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Methodologies used in Italy for the estimation of air emission inventory in the agriculture sector

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CONTENT

PREFACE

This technical report wants to contribute to the diffusion of the methodologies use in the agriculture sector for the estimation of greenhouse gases (GHG) and ammonia emissions according to the guidelines prepared by the Intergovernmental Panel on Climate Change (IPCC) and the CORINAIR/EMEP, both provided under the United Nations Framework Convention on Climate Change (UNFCCC) and the Convention on Long-range Transboundary Air Pollution (CLRTAP), respectively.
In the report, methodologies for the estimation of carbon dioxide (CO_2) from soil, methane (CH_4), nitrous oxide (N_2O) and ammonia (NH_3) air emissions for the agricultural sector are described. Background information, activity data, emission factor, methods and emissions are provided for each compound.
The first chapter provides background information on the topics described on chapter 2, 3 and 4. The second chapter provides information related to methane and nitrous oxide emissions estimation, the third chapter information on ammonia emissions, and the fourth on carbon dioxide emissions from soil.
The report covers the description of all compounds estimated for the Italian air emission inventory in the agriculture sector. Methane and nitrous oxide emissions are estimated for the agriculture sector while carbon dioxide emissions from forest, cropland and grassland soils are included in Land Use, Land Use Change and Forestry sector.

1. INTRODUCTION

1.1 United Nations Framework on Climate Change (UNFCCC)

The **Intergovernmental Panel on Climate Change** (**IPCC**), with its first report in 1990, although considering the high uncertainties in the evaluation of climate change, put into evidence the risk of a global warming with effects on climate balance due to the increase of greenhouse gas (GHG) anthropogenic emissions caused by industrial development and use of fossil fuel. Thus the need of reducing those emissions particularly for the most industrialized countries.
At the end of 1990, the European Union (EU), adopted the goal of a stabilization of carbon dioxide emissions by the year 2000 at the level of 1990 and requested Member States to plan and assume initiatives for the environment protection and the energy efficiency. The contents of EU statement were the base for the negotiation of the **United Nations Framework Convention on Climate Change** (**UNFCCC**).
The United Nations Framework Convention on Climate Change (UNFCCC) was approved and signed during the summit of the Earth in Rio the Janeiro in June 1992, as main objective, the stabilization of greenhouse gas concentrations in the atmosphere. This convention was ratified by Italy in 1994 with the law n.65 of 15/01/1994. Under the Convention, all Parties must report on the steps they are taking to implement the Convention (Articles 4.1 and 12). Most of the 40 Annex I Parties submitted their first **National Communications** in 1994-1995 and their second in 1997–1998. Thirty-seven parties submitted the third national communications by 1 March 2004; the deadline for the next communication is 1 January 2006 (decision 4/CP.8).
Moreover, under the Convention, Parties have to submit to the secretariat National Greenhouse Gas (GHG) Inventories of anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol. For Annex I Parties, two sequential processes have been established: a) the annual reporting of national greenhouse gas inventories (National Inventory Report - NIR and Common Reporting Format - CRF[1]; and b) the annual review of the inventories, which comprises three stages (initial, synthesis and assessment and individual reviews), each one is finalized with a review report[2]. Italy has complied with the presentation of the tree national communications[3], the CRF and the NIR. Information from recent CRF and NIR can be found in the UNFCCC web[4], previous ones can be found in the National Network for Environmental Information (SINAnet) web site[5]. Description of methodologies and GHG emissions under the UNFCCC are reported in Chapters 2 and 4.
In Italy, the Agency for the Protection of the Environment and for Technical Services (APAT)[6] is recognized by the competent Ministries and Administrations, as responsible for the compilation of the National Air Emission Inventory through the collection, elaboration and diffusion of data. In particular, as National Reference Centre of the European Environment Agency (EEA), APAT is

[1] The NIRs contain detailed descriptive and numerical information and the CRFs contain summary, sectoral and trend tables for all greenhouse gas (GHG) emissions and removals, and sectoral background data tables for reporting implied emission factors and activity data
[2] http://unfccc.int/national_reports/annex_i_ghg_inventories/review_process/items/2762.php
[3] http://unfccc.int/national_reports/annex_i_natcom/submitted_natcom/items/1395.php
[4] http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/618.php
[5] http://www.sinanet.apat.it/site/it-IT/Data_Service/Tipologie/Dati/
[6] Agenzia per la Protezione dell’Ambiente e per i Servizi Tecnici

required to prepare the national atmospheric emission inventory in order to assure the compliance with international commitments concerning the protection of the environment (Framework Convention on Climate Change, Convention on Long Range Transboundary Air Pollution, European Directives on emission ceilings).
Additionally to the convention, the Kyoto Protocol (December 1997) has been adopted, and emission reduction objectives for Annex B Parties (i.e. industrialized countries and countries with economy in transition) were established. For Italy, a reduction of 6.5% Greenhouse gases (GHG) by the commitment period in comparison with 1990 levels was established. On 1st June 2002, Italy ratified the Kyoto Protocol with the law n.120 of 01/06/2002. The ratification law prescribed also the preparation of a National Action Plan to reduce greenhouse gas emissions, adopted by the Interministerial Committee for Economic Planning (CIPE) on 19th December 2002. The Kyoto Protocol entered into force on 16 February 2005.
At European level, the new legal basis of the compilation of EC inventory is decision nº 280/2004/EC (February 11th, 2004). The decision establishes a mechanism designed to monitor in the Member States all anthropogenic greenhouse gas emissions (including their removal by sinks) not controlled by the Montreal Protocol, evaluate progress made in this field to ensure compliance with the Community's commitments concerning emissions and their removal, implement the UNFCCC and the Kyoto Protocol, and ensure that information reported by the Community to the UNFCCC Secretariat is complete, accurate, consistent, transparent and comparable. Under the provisions of Art 3.2 of Decision 280/2004/EC, the Member States shall report to the Commission each year, *x*, not later than 15 January their anthropogenic Greenhouse gas emissions by sources and removal by sinks for the year *x-2*; in line with the reporting requirements under the UNFCCC[7]. For example, in 2005, national air emission inventory has reported 2003 emissions.

1.2 Convention on Long-range Transboundary Air Pollution (CLRTAP)

In 1979, the Convention on Long-range Transboundary Air Pollution (CLRTAP[8]) was signed, and entered into force in 1983, till now 49 parties have ratified. Italy has ratified the convention on 15/07/1982. This convention has contributed to the development of international environmental law and has created the essential framework for controlling and reducing the damage to human health and the environment caused by transboundary air pollution. Furthermore, Parties agree to participate in co-ordinating measures under the Co-operative programme for the long-range transmission of air pollutants in Europe (EMEP). The Executive Secretary of the United Nations Economic Commission for Europe (UNECE) provides the secretariat for the Executive Body of the CLRTAP. Emissions inventory are prepared following EMEP/CORINAIR guidelines and reported every year to UNECE. As mentioned in the previous section (1.1), APAT is responsible for the communication of ammonia emissions. Description of methodologies and ammonia emissions under CLRTAP are reported in Chapter 3.
Nowadays, the convention has been extended to eight specific protocols, and one of these protocols, the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone was signed on 30 November 1999 in Gothenburg (Sweden) with 31 signatories and 17 ratifications. The Protocol

[7] http://europa.eu.int/comm/environment/climat/greenhouse_monitoring.htm
[8] http://www.unece.org/env/lrtap/welcome.html

entered into force on 17 May 2005. Italy has not ratified the protocol yet. This Protocol sets emission ceilings for 2010 for four pollutants: sulphur dioxide (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOC) and ammonia (NH_3), and also sets tight limit values for specific emission sources (e.g. combustion plant, electricity production, dry cleaning, cars and lorries) and requires Best Available Techniques (BAT) to be used to keep emissions down. The agriculture sector will have to take specific measures to control ammonia emissions.

2. METHANE AND NITROUS OXIDE EMISSIONS

2.1 Background

In the framework of the United Nations Framework Convention on Climate Change (UNFCCC), as mentioned in section 1.1, there are two reporting obligations, the National Inventory Report (NIR) and the Common Reporting Format (CRF). Methodologies and data presented in this section (methane and nitrous oxide emissions) are those reported in 2005 to the secretariat of the UNFCCC and to the European Commission in the framework of the Greenhouse Gas Monitoring Mechanism (APAT, 2004; APAT, 2005).

2.2 Introduction

A national emission inventory for the most significant greenhouse gases (CH_4 and N_2O) from the agriculture sector has being prepared by the Agency for the Protection of the Environment and for Technical Services with the support of the Research Centre on Animal Production[9]. For the years 1990 and 1995 the inventories were scaled on a provincial basis (95 provinces), for the other years the assessment has been made on a national basis. Emission inventory has been prepared according to national or IPPC methodologies (IPCC, 1997; IPCC, 2000; APAT, 2004; APAT, 2005).
The agriculture sector in the Italian inventory includes five source categories: enteric fermentation, manure management, rice cultivation, agriculture soils and field burning of agriculture residues and the estimation of methane (CH_4) and nitrous oxide (N_2O) emissions. Methane emissions from enteric fermentation and nitrous oxide emissions from agriculture soils are the most relevant source categories in this sector.

2.3 Methane (CH_4)

In general, the estimation of emissions, both CH_4 and N_2O, has been done by defining an emission factor (EF) and multiplying by the activity data. Methane emission inventory is mainly focused on animal husbandry. In 2003, methane emissions from enteric fermentation were 520.63 Gg, which represents 67% of CH_4 emissions for the agriculture sector. Methane emissions from 1990 to 2003 are presented in the following table:

[9] Centro Ricerche Produzioni Animali (CRPA), Reggio Emilia

Methane emissions from the Agriculture sector from 1990 to 2003

Gg

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Enteric Fermentation	587.68	606.39	589.54	583.59	585.50	594.09	594.21	597.37	594.35	595.84	583.31	559.53	554.51	520.63
Manure Management	191.70	193.53	186.46	186.02	181.09	184.88	185.99	185.72	187.53	189.44	183.97	188.08	186.75	181.94
Rice Cultivation	73.26	70.17	73.58	78.81	80.24	81.36	80.78	79.18	75.73	75.08	74.93	74.01	74.36	74.36
Field Burning of Agricultural Residues	0.62	0.68	0.66	0.64	0.64	0.62	0.64	0.57	0.64	0.62	0.58	0.53	0.60	0.54
Total	**853.27**	**870.77**	**850.24**	**849.05**	**847.47**	**860.95**	**861.62**	**862.85**	**858.26**	**860.98**	**842.78**	**822.15**	**816.22**	**777.47**

Source: Italian emissions reported to the UNFCCC through the *Common Reporting Format* - CRF in 2005

2.3.1 Activity Data

Up to now, data collection and timing availability are the main difficulties faced by Italy, which do not allow the submission of the emission inventory within the time scheduled. Activity data used for the estimation of CH_4 emissions for the agriculture sector, are collected from the National Institute of Statistics, and are based on specific national surveys (milk production, farm structure and production) and from a general agriculture census done each 10 years. Activity data collected are the different livestock categories (ISTAT, several years [a], [b], [c], [g], [h]; ISTAT, 2000), fat content in milk (ISTAT, several years [a], [b], [c] [d], [e]) and milk production. For the reconstruction of milk production, national statistics (ISTAT, several years [a], [b], [c] [d], [e], [h]) as well as other national publications (OSSLATTE, 2001; OSSLATTE/ISMEA, 2002; OSSLATTE/ISMEA, 2003; AIA/ISMEA/OSSLATTE, 2003; OSSLATTE/ISMEA, 2004) have been used. Livestock categories provided by ISTAT are classified according to the type of production, slaughter or breeding, and the age of animals. Dairy cattle, non-dairy cattle, buffalo, sheep, goat, horses, mules and asses, swine and rabbit, are the livestock categories which have been used. Future improvements on estimations are expected since more detailed information on activity data or parameters will be available from the national agriculture statistics (Cóndor et al., 2005).

2.3.2 Emission factor

Methane emissions from enteric fermentation for dairy cattle are estimated using Tier 2 approach, as suggested in the Good Practice Guidance (IPCC, 2000). The dairy cattle EF is proportional to the gross energy (GE) intake, which is the amount of energy (MJ/day) an animal needs to perform activities such as growth, lactation, and pregnancy. Different country specific parameters have been used for the estimation of GE intake, such as the average weight, percentage of dairy cattle grazing, weight gain, fat content in milk, hours of work per day, portion of cows giving birth, milk production, and digestibility of feed (CRPA, 2000; IPCC, 2000; AIA, 2001; NRC, 2001; CRPA, 2004[a]; CRPA, 2004[b]; ISTAT several years [a], [b], [c], [d] [e], [f]). In order to obtain the final dairy cattle EF, express in CH_4/head/year, the GE intake is multiplied by the methane conversion rate[10], 365 days and the conversion factor 55.65 MJ/kg CH_4. In the following table, a summary of methods and emission factors used for the estimation of CH_4 emissions, are presented:

Greenhouse Gas sources	**CH_4**	
	Method applied[11]	Emission factor
Enteric fermentation	*IPCC default, IPCC Tier 2*	*IPCC default,* Country specific
Manure management	*IPCC default, IPCC Tier 1 - Tier2*	*IPCC default, IPCC Tier1 - Tier 2*
Rice cultivation	*IPCC default*	*IPCC default*
Agricultural soil	*not occurred*	*not occurred*
Field Burning of Agricultural Residues	*Country specific*	*IPCC default*

[10] Methane conversion rate is the fraction of gross energy in feed converted to methane
[11] IPCC Tier 1 is the basic level methodology for the estimation of GHG; IPCC Tier 2 is a higher level methodology (IPCC, 1997; IPCC, 2000).

For non-dairy cattle, methane emissions from enteric fermentation are estimated with Tier 2 approach (IPCC, 2000), and are based on the ingestion of dry matter intake, calculated as percentage of live weight (Borgioli, 1981; NRC, 1984, 1988; INRA, 1988; Holter and Young, 1992; Sauvant, 1995; CRPA, 2000). Emission factors for buffalo, swine, sheep, goats, horses, mules and asses, and swine are IPCC default values (IPCC, 1997). For rabbits emission factor suggested by CRPA have been used (CRPA, 2004[c]). In the following table a summary of emission factors for enteric fermentation for the year 2003, compared with IPCC default emission factors are presented:

Livestock category	Enteric fermentation EF *kg CH_4/head/year*	IPCC default EF *kg CH_4/head/year*
Dairy cattle	99.86	100
Other cattle	48.35	48
Buffalo	55	55
Sheep	8	8
Goat	5	5
Horses	18	18
Mules and asses	10	10
Swine	1.5	1.5
Rabbit	0.08	*not provided*

For the manure management source category, the IPCC Tier 2 approach for estimating methane emission factors for cattle, buffalo and swine have been used. Cattle and buffalo emissions factors have been calculated for the years 1990 and 1995 at regional level and on a monthly basis (CRPA, 1997 [a]; CRPA, 2000); for later years, instead, average emission factors calculated on a regional basis have been used and applied to the whole time series with a simplified methodology (APAT, 2004; APAT, 2005). Emission factors for cattle and buffalo have been elaborated on the basis of research studies (Safley et al., 1992; Husted, 1993; Husted, 1994; Steed and Hashimoto, 1995) and national parameters (CRPA, 1993; CRPA, 1997[a]).

For the estimation of swine CH_4 emissions, a country-specific *methane emission rate* has been determined experimentally by the Research Centre on Animal Production (CRPA, 1996). In 2003, emission factor for sow including piglets is equal to 20.75 kg CH_4/head/year and for other swine is equal to 8.22 kg CH_4/head/year. Implied Emission factor (IEF), as reported in the CRF, is equal to 7.76 kg CH_4/head/year because it refers to the total number of swine including piglets. Emission factors used for estimating other livestock categories for the manure management category, are those proposed by IPCC, according to the average temperature in Italy (13.1°C), emission factors chosen belong to the “cold” climatic region (APAT, 2004; APAT, 2005). In the following table emission factors from manure management for the year 2003 are presented:

Livestock category	Manure management EF *kg CH_4/head/year*	IPCC default EF - cold temperature *kg CH_4/head/year*
Dairy cattle	20.0	14
Other cattle	10.62	6
Buffalo	14.95	3
Sheep	0.22	0.19
Goat	0.15	0.12
Horses	1.48	1.4
Mules and asses	0.84	0.76
Swine	7.76	3
Poultry	0.08	0.078

For the rice cultivation category source, the seasonally integrated emission factor used is equal to 33g $CH_4/m^2 \cdot$year (APAT, 2004; APAT, 2005) and has been increased by 20% taking into account post harvest emissions, therefore it becomes 39.6g $CH_4/m^2 \cdot$year (Wassmann et al., 1994). The final seasonally integrated emission factor chosen for estimating methane emissions is derived from field measurements of methane emissions rates, which were performed in rice paddies of the Italian Rice Research Institute[12] (Schütz et al., 1989 [a] and [b]).

2.3.3 Method

Enteric fermentation

Methane emissions from enteric fermentation are estimated by defining an emission factor for each livestock category and multiplied by the population of the same category (IPCC, 1997; IPCC, 2000). Estimates have taken into account Italian husbandry conditions, considering the availability of specific data for this situation and including information on the type of diet. Average emission factors reflect national circumstances and vary according to the age distribution of animals and average daily feed intake.

Manure management

For manure management source (cattle and buffalo), the regional basis methodology has included specific manure management practices and environmental conditions, such as the average regional monthly temperatures, when temperatures are under 10°C emissions are considered negligible (UCEA, 2005), amount of slurry and solid manure produced per livestock category (CRPA, 1993), and the management techniques for the application of slurry and solid manure for agricultural purposes in Italy. Emission factors for slurry and solid manure have been estimated, and are obtained with the *methane emission rates* (Husted, 1993; Husted, 1994) and the volume produced, respectively. The volume of slurry and solid manure produced per livestock category has been calculated with the average production of slurry and solid manure per livestock category per day (m^3/head/day) and the days of storage of slurry and solid manure, which are related to the temporal application dynamics of slurry and solid manure under Italian conditions (CRPA, 1997[a]).

[12] Istituto Sperimentale per la Cerealicoltura, Sezione Specializzata per la Risicoltura

For manure management source (swine), the estimation of the EF considers the structure of the storage for slurry (tank and lagoons), type of breeding, and the seasonal production of biogas. Different parameters have been considered such as a reduction of emissions of 8% for storage structures that are covered, an average weight from fattening swine and sows, including piglets, and the *methane emission rate*, which has been determined experimentally. Methane emission rate used are 41 normal litre CH_4/100 kg live weight/day for other swine and 47 normal litre CH_4/100 kg live weight/day for sow (CRPA, 1997[a]).

Rice cultivation

Methane emissions from rice cultivation have been calculated following IPCC Good Practice Guidance (IPCC, 2000). For estimating CH_4 emissions, the seasonally integrated emission factor has been adjusted with scaling factors in order to account for the differences in ecosystem and water management regime, for both types and amount of amendment applied, and for soil type. A specific study on Italian paddies has been carried out in 2000 (Tani, 2000); therefore, country-specific characteristics of rice cultivation have been included during estimations. In Italy, methane emissions from rice cultivation are estimated only for an irrigated regime, other categories suggested by IPCC (rainfed, deep water and “other”) are not present (APAT, 2004; APAT, 2005). Further inputs to refine the estimation are expected for future submissions.

Field burning of agriculture residues

Emissions from field burning of agriculture residues have been calculated with a country-specific methodology. National parameters used during estimations are the removable residues/product ratio (CESTAAT, 1988), fraction of dry matter in residues (Borgioli, 1981; CESTAAT, 1988; CRPA/CNR, 1992; IPCC, 1997), fraction of the field where “fixed” residues are burned (CESTAAT, 1988; IPCC, 1997; ANPA-ONR, 2001), and other default parameters suggested by IPCC (IPCC, 1997) such as the fraction of residues oxidised during burning, the fraction of carbon from the dry matter of residues and the IPCC default emission rates for methane and nitrous oxide. Emissions from burning of agriculture residues, both fixed and removable, have been estimated with the same methodology but reported in two different sectors; emissions from fixed residues, stubble, burnt on open fields are reported in the *field burning of agriculture residues* category while emissions from removable residues burnt off-site are reported under the *waste* category (APAT, 2005). In order to obtain CH_4 emissions (0.54 Gg), C-CH4 value (0.404.3 Gg C-CH_4) is multiplied by coefficient 16/12. In the following table parameters used for the estimation of CH_4 emissions from field burning are presented:

Crop	Harvested annual production *kt*	Amount of "fixed" dry residues oxidised *kt dry matter*	Amount of carbon from stubble burning *kt*	$C\text{-}CH_4$ from stubble burning *t* $C\text{-}CH_4$
Wheat	6,229	80	39	194.8
Rye	7	0.09	0.03	0.2
Barley	1 021	16	6	29.1
Oats	306	4	2	8.3
Rice	1,402	79	33	164.3
Maize	8,702	0	0	0
Sorghum	158	4	2	7.7
Total	**17,827**	**184**	**81**	**404.3**

2.4 Nitrous Oxide (N_2O)

In Italy agricultural soils emissions are estimated for direct and indirect soil emissions and animal production. For direct soil emissions all sources have been estimated: synthetic fertilizers, animal waste applied to soil, N-fixing crops and cultivation of histosols. For indirect soil emissions, atmospheric deposition, and nitrogen leaching and run-off have been estimated. Nitrous oxide emissions from animal production are calculated together with the manure management category on the basis of nitrogen excretion, and reported in the *agricultural soils* category. For 2003, nitrous oxide emissions from agricultural soils were 59.50Gg, which represents 82.3% of N_2O emissions for the agriculture sector. Nitrous oxide emissions from 1990 to 2003 are presented in the following table:

Nitrous oxide emissions from the Agriculture sector from 1990 to 2003

Gg

Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Manure Management	12.4	12.7	12.4	12.3	12.3	12.9	13.0	13.2	13.4	13.6	13.1	13.6	13.5	12.8
Agricultural Soils	60.9	63.4	64.2	65.5	64.1	62.3	61.5	64.7	62.6	63.2	62.0	60.8	60.8	59.5
Field Burning of Agricultural Residues	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**73.2**	**76.1**	**76.6**	**77.7**	**76.4**	**75.2**	**74.5**	**77.9**	**76.0**	**76.8**	**75.1**	**74.4**	**74.3**	**72.3**

Source: Italian emissions reported to the UNFCCC through the *Common Reporting Format* - CRF in 2005

2.4.1 Activity Data

Activity data used for estimating N_2O emissions are the different livestock categories, cultivated surface, annual crop production, fertilizers distribution and nitrogen content, all of them collected from the National Institute of Statistics (ISTAT several years [a] [b], [c], [f], [g]).

2.4.2 Emission factor

In the following table a summary of methods applied and emission factors used for the estimation of nitrous oxide emissions are presented:

Greenhouse Gas source	**N_2O**	
	Method applied	*Emission factor*
Enteric fermentation	*not occurred*	*not occurred*
Manure management	*IPCC default*	*IPCC default, country specific*
Rice cultivation	*not occurred*	*not occurred*
Agricultural soil	*IPCC default*	*IPCC default, country specific*
Field Burning of Agricultural Residues	*Country specific*	*IPCC default*

For the manure management source category, the main parameters are the country-specific nitrogen excretion rates per livestock category (CRPA, 2000), which have been estimated by livestock categories and are defined by the livestock population characteristics in Italy on the basis of recent European literature (Smith and Frost, 2000; Smith et al., 2000; Jongbloed et al., 1999) as described by the Research Centre on Animal Production (CRPA, 2000). The fraction of total annual excretion for each livestock category and manure management system has also been estimated (CRPA, 1997[b]; CRPA, 2000).

2.4.3 Method

Manure management

The starting point of the methodology used for estimating N_2O manure management emissions is to consider that nitrogen, present in manure, in organic form or in form of ammonia, at the exit of livestock housing encounters transformation processes (nitrification, denitrification), which could lead to the production of N_2O emissions, depending on whether or not animal waste is slurry or solid manure (APAT, 2004). Nitrous oxide emissions have been estimated by using the methodology proposed by IPCC in the Good Practice Guidance (IPCC, 2000). For estimations, different parameters have been used such as the number of the different livestock categories, country-specific nitrogen excretion rates per livestock category (CRPA, 2000), fraction of total annual excretion per livestock category related to a manure management system (CRPA, 2000), and emission factors for the different manure management systems (IPCC, 1997).

Liquid system, solid storage and other management systems (chicken-dung drying process system) have been considered according to their significance and major applications in Italy. Emission factors used are equal to 0.001 kg N_2O-N/kg N excreted, 0.02 kg N_2O-N/kg N excreted and 0.02 kg N_2O-N/kg N excreted, respectively (IPCC, 1997; IPCC, 2000). In the following table, estimated annual excretion rates per livestock category for 2003 are presented:

Livestock category	N excreted Housing	N excreted Grazing	TOTAL Nitrogen excreted
	kg/head/yr	*kg/head/yr*	*kg/head/yr*
Dairy cattle	98.0	10.6	108.6
Non-dairy cattle	42.6	2.2	44.8
Buffalo	73.0	7.9	80.9
Other swine	12.7	0	12.7
Sow (include piglets)	25.9	0	25.9
Sheep	1.6	14.6	16.2
Goat	1.6	14.6	16.2
Horses, mules and asses	20.0	30.0	50.0
Poultry	0.57	0	0.57
Rabbit	0.60	0	0.60

Agricultural soils

For estimating N_2O emissions (direct soil emissions), the IPCC approach has been followed (IPCC, 1997; IPCC, 2000) and some modifications have been included because of country-specific peculiarities (APAT, 2005). Emissions related to the total use of synthetic fertilizer applied to cultivated soils (F_{SN}), manure nitrogen used as fertilizer excluding quantities excreted while grazing (F_{AM}), nitrogen input from crop residues (F_{CR}), nitrogen input from N-fixing crops and forage legumes (F_{BN}) and area of organic soils cultivated annually, histosols (F_{OS}) have been estimated. Nitrous oxide emissions have been calculated on the basis of IPCC emission factors (IPCC, 2000) and converted from N-N2O to N_2O emissions by multiplying with coefficient 44/28; in order to obtain the total direct soil emissions all sources have been added (APAT, 2005).

Regarding soil emissions, in particular, the IPCC method calculates the total nitrogen which returns to the soil as a result of nitrogen-fixing crops but does not include crops which are important in Italy, such as forage legumes, and seems not too accurate in the calculation of the total biomass produced. Therefore, data for cultivated areas and the quantities of nitrogen fixed per hectare were used for the principal leguminous crops (Erdamn, 1959 in Giardini, 1983). To estimate the amount of nitrogen from nitrogen-fixing and non nitrogen-fixing crops, which return to the soil with crop residues, national estimates of protein residues gathered from ad hoc surveys were used (residue production in relation to the product or to the area cultivated and protein content of the residue in relation to dry matter content). For cereals, apart from sorghum, for field vegetables (potatoes, beetroot, tomatoes) and for cabbage and artichokes, the net harvest quantities were used, as well as the ratio of product/by product, the dry matter content of the residue and the protein content (CESTAAT, 1988). The N content is obtained by dividing the quantity of proteins by 6.25. For the rest of the crops, estimation of the dry matter content of by products was done according to data obtained by the CNR-CRPA survey on organic waste in Emilia Romagna (CRPA/CNR, 1992). It is estimated, for all crops except for rice, that 90% is re-incorporated into the soil, assuming that combustion accounts for 10% and that, in the case of straw or other residues used as bedding, the nitrogen returns to the soil with the droppings (APAT, 2004).

Indirect soil emissions have been estimated using methodologies suggested by IPCC (IPCC, 1997), this category includes emissions from the atmospheric deposition and surface runoff of nitrogenous products. In both cases the starting point is an estimate of the nitrogen supply; therefore emissions are

calculated by appropriate emission factors, kg N_2O/kg N supplied by atmospheric deposition and surface runoff, respectively.
For animal production, emissions from animal waste excreted while grazing is calculated from nitrogen excreted in this phase and by using an appropriate emission factor, kg N_2O/kg. Nitrogen amount from animal waste and implied emission factors reflect national circumstances.

In the following table, estimated parameters from direct soil emissions for the year 2003 are presented:

Parameter	Value	Data used	IPCC emission factor
F_{SN}	745,417 t N/yr	*Fertilizers distributed and nitrogen content*	0.0125 kg N_N_2O/kgN
F_{AM}	394,878 t N/yr	*Country-specific N excretion values, number of animals*	0.0125 kg N_N_2O/kgN
F_{BN}	175,133 t N/yr	*Country specific cultivated crop surface (N-fixing and forage legumes) and nitrogen fixed per hectare*	0.0125 kg N_N_2O/kgN
F_{CR}	119,273 t N/yr	*Annual crop production, residue/crop product ratio, dry matter content, cultivated surface, and crop residue production*	0.0125 kg N_N_2O/kgN
F_{OS}	9,000 hectares	*Area (in hectares) of organic soils cultivated annually (histosols*	8 kg N-N_2O/hectare/year

Field burning of agricultural residues
Nitrous oxide emissions from residues, stubble, burned on open fields are calculated with the same parameters described in section 2.3.3. All parameters refer both to the IPCC default values (IPCC, 1997) or country-specific values when available, as described before (Borgioli, 1981; CESTAAT, 1988; CRPA/CNR, 1992; ANPA-ONR, 2001) including also raw protein content from residues - dry matter fraction (CESTAAT, 1988; Borgioli, 1981). In order to obtain N_2O emissions (0.012 Gg), N-N_2O value (0.0074 Gg N) is multiplied by coefficient 44/28. In the following table, parameters used for the estimation of nitrous oxide emissions are presented:

Crop	Amount of "fixed" dry residue oxidized *kt dry matter*	Fraction of nitrogen from the dry matter of residues	Amount of nitrogen from stubble burning *kt*	N-N_2O from stubble burning *t N-N_2O*
Wheat	80	0.05	0.385	2.7
Rye	0.09	0.06	0.001	0
Barley	16	0.06	0.093	0.7
Oats	4	0.06	0.027	0.2
Rice	79	0.07	0.520	3.6
Maize	0	0.07	0	0
Sorghum	4	0.06	0.024	0.2
Total	**184**	**-**	**1.050**	**7.4**

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3. AMMONIA (NH_3) EMISSIONS

3.1 Background

In 1996, at European Union level, the Environment Council adopted the Framework Directive 96/62/EC (27/09/1996) on ambient air quality assessment and management, followed by daughter directives, which set numerical limit values. The National Emission Ceilings (NEC) Directive (2001/81/EC) for certain atmospheric pollutants, valid from 23/11/2001, is part of the third daughter directives. The NEC Directive aims to limit emissions of acidifying and eutrophying pollutants and ozone precursors diffuse source into the atmosphere (SO_2, NO_x, VOC and NH_3). By the year 2010 at the latest, Member States shall limit their annual national emissions to amounts not greater than the emission ceilings. There are two reporting obligations; the national inventory and the emission projections, and the national programme on air emissions, using methodologies agreed upon by the Convention on Long-range Transboundary Air Pollution and requested to use the joint EMEP/CORINAIR guidelines. In Italy emissions ceiling for NH_3 gas are 419 kilotonnes by 2010, and according to the national programme and projections, in a baseline situation Italy will not be able to reach the ceiling since it is estimated emissions for 433 kilotonnes of NH_3 by 2010[13]. The national programme was prepared by the Ministry of Environment and the Territory in collaboration with the Agency for the Protection of the Environment and for Technical Services - APAT[14] and the Agency for the new technology, energy and environment-ENEA[15]. In Italy, the NEC directive has been adopted with the Legislative Degree n° 171 (21/05/2004).

Another important European directive is the Integrated Pollution Prevention and Control Directive 96/61/EC (24/09/1996), so called IPPC Directive[16], which establishes common rules on permitting for industrial installations. These permits must contain conditions based on Best Available Techniques (BAT). For the Agriculture sector it includes only breading of poultry or pigs with more than: (a) 40,000 places for poultry, (b) 2,000 places for production pigs (over 30 kg), or (c) 750 places for sows. Moreover, the European IPPC Bureau organizes exchange of information and produces BATs reference documents (BREFs), which Member States are required to take into account when determining BATs generally or for specific cases. In Italy, the directive has been adopted with the Legislative Degree n° 372 (04/08/1999), introducing the Environmental Integrated Authorization as an instrument to implement IPPC.
According to Article 15 of the IPPC directive, the European Pollutant Emission Register (EPER) has been established at a European level[17]. According to the Italian Degree of 23 November 2001, data from the Italian EPER are validated and communicated by APAT to the Ministry of the Environment and the Territory and to the European Community within October of the current year for the previous year. In Italy the National Emission Register has been created and it is called INES[18] [19].

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13 http://europa.eu.int/comm/environment/air/pdf/200181_progr_it.pdf
14 Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici
15 Ente per le Nuove tecnologie, l'Energia e l'Ambiente
16 http://europa.eu.int/comm/environment/ippc/
17 http://www.eper.cec.eu.int/eper/default.asp
18 INES, Inventario Nazionale delle emissioni e loro sorgenti
19 http://www.eper.sinanet.apat.it/

In 1991, the EU member states adopted the Council Directive 91/676/EEC (12/12/1991), concerning the protection of waters against pollution caused by nitrates from agricultural sources (the Nitrate Directive). The Nitrates Directive provides two options for designation within Article 3; to designate separate zones or announce the whole national territory as vulnerable to nitrate pollution. According to Report COM (2002) 407[20], at least 30-40% of rivers and lakes show eutrophication symptoms or bring high nitrogen fluxes to coastal waters and seas. The agricultural origin of these nitrogen fluxes accounts for 50 to 80% of total nitrogen inputs to EU waters, depending on Member States, watersheds and annual variations. Currently, all member states have adopted the nitrate directive, created a network of monitoring, established a Code of Good Agricultural Practise[21] and designated vulnerable zones (except for Ireland). Italy adopted the Nitrate Directive by Legislative degree n° 152 (11/05/1999).

3.2 Introduction

A national emission inventory for ammonia (NH_3) has been prepared by Agency for the Protection of the Environment and for Technical Services with the support of Research Centre on Animal Production, according to EMEP/CORINAIR guidelines.
For the calculation of ammonia emissions the following sources have been estimated, animal husbandry (housing, storage, manure application and animal grazing), and agricultural soils (with and without fertilizer application). In 2003, ammonia emissions from the agriculture represent 95% of the total ammonia emissions, where the most relevant source is manure application**.** In the following table, ammonia emissions, expressed in Gg, from the different sources are presented:

Years	*Housing*	*Storage*	*Manure application*	*Agricultural soils without fertilizers*	*Agricultural soils with fertilizers*	*Total*
1990	101.130	87.485	121.805	13.488	73.445	397.353
1991	101.301	89.161	124.905	13.260	80.906	409.533
1992	98.274	86.681	121.471	13.116	84.630	404.172
1993	97.777	85.856	119.924	13.038	95.058	411.653
1994	96.774	85.252	119.320	14.048	89.770	405.164
1995	99.362	87.930	122.874	14.240	79.626	404.031
1996	99.406	88.189	123.104	14.532	71.491	396.722
1997	100.217	88.835	123.521	14.505	82.539	409.617
1998	102.568	89.922	124.336	14.614	77.410	408.850
1999	102.711	90.530	125.569	14.632	81.582	415.024
2000	98.472	87.004	121.745	14.578	80.095	401.895
2001	103.274	90.054	122.194	12.344	82.100	409.967
2002	103.075	89.220	121.261	12.080	85.693	411.329
2003	99.571	86.630	117.001	11.614	86.312	401.128

Source: APAT

[20] http://europa.eu.int/comm/environment/water/water-nitrates/report.html
[21] For Italy, it was published in the Gazzetta Ufficiale n. 102 del 04-05-1999 *(Supplemento Ordinario n. 86)*

3.3 Activity Data

Population data for each livestock category, dairy cattle, non-dairy cattle, buffalo, other swine, sow, equine, goat, sheep, poultry and rabbit, fertilizer distribution, nitrogen content and cultivated surface data is collected from the National Institute of Statistics (ISTAT, several years [b],[c],[f],[g]). Milk production data has been reconstructed using data from the National Institute of Statistics (ISTAT, several years [a], [b], [c] [d], [e], [h]) and other national publications (OSSLATTE, 2001; OSSLATTE/ISMEA, 2002; OSSLATTE/ISMEA, 2003; AIA/ISMEA/OSSLATTE, 2003; OSSLATTE/ISMEA, 2004). As mentioned in section 2.3.1, future improvements on estimations are expected, since detailed agriculture statistics will be available.

3.4 Emission factor and methodology

3.4.1 Animal husbandry

Estimation of ammonia (NH_3) emissions are based on the different livestock categories, the nitrogen excretion rates by livestock category and the ammonia emission factors (housing, storage, manure application and grazing). Ammonia inventory calculations were made on the basis of a step-by-step procedure, starting from nitrogen excreted by livestock category. Nitrogen excretion rates (N excretion) have been estimated by livestock categories and are defined by livestock population characteristics in Italy on the basis of recent European literature (Smith and Frost, 2000; Smith et al., 2000; Jongbloed et al., 1999) as described by the Research Centre on Animal Production (CRPA, 2000). N excretion rates are related to the weight of the different animals. In the following table, total N excretion rates (kg/head/year) and average weight (kg) from 2003 Italian inventory are presented:

Livestock category	Average weight *kg*	Total Nitrogen excreted *kg/head/yr*
Dairy cattle	650.0	108.6
Non-dairy cattle	387.0 [a]	44.8
Buffalo	517.6	80.9
Other swine	82.8 [b]	12.7
Sow (include piglets)	160.0	25.9
Sheep	46.0	16.2
Goat	42.4	16.2
Horses, mules and asses	528.4	50.0
Poultry	1.8	0.6
Rabbit	1.6	0.6

[a] considered the weight of the total number of cattle without dairy cattle;
[b] considered the total weight of sows without fattening sows and piglet;
[c] CORINAIR/EMEP only provides a value for fur animals and not for rabbits

Ammonia emission factors from different stages (housing, storage, manure application, and animal grazing) are based on bibliographic research using as main reference EMEP/CORINAIR. For example, for storage EF, those proposed by the Dutch Ministry of Agriculture have been used, other

EF are derived from field measurements. All these emission factors are corrected for Italian conditions considering the different average temperature, average animals weight, milk production, breeding systems, storage systems and manure application (CRPA, 1997; CRPA, 2000).

The estimation procedure consists in successive subtractions from the quantification of nitrogen excreted annually for each livestock category. This quantity can be divided in two different fluxes, depending if animals are inside (housing, storage and manure application) or outside the stable (grazing).

The calculation procedure**,** similar with other inventories and models elaborated at European level, is implemented through successive subtractions from the quantification of the N excreted annually for every single category of animal. This quantity can be divided in two different fluxes, depending if animals are inside (housing, storage and manure application) or outside the stable (grazing).
A fraction of N excreted in the stable is emitted in air as ammoniacal nitrogen (N_NH_3) because of volatilisation during the permanence of the manure inside the stable (housing); this fraction is subtracted from the total N excreted, in order to obtain the amount of N in the stored manure. During storage another fraction of N_NH_3 gets lost (storage), and is then subtracted in order to obtain the quota of N available for manure application. The losses of ammoniacal nitrogen respect to total nitrogen contained in the manure used for application to soils are calculated (manure application).
The quota of N excreted outside the stable - when grazing – has volatilisation losses (grazing) only at that phase. Emissions from this phase are considered in the agricultural soil category.
The sum of all N_NH_3 losses occurred for the four phases, converted to NH_3, are the global annual losses of NH_3 referred to the animal breeding category. In the following table ammonia emission factors from 2003 together to those proposed by EMEP/CORINAIR guidelines are presented:

NH_3 EF (Kg/head/year)	**Housing**		**Storage**		**Manure application**		**Total**	
	Italian	*EMEP/ CORINAIR*	*Italian*	*EMEP/ CORINAIR*	*Italian*	*EMEP/ CORINAIR*	*Italian*	*EMEP/ CORINAIR*
Dairy cattle	7.93	8.70	10.9	3.80	17.10	12.10	35.93	24.60
Other cattle	4.6	4.40	4.02	1.90	7.33	6.00	15.95	12.30
Other sows	1.8	2.89	1.9	0.85	1.64	2.65	5.34	6.39
Fattening sows	4.0	7.43	3.7	2.18	3.3	6.82	11	16.43
Equine	2.6	2.90	*not provided*	*not provided*	1.9	2.20	4.5	5.10
Goat/sheep	0.18	0.24	*not provided*	*not provided*	0.31	0.22	0.49	0.46
Laying hens	0.18	0.19	0.08	0.03	0.08	0.15	0.34	0.37
Broilers	0.11	0.15	0.06	0.02	0.02	0.11	0.19	0.28
Rabbit	0.16	*not provided*	0.07	*not provided*	0.06	*not provided*	0.29	*not provided*

3.4.2 Agricultural soils

For this source category, there are emissions, which accounts for the direct application of synthetic fertilizers to soil, direct emission from grazing and emissions from nitrogen fixed in leguminous. Emissions from synthetic fertilizer are based on the detailed EMEP/CORINAIR methodology, which provides different emission factors for the different type of fertilizers, taking into account climatic conditions. Emission factors for the agricultural soil category are presented in the following table:

Type of fertilizer	Emission factor *kg NH_3-N volatilize / kg N applied*
Ammonium sulphate	0.10
Calcium cyanamide	0.02
Ammonium nitrate < 27%	0.02
Ammonium nitrate > 27%	0.02
Calcium nitrate	0.02
Urea	0.15
Phosphate nitrogen	0.05
Potassium nitrogen	0.02
NPK nitrogen	0.02
Organic mineral	0.02

Source: EMEP/CORINAIR guidelines

Ammonia emissions from the application of synthetic fertilizers are obtained with the amount of the nitrogen content by type of fertilizer multiplied by the specific emissions factors. The amount of fertilizers distributed by type of fertilizer is needed for ammonia estimations. Nitrogen input from N-fixing crops has considered N-fixing crops as well as forage legumes, parameters used are the cultivated surface and nitrogen fixed per hectare (Erdamn, 1959 in Giardini, 1983). As mentioned before, the quota of nitrogen excreted outside from the stable when grazing, calculated in the animal husbandry category is reported in agricultural soil category under soil without the application of synthetic fertilizers.

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4. CARBON DIOXIDE (CO_2) EMISSIONS FROM SOIL

4.1 Background

Carbon sequestration in agricultural soils is accountable under Article 3.4 of the Kyoto Protocol (additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories). The Bonn Agreement, formulated at COP6bis in July 2001, clarifies the implementation of Article 3.4 as follows: "In the context of agriculture, eligible activities included "*cropland management*", "*grazing land management*" and "*revegetation*" provided that these activities have occurred since 1990, and are human-induced". The Marrakech Accord agreed at COP7 in November 2001, sets legally binding guidelines for reporting and accounting for agricultural carbon sinks.

At the European level, the Common Agricultural Policy (CAP) since 1992 provides opportunities for carbon sequestration in the soil. A number of agri-environmental measures, which are mandatory for Member States, offer opportunities for the build-up of soil organic matter, the enhancement of soil biodiversity, the reduction of erosion, diffuse contamination and soil compaction. These measures include support to organic farming, conservation tillage, the protection and maintenance of terraces, safer pesticide use, integrated crop management, management of low-intensity pasture systems, lowering stock density and the use of certified compost. According to the integration approach these measures can be developed further to enhance beneficial practices.

On December 1999, Italian Government issued a National Action Program against Drought and Desertification in order to apply the United Nation Convention against Desertification, signed in Paris on October 17th 1994, and active since December 29th 1996. The first National Communication on the U.N. Convention in 1998 highlighted the role of good agricultural practices, such as the correct use of organic manure, to support soil fertility. The goal was to promote, in agreement with the European regulation 99/31/EC[22] on landfill management, the elimination of the organic fraction from wastes and its use for the production of quality compost suitable to be used in a satisfactory way to enhance soil physical and chemical quality. The integrated waste management system is one of the interventions aimed to reduce greenhouse effect on global climate.

On October 2003, the European Commission communication "Towards a Thematic Strategy for Soil Protection"[23] highlighted the need of a thematic strategy for soil protection, with different objectives, as protecting soil in its role in storing CO_2. The communication urges the European Commission to draw up by 2007, in cooperation with the Member States and the competent regional authorities, a scientific soil catalogue which should include the nature of the soil, its biography, health and vulnerability, degradation and erosion processes and contaminated areas, recognizing the existence of high-value soils (in terms of agriculture, geology, ecology, history or the countryside) and the need to draw up recommendations for their conservation and sustainable use.

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[22] Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste; Official Journal L 182 , 16/07/1999 P. 0001 – 0019

[23] CEC (2002). '*Towards a Thematic Strategy for Soil Protection*'. Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions. Bruxelles,16.4.2002 COM(2002) 179 final, 35pp.

4.2. Introduction

In Italy, it has been calculated that 0.15% increase of organic carbon content in agricultural soils (that is a increase of 0.26% in soil organic matter) would be equivalent to fix an amount of carbon dioxide corresponding to the total amount of the yearly emission of fossil fuels in the whole country (Laraia, 2001).

In order to comply with national and international commitments, a national GHG emission inventory is communicated annually to the UNFCCC secretariat and the *European Union's Greenhouse Gas Monitoring Mechanism* through the compilation of the *Common Reporting Format* (CRF), and in agreement with the guidelines (IPCC, 1997; IPCC, 2000).

IPCC methods for carbon stocks change and GHG emission and removal estimates, for the Land-Use, Land-Use Change and Forestry (LULUCF) sector, have been revised and modified, following the decision 11/CP.7 of the Conference of Parties in the Marrakech accords. In the 2005 submission of the national GHG emission inventory the Good Practice Guidance for LULUCF (IPCC, 2003) has been applied. The GPG gives estimation procedures and *good practices* for estimating CO_2 emissions and uptake by soils from land-use and management that can be applied to all land uses. The methodology considers organic carbon stock changes (CO_2 emissions or removals) for mineral soils and CO_2 emissions from organic soils and emissions of CO_2 from liming of agricultural soils.

Carbon dioxide emissions from soils from 1990-2003 are presented in the following tables, according to the GPG classification and definition: dead organic matter (dead wood and litter) and soils (soil organic matter).

Net carbon stock change in soils[24]

Gg C

Year	*Forest Land*	*Grassland*	*Cropland*
1990	8845.21	-4320.74	-222.07
1991	10523.89	-4202.47	-274.24
1992	10255.69	-4305.25	-296.79
1993	8896.17	-4527.78	-365.72
1994	10267.55	-4387.67	-442.14
1995	10755.72	-4439.78	-508.15
1996	10998.58	-4505.21	-461.53
1997	10366.13	-4450.35	-338.17
1998	10083.91	-4706.32	-225.93
1999	10766.94	-4772.28	-72.10
2000	10174.55	-4698.59	-195.67
2001	10948.56	-4465.48	-172.19
2002	11480.03	-4479.33	-192.37
2003	10440.39	-4322.40	-319.89

Source: Italian emissions reported to the UNFCCC through the *Common Reporting Format*-CRF, LULUCF in 2005

[24] The signs for estimates of increases in carbon stocks are positive (+) and of decreases in carbon stocks are negative (-).

4.3 Activity Data

Data collection and timing availability are the main difficulties faced by Italy, up to now. In fact, several sectoral statistics are available with significant delay, as the case of agriculture and forestry statistics, which are published with two years of delay.
In the following table different sources for activity data, concerning the sector "*Land Use change and Forestry*", are reported.

Sector	Activity Data	Source
Land Use Change and Forestry	Forest Land	Statistical Yearbooks – National Statistics Institute National and Regional Forestry Inventory Universities and research institutes
	Cropland	Statistical Yearbooks – National Statistics Institute Universities and research institutes
	Grassland	Statistical Yearbooks – National Statistics Institute Universities and research institutes

4.4 Emission factor

Emission factors used in the estimation process are consistent with the IPCC Good Practice Guidance and supported by national experiences and circumstances.
In the following table a summary report for methods and emission factor used for estimates of soils emission and removals, for the land use change and forestry, is given:

Greenhouse Gas source and sink categories	**CO_2**	
	Method applied	*Emission factor*
Forest Land	*Model, IPCC default*	*Country specific*
Cropland	*IPCC default*	*IPCC default, Country specific*
Grassland	*IPCC default*	*IPCC default, Country specific*

4.5 Method

The 2003 IPCC Good Practice Guidance for LULUCF have been entirely applied for all the categories of this sector as detailed data were available from national statistics and from researches at national and regional level, whereas for category 5A (Forest Land) estimates were supplied by a growth model (Federici et al.) applied to national forestry inventory data, with country specific emission factors.
Carbon stocks in soils in forest land, cropland or grassland or changes of carbon stocks in soils for "land converted to land" have been estimated following land uses and land use changes, respectively. The land uses and the land use changes data were provided by the National Statistics Institutes[25] (ISTAT) and by the Italian National Forest Inventories (I NFI-1985, II NFI-2002),

[25] ISTAT, several years . Statistiche dell'Agricoltura. Istituto Nazionale di statistica, Roma - Agriculture statistics available on the web-site http://www.istat.it/Imprese/Agricoltur/index.htm; ISTAT, several years. Annuario Statistico Italiano. Istituto Nazionale di statistica, Roma

carried out by Italian Ministry of Agriculture and Forests (MAF) and Experimental Institute for Forest Management (ISAFA).
The equation for estimating changes in carbon stocks in soils, according the Good Practice Guidance (IPCC, 2003), are shown below:

$$\Delta C_{LU\ Soils} = \Delta C_{LU\ Mineral} - \Delta C_{LU\ Organic} - \Delta C_{LU\ Lime}$$

where:

$\Delta C_{LU\ Soils}$ is the annual change in carbon stocks in soils. [t C yr^{-1}]
$\Delta C_{LU\ Mineral}$ is the annual change in carbon stocks in mineral soils. [t C yr^{-1}]
$\Delta C_{LU\ Organic}$ is the annual carbon emissions from cultivated organic soils (estimated as net annual flux). [t C yr^{-1}]
$\Delta C_{LU\ Lime}$ is the annual carbon emissions from agricultural lime application. [t C yr^{-1}]

The change in carbon stocks in <u>mineral soils</u> is:

$$\Delta C_{LU\ Mineral} = \Sigma_{ij} \lfloor (SOC_0 - SOC_{(0-T)}) \cdot \mathrm{A} \rfloor / \mathrm{T}$$

where:

$$\mathrm{SOC}_i = \mathrm{SOC}_{ref} \cdot \mathrm{F}_{LU} \cdot \mathrm{F}_{MG} \cdot \mathrm{F}_I$$

$\Delta C_{LU\ Mineral}$ is the annual change in carbon stocks in mineral soils. [t C yr^{-1}]
SOC_0 is the soil organic carbon stock in the inventory year. [t C yr^{-1}]
SOC_{0-T} is the soil organic carbon stock T years prior to the inventory. [t C yr^{-1}]
T is the inventory time period. [yr] (default is 20 yr)
A is the land area of each parcel
SOC_{REF} is the reference organic carbon stock. [t C yr^{-1}]
F_{LU} is stock change factor for land-use change type
F_{MG} is stock change factor for management regime
F_I is stock change factor for input of organic matter

The change in carbon stocks in <u>organic soils</u> is:

$$\Delta C_{LU\ Organic} = \Sigma_c (A \cdot EF)_c$$

where:

$\Delta C_{LU\ Organic}$ is the CO_2 emissions from cultivated organic soils. [t C yr^{-1}]
A is the land area of organic soils in climate type. *c*. [ha]
EF is the emission factor for climate type c. [t C ha^{-1} yr^{-1}]

The change in carbon emission from <u>agricultural lime application</u> is:

$$\Delta C_{LU\ Lime} = M_{Limestone} \cdot EF_{Limestone} + M_{Dolomite} \cdot EF_{Dolomite}$$

where:

$\Delta C_{LU\ Lime}$ is the annual C emissions from agricultural lime application. [t C yr^{-1}]
M is the annual amount of calcic limestone or dolomite. [t C yr^{-1}]
EF is the emission factor [t C (t limestone or dolomite)$^{-1}$]

No CO_2 emissions from organic soils or from application of carbonate containing lime or dolomite to agricultural soils have occurred, therefore only mineral soils have been considered. The amount of carbon stocks in mineral soils have been estimated according to land uses[26]; furthermore changes of carbon stocks in mineral soils resulting from land use change have been assessed[27].

Land remaining land

Changes in carbon stocks in mineral soils in total grassland or cropland have been estimated following changes in management that impact soil carbon content. Previous soil carbon stock [$SOC_{(0-T)}$] and soil carbon stock in the inventory year [SOC_0] for the grassland or cropland area have been estimated from the reference carbon stocks. According to the indications of national experts, the carbon content of one hectare of land with a soil depth of 30cm can be estimated as equal to 44,5 ±10t (Ciccarese *et al.*, 2000).

For the two grassland systems (forage crops and permanent pasture, set-aside lands) a set of default stock change factors (F_{LU}, F_{MG}, F_I) has been chosen among the relative stock change factors for grassland or cropland management given in GPG, taking into account the land use, the different level of degradation and the applied input to lands. F_{LU} reflects C stock changes associated with type of land use, F_{MG} is a management factor, representing, for permanent cropland, different types of tillage and F_I is an input factor, representing different levels of C inputs to soil.

The land use stock change factor (F_{LU}) for the so-called set aside lands has been derived, according to the indications of national experts, from the default values reported in the IPCC GPG.

In the following table the stock change factors used for grassland and cropland are shown:

	Stock change factors	F_{LU}	F_{MG}	F_I
Grassland	Forage crops and permanent pasture	1.0	0.95	1.0
	Grassland from set aside lands	0.82	1.0	0.92
Cropland	Cropland	0.82	1.0	1.0

With the stock change factors the soil carbon stock [t C] for the inventory year [SOC_0] and the previous soil carbon stock [$SOC_{(0-T)}$] have been estimated, starting from the soil carbon stock for unit of area [t C ha^{-1}]. The inventory time period has been established, as the GPG default, in 20 years. The annual change in carbon stocks in mineral soils has been, at last, assessed as described in the abovementioned equation. Net changes in soil C stocks obtained are equal, for cropland, to -0.222Tg[28] C for 1990, and -0.32 Tg C for 2003, and to -4.341 Tg C for 1990, and -4.322 Tg C for 2003 for grassland.

Land converted to land

Changes in carbon stocks in mineral soils in land converted to land (cropland or grassland) have been estimated following land use changes, resulting in a change of the total soil carbon content. Initial land use soil carbon stock [$SOC_{(0-T)}$] and soil carbon stock in the inventory year [SOC_0] for the cropland area have been estimated from the reference carbon stocks. According to the indica-

[26] See the section "*Land remaining land*"
[27] See the section "*Land converted to land*"
[28] According to the Revised 1996 IPCC Guidelines, the signs for removals are always negative (-) and for emissions positive (+). Net changes in carbon stocks are converted to CO2 by multiplying C by 44/12

tions of national experts, the carbon content of one hectare of grassland or cropland, at the default depth of 30cm, has been estimated as equal to 44,5±10t (Ciccarese *et al.*, 2000). Different stock change factors (F_{LU}, F_{MG}, F_I) have been used for the for diverse management activities on initial land use and final land use.

With the stock change factors, the soil carbon stock [t C] for the inventory year [SOC_0] and the final land use soil carbon stock [$SOC_{(0-T)}$] have been estimated, starting from the soil carbon stock for unit of area [t C ha^{-1}]. The inventory time period has been established, as the GPG default, in 20 years. The annual change in carbon stocks in mineral soils has been, at last, assessed, only for the years where conversion has taken place.

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