	0.50	0.50	0.50

Telangana	0.34	0.34	0.35	0.35	0.34	0.34	0.33	0.32	0.31	0.31	0.32
Tripura	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Uttar Pradesh	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Uttarakhand	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
West Bengal	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
India	**5.02**	**5.04**	**5.06**	**5.08**	**5.10**	**5.12**	**5.14**	**5.16**	**5.18**	**5.23**	**5.27**

Annexure XIII

Emission estimates (in $MtCO_2e$) from 3C2. Biomass Burning from Cropland from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Andaman and Nicobar Island	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	0.16	0.17	0.19	0.18	0.14	0.17	0.17	0.17	0.17	0.15	0.15
Arunachal Pradesh	0.00	0.00	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	0.06	0.06
Bihar	0.13	0.17	0.16	0.18	0.16	0.17	0.23	0.27	0.24	0.24	0.26
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.05	0.05	0.05	0.05	0.04	0.06	0.06	0.06	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	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	0.00	0.00
Delhi	0.00	0.00	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	0.00	0.00
Gujarat	0.18	0.18	0.20	0.20	0.17	0.20	0.21	0.17	0.22	0.21	0.18
Haryana	0.50	0.54	0.56	0.55	0.55	0.57	0.62	0.61	0.62	0.60	0.61
Himachal Pradesh	0.03	0.03	0.03	0.03	0.02	0.03	0.03	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	0.05	0.04
Jharkhand	0.03	0.05	0.06	0.07	0.04	0.03	0.06	0.07	0.07	0.07	0.07
Karnataka	0.18	0.20	0.22	0.20	0.22	0.28	0.28	0.26	0.27	0.29	0.27
Kerala	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	0.13	0.13	0.12	0.13	0.14	0.15	0.18	0.21	0.22	0.26	0.29
Maharashtra	0.27	0.44	0.54	0.43	0.41	0.50	0.53	0.46	0.48	0.50	0.44
Manipur	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Meghalaya	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mizoram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nagaland	0.00	0.00	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Odisha	0.07	0.07	0.08	0.07	0.07	0.07	0.06	0.07	0.08	0.08	0.06
Puducherry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Punjab	1.11	1.11	1.15	1.19	1.19	1.19	1.20	1.23	1.26	1.21	1.24
Rajasthan	0.18	0.19	0.19	0.20	0.18	0.21	0.22	0.23	0.22	0.23	0.22
Sikkim	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamil Nadu	0.22	0.27	0.26	0.23	0.22	0.23	0.27	0.23	0.23	0.23	0.24
Telangana	0.08	0.08	0.09	0.09	0.07	0.09	0.09	0.09	0.10	0.09	0.07
Tripura	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Uttar Pradesh	1.41	1.48	1.49	1.50	1.48	1.54	1.64	1.69	1.70	1.52	1.58
Uttarakhand	0.05	0.05	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05	0.05
West Bengal	0.17	0.17	0.18	0.18	0.18	0.16	0.17	0.18	0.19	0.19	0.19
India	**5.06**	**5.49**	**5.75**	**5.66**	**5.46**	**5.84**	**6.22**	**6.25**	**6.35**	**6.17**	**6.16**

Annexure IVX

Emission estimates (in $MtCO_2e$) from 3C3. Direct N_2O emissions from managed soils from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	4.17	3.97	3.79	4.04	4.11	4.57	4.74	4.39	3.11	2.62	2.49
Arunachal Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Assam	0.22	0.23	0.24	0.27	0.30	0.33	0.36	0.36	0.36	0.37	0.40

Bihar	2.07	2.14	2.21	2.25	2.17	2.17	2.34	2.47	2.37	2.37	2.85
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.60	0.62	0.65	0.65	0.73	0.77	0.84	0.87	0.87	0.89	0.93
Dadra and Nagar Haveli	0.00	0.00	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	0.00	0.00
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.01
Goa	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Gujarat	2.50	2.51	2.52	2.56	2.63	2.90	2.88	2.45	2.69	2.89	2.72
Haryana	2.20	2.23	2.25	2.27	2.30	2.33	2.42	2.32	2.31	2.40	2.48
Himachal Pradesh	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09
Jammu and Kashmir	0.12	0.13	0.13	0.16	0.18	0.18	0.16	0.17	0.17	0.16	0.19
Jharkhand	0.20	0.21	0.21	0.21	0.22	0.20	0.26	0.27	0.22	0.21	0.28
Karnataka	1.80	1.84	1.89	2.03	2.25	2.41	2.80	2.34	2.24	2.37	2.37
Kerala	0.21	0.22	0.22	0.26	0.27	0.28	0.31	0.30	0.32	0.27	0.26
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	1.71	1.80	1.89	1.92	2.18	2.36	2.51	2.50	2.83	2.74	2.89
Maharashtra	2.93	2.98	3.02	3.17	3.47	3.87	3.90	3.43	3.68	3.73	3.54
Manipur	0.04	0.04	0.03	0.03	0.02	0.01	0.01	0.02	0.02	0.02	0.03
Meghalaya	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Mizoram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
Nagaland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odisha	0.62	0.64	0.65	0.70	0.71	0.71	0.76	0.76	0.75	0.75	0.78
Puducherry	0.06	0.06	0.05	0.04	0.04	0.05	0.04	0.03	0.03	0.02	0.02
Punjab	3.08	3.12	3.15	3.19	3.25	3.34	3.39	3.36	3.34	3.25	3.42
Rajasthan	1.53	1.60	1.67	1.70	1.73	2.00	2.17	2.16	2.24	2.27	2.50
Sikkim	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamil Nadu	1.23	1.26	1.30	1.49	1.48	1.52	1.62	1.43	1.33	1.41	1.59
Telangana	1.89	1.80	1.72	1.83	1.86	2.07	2.15	1.99	2.25	2.08	2.08
Tripura	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02
Uttar Pradesh	6.51	6.55	6.60	6.84	6.95	7.06	7.30	7.55	7.33	7.49	7.18

Uttarakhand	0.25	0.26	0.27	0.27	0.27	0.27	0.29	0.28	0.31	0.33	0.39
West Bengal	1.56	1.60	1.63	1.67	1.74	1.72	1.93	1.94	1.74	1.78	1.96
India	**35.62**	**35.92**	**36.24**	**37.67**	**38.98**	**41.25**	**43.31**	**41.53**	**40.65**	**40.58**	**41.46**

Annexure XV

Emission estimates (in $MtCO_2e$) from 3C4. Indirect N_2O emissions from managed soils from 2005 to 15:

State/UT	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Andaman and Nicobar Island	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Andhra Pradesh	1.06	1.01	0.96	1.02	1.04	1.16	1.20	1.11	0.79	0.66	0.63
Arunachal Pradesh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Assam	0.06	0.06	0.06	0.07	0.08	0.08	0.09	0.10	0.09	0.09	0.10
Bihar	0.53	0.54	0.56	0.57	0.55	0.55	0.53	0.75	0.62	0.60	0.72
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	0.15	0.16	0.16	0.16	0.18	0.20	0.21	0.24	0.22	0.22	0.24
Dadra and Nagar Haveli	0.00	0.00	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	0.00	0.00
Delhi	0.00	0.00	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	0.00	0.00
Gujarat	0.63	0.64	0.64	0.65	0.67	0.73	0.73	0.71	0.68	0.73	0.69
Haryana	0.56	0.56	0.57	0.58	0.58	0.59	0.61	0.74	0.61	0.61	0.63
Himachal Pradesh	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Jammu and Kashmir	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.05
Jharkhand	0.05	0.05	0.05	0.05	0.06	0.05	0.07	0.07	0.05	0.05	0.07
Karnataka	0.46	0.47	0.48	0.51	0.57	0.61	0.71	0.59	0.57	0.60	0.60
Kerala	0.05	0.06	0.06	0.07	0.07	0.07	0.08	0.08	0.08	0.07	0.07
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	0.43	0.46	0.48	0.49	0.55	0.60	0.64	0.73	0.72	0.70	0.73
Maharashtra	0.74	0.75	0.77	0.80	0.88	0.98	0.99	0.87	0.93	0.95	0.90
Manipur	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01
Meghalaya	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mizoram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nagaland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Odisha	0.16	0.16	0.16	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.20
Puducherry	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Punjab	0.78	0.79	0.80	0.81	0.82	0.85	0.86	1.04	0.86	0.83	0.87
Rajasthan	0.39	0.41	0.42	0.43	0.44	0.51	0.55	0.69	0.59	0.58	0.63
Sikkim	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tamil Nadu	0.31	0.32	0.33	0.38	0.38	0.39	0.41	0.38	0.34	0.36	0.40
Telangana	0.48	0.46	0.44	0.46	0.47	0.52	0.54	0.50	0.57	0.53	0.53
Tripura	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Uttar Pradesh	1.65	1.66	1.67	1.74	1.76	1.79	1.85	2.28	1.90	1.90	1.82
Uttarakhand	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08	0.10
West Bengal	0.40	0.41	0.41	0.42	0.44	0.44	0.49	0.54	0.44	0.45	0.50
India	**9.04**	**9.11**	**9.19**	**9.55**	**9.88**	**10.46**	**10.92**	**11.81**	**10.42**	**10.29**	**10.52**

Annexure XVI

Emission estimates (in $MtCO_2e$) from 3C5. Rice Cultivation from 2005 to 15:

State/UT	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Andaman and Nicobar Island	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Andhra Pradesh	4.10	4.32	4.33	4.66	3.98	4.78	4.61	4.06	4.51	4.44	4.04
Arunachal Pradesh	0.37	0.36	0.35	0.36	0.37	0.40	0.40	0.41	0.43	0.73	0.58
Assam	5.50	5.11	5.23	5.55	5.65	5.79	5.79	5.68	5.51	5.45	5.40

Bihar	6.75	7.12	7.24	7.27	6.71	6.08	6.72	6.90	6.64	6.73	6.71
Chandigarh	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chhattisgarh	5.29	5.27	5.24	5.27	5.22	5.24	5.24	5.24	5.25	5.29	5.08
Dadra and Nagar Haveli	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	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	0.00	0.00
Delhi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goa	0.07	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.07
Gujarat	1.32	1.37	1.43	1.37	1.25	1.39	1.49	1.46	1.44	1.44	1.39
Haryana	1.14	1.13	1.16	1.28	1.32	1.35	1.35	1.32	1.35	1.39	1.46
Himachal Pradesh	0.02	0.02	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	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Jharkhand	2.20	2.34	2.37	2.38	2.04	1.71	1.86	2.06	2.10	1.97	2.79
Karnataka	1.48	1.45	1.42	1.52	1.55	1.63	1.52	1.31	1.37	1.41	1.20
Kerala	0.50	0.46	0.40	0.36	0.35	0.33	0.29	0.30	0.31	0.29	0.29
Lakshadweep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madhya Pradesh	2.12	2.09	2.02	2.04	1.95	1.87	1.94	1.99	2.02	2.10	2.10
Maharashtra	1.98	1.90	2.03	2.03	1.97	1.99	2.04	2.06	2.12	2.08	2.04
Manipur	0.31	0.30	0.30	0.30	0.31	0.36	0.40	0.32	0.37	0.41	0.36
Meghalaya	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.12	0.11	0.11	0.11
Mizoram	0.10	0.10	0.10	0.08	0.07	0.05	0.04	0.04	0.03	0.03	0.04
Nagaland	0.26	0.28	0.28	0.28	0.27	0.29	0.29	0.29	0.30	0.30	0.28
Odisha	8.37	8.33	8.07	7.77	7.75	8.22	7.98	7.87	8.14	7.77	7.45
Puducherry	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03
Punjab	1.07	1.06	1.05	1.09	1.12	1.14	1.14	1.15	1.15	1.16	1.19
Rajasthan	0.02	0.02	0.02	0.03	0.04	0.03	0.03	0.03	0.03	0.04	0.05
Sikkim	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04
Tamil Nadu	3.67	3.58	3.34	3.46	3.41	3.45	3.47	2.92	3.05	3.23	3.58
Telangana	2.79	2.96	2.96	3.18	2.73	3.29	3.16	2.78	3.44	2.87	2.09
Tripura	0.49	0.47	0.47	0.46	0.44	0.46	0.47	0.45	0.45	0.46	0.48
Uttar Pradesh	9.07	8.76	8.61	8.71	8.31	8.17	8.26	7.89	7.98	7.94	7.67
Uttarakhand	0.48	0.46	0.45	0.45	0.43	0.44	0.42	0.40	0.39	0.39	0.39

West Bengal	10.62	11.72	11.68	12.03	11.65	10.44	10.84	11.11	11.12	11.14	11.05
India	**70.52**	**71.47**	**71.10**	**72.46**	**69.38**	**69.40**	**70.23**	**68.45**	**69.89**	**69.46**	**68.14**

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Abbreviations

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

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