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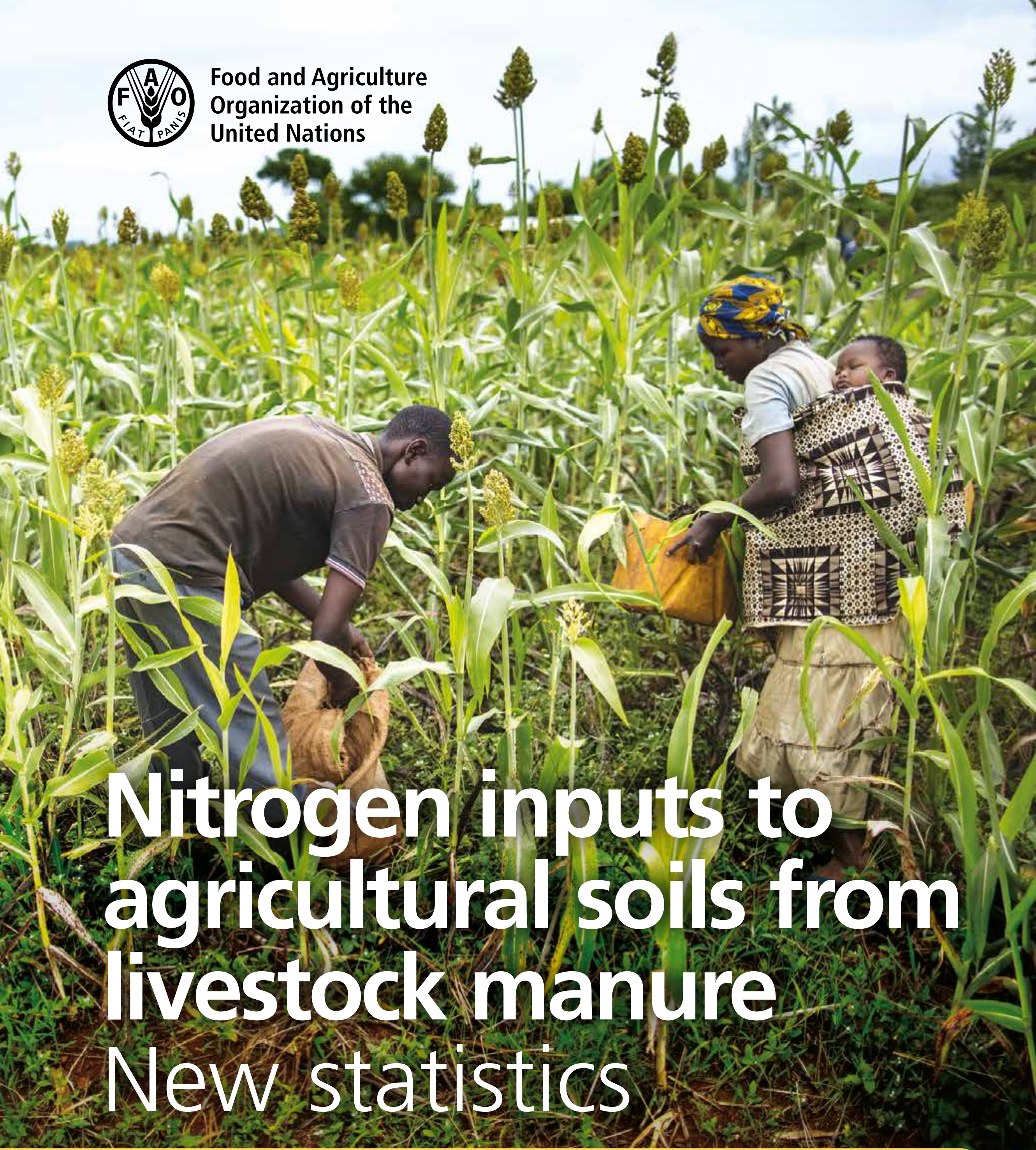

Nitrogen inputs to agricultural soils from livestock manure
New statistics

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PREFACE

The global agricultural sector is currently facing the twofold challenge of feeding a growing population while preserving the environment for future generations. Over a third of our soils are degraded and inefficient nutrient management is damaging natural resources. Proper soil and nutrient management is therefore critical to ensuring the productivity and sustainability of current and future agricultural systems. Global initiatives like the Land Degradation Neutrality (LDN) conceptual framework of the United Nations Convention to Combat Desertification (UNCCD), the Global Soil Partnership (GSP), and the Global Soil Biodiversity Initiative highlight the need to reverse soil degradation and increase the nutrient use efficiency of fertilizers, manures and other nutrients applied to agricultural soils in order to contribute to achieving various targets of the Sustainable Development Goals (e.g. SDG 1, 2, 3, 6, 13 and 15).

Agricultural statistics are essential to assess, monitor and measure progress towards achieving national and global development goals. FAO plays a pivotal role in compiling and disseminating agricultural data for global monitoring, and in the development of standards and guidance for collecting, analyzing and interpreting agricultural statistics. FAO collects detailed country data on the production and consumption of the three main agricultural nutrients in chemical fertilizers – nitrogen (N), phosphate (P_2O_5) and potash (K_2O) – via the fertilizers questionnaire, and disseminates this data on the FAOSTAT database. These statistics cover about 200 countries and territories over the period 1961 to the present. Although organic fertilizers are of agronomic importance, supplying a wide range of nutrients together with organic matter to soils, the relevant country data collection has rather low response rates, so that country statistics on organic inputs are at present not disseminated in FAOSTAT alongside the information on chemical fertilizers. Rather, FAO estimates and disseminates analytical databases on manure-nitrogen inputs by country or regions. In FAOSTAT, manure-nitrogen inputs are estimated and disseminated by country over the period 1961-present. They were originally computed as an intermediate data product needed for the computation of greenhouse gas emissions (GHG) from agriculture. In addition, the FAO Global Livestock Environmental Assessment Model (GLEAM) produces and disseminates manure-nitrogen estimates by country, but limited to the year 2005, as a basis to support a wide range of livestock analyses.

This report presents a nutrient input analysis of the FAOSTAT livestock manure-nitrogen dataset and complements it with information from GLEAM. The FAOSTAT manure-nitrogen dataset was produced using region-specific coefficients and following the default methodology proposed by the Intergovernmental Panel on Climate Change (IPCC). For the year 2005, this report further integrates and compares the results obtained using the IPCC default estimates in FAOSTAT with estimates of the GLEAM dataset, calculated using more country-specific coefficients.

The information provided with this report is intended for various audiences, including agricultural statistics services or departments of FAO member countries, governments, academia, industry and the general public interested in country-level reference information on manure-nitrogen inputs to agricultural soils, produced using internationally-recognized and transparent methodologies.

Overall, the report sheds light on the amount of nitrogen input applied to agricultural soils from livestock manure at different scales, and on the relevance of producing, refining and monitoring statistics on livestock manure for environmental and agronomic policy and planning.

We are confident that the findings of this report and the analytical data provided offer member countries an additional tool to help them better assess, monitor and measure progress towards achieving their national agricultural development goals, with a focus on soil fertility, thus contributing to support national analysis as well as international reporting needs within the relevant international processes.

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This study is a result of a collaboration between FAO's Plant Production and Protection Division (AGP), Statistics Division (ESS), and Animal Production and Health Division (AGA).

The report was written by the following FAO staff members: Dylan Warren Raffa, Francesco Nicola Tubiello, Debra Turner and Javier Montero Serrano. The report largely benefited from the comments of many FAO colleagues: Caterina Batello, Giulia Conchedda, Alessandra Falcucci, Alessandro Ferrara, Ruben Martinez Rodriguez, Anne Mottet, Carolyn Opio, Giuseppe Tempio, Aimable Uwizeye and Verena Wilke.

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ACRONYMS

C	Carbon
DM	Dry Matter
FAO	Food and Agriculture Organization
GLEAM	Global Livestock Environmental Assessment Model
IPCC	Intergovernmental Panel on Climate Change
MMS	Manure Management System
N	Nitrogen
P	Phosphorus
P_2O_5	Phosphate (Phosphorus anhydride)
K	Potassium
K_2O	Potash (Potassium oxide)
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change

EXECUTIVE SUMMARY

Soil is a non-renewable natural resource that is crucial for the provision of multiple ecosystem services and to overall functioning of the ecosystem. Soils are the basis from which most of the world's food is produced, thus they are subject to various disturbances and stresses from the application of agricultural management practices. Sustainable soil management is necessary for maintaining the production of sufficient and nutritious food, and for increasing future food production while preserving natural resources and the environment. Considering that around 33 percent of the world's soil and 40 percent of the soils in Africa are already degraded, a special focus on the restoration of degraded soils and maintenance of soil health is required (FAO, 2011a). Furthermore, degraded soils are often located in areas where people are afflicted by poverty and malnutrition. Restoring and maintaining soil health will, hence, play an important role to help meet the food demands of growing populations in areas of the world where it is most needed.

In recent decades, modern agriculture has increasingly relied on inputs of mineral and chemical (synthetic or inorganic) fertilizers to meet plant nutrient demands. This has contributed to the steep increase in crop production; however inefficient management practices have led to large nutrient losses to the environment, thereby raising concerns on the long-term sustainability of the global agriculture sector.

Availability and use of organic fertilizers, mainly livestock manure, are also increasing significantly due to the increase in livestock populations. Besides macro and micronutrients, manure also provides organic matter to agricultural soils – a key determinant of soil health. However, inappropriate manure management and excessive applications can also have detrimental effects on the environment, contributing to the contamination of water and soil resources and to increased greenhouse gas (GHG) emissions.

Efficient nutrient management plans and strategies are needed to maximize crop productivity while minimizing the potential environmental impact due to the high amount of nutrients being applied today. More detailed inventories and statistics on the use of synthetic and organic fertilizers are crucial to identify current practices and trends, and design and implement more sustainable agricultural systems.

FAO collects, analyses and disseminates fertilizer input statistics for inorganic fertilizer nutrients in the online FAOSTAT database, with country-level time series from 1961 to the present, on the use of the three main agricultural nutrients: nitrogen (N), phosphorus anhydride (P_2O_5) and potassium oxide (K_2O). A similar dataset of country data on organic fertilizers is lacking due to very low response rates to the FAOSTAT Fertilizers Questionnaire in relation to these statistics. This report seeks to address this gap by utilizing the analytical, manure-related data in the FAOSTAT Livestock Manure database containing estimates of N input to soils and pastures from livestock manure. These data are computed based on Tier 1 methodology of the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines to estimate GHG emissions from manure in agriculture.

The main aim of this report is to use this dataset to quantify the amount of N applied to soils via livestock manure at global and regional levels, and to compare them to the N input from synthetic fertilizers. A secondary aim is to work towards the expansion of the existing FAOSTAT manure-N statistics by complementing the IPCC Tier 1 default dataset with Tier 2, country-specific data based on the FAO Global Livestock Environmental Assessment Model (GLEAM).

The first part of the report presents an analysis of global and regional trends in manure-N inputs to soils using the Tier 1 IPCC methodology for the period 1961-2014. The study indicates that in 2014, annual global N inputs from manure applied to soils, manure left on pasture and synthetic fertilizers applied to soils were 27.6 million tonnes, 85.5 million tonnes and 102.2 million tonnes, respectively. Over this period of analysis, the total amount of N applied via livestock manure and inorganic fertilizers increased significantly in most regions except for Europe – where there has been a marked decrease since the 1990s due to stringent legislation to limit excessive N input to soils, from both organic and inorganic sources. The analysis also shows that while N inputs from synthetic fertilizers were much smaller than those from manure at the beginning of the analysis period, by the 1980s, they had surpassed the largest organic N input due mostly to manure left on pasture. The report also highlights that the current amount of N used in agriculture in synthetic N-fertilizer applications equals that of manure-N used on cropland and pastures at around 100 million tonnes of N per year.

The second part of the report presents an initial comparison of Tier 1 and Tier 2-calculated manure-N input datasets for the year 2005 at global and regional levels, as well as by livestock species. At a global level, Tier 1 manure-N input estimates were 29 percent higher than those of Tier 2, with cattle being responsible for the largest share of the total manure-N input in both datasets. At a regional level, Tier 1 and Tier 2 manure-N estimates were similar for cattle manure-N inputs in all regions except Africa. Notable differences between Tier 1 and Tier 2 manure-N estimates were observed within regions, particularly in Africa and in Asia, and for animal species, especially for sheep and goats.

In conclusion, livestock manure represents a large source of N that needs to be efficiently managed and recycled within agricultural systems for an adequate balance with, and to reduce the need for, synthetic N-fertilizer inputs. These large quantities of manure also need to be managed appropriately to minimize N-losses and environmental pollution. Furthermore, the comparison between Tier 1 and Tier 2 datasets in this report also indicates for what regions and for which livestock species there is a need for improved calculation of coefficients and estimations.

This report thus contributes to (i) shedding light on the amounts of N contained in livestock manure across the regions of the world to support policy analysis and planning; (ii) raising awareness on the need for action to recycle the large quantities of nutrients contained in manure produced by livestock; and (iii) highlighting in which regions and for which livestock species refined coefficients may require improved statistics on, and thus the analysis of, the N inputs from livestock manure.

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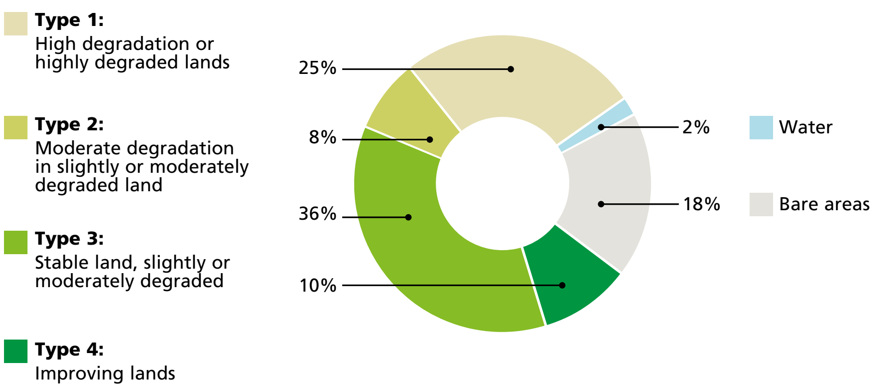
Introduction

1.1 Soil degradation: a threat to food security and ecosystem stability

Soils are the foundation for agriculture and ecosystem functioning. They are responsible for 95 percent of the production of our food (FAO, 2015a) and mediate crucial ecosystem services (Kibblewhite *et al.*, 2008). However, soils are a non-renewable resource as they are characterized by a high degradation potential and slow regeneration rates (Diacono and Montemurro, 2010).

To date, 33 percent of soils are moderately to highly degraded due to erosion, salinization, compaction, acidification, chemical pollution and nutrient depletion (See status types 1 and 2 in Figure 1). It has been estimated that every year approximately 12 million hectares of agricultural soils are lost due to soil degradation (Nair, 2014). Such a degradation rate jeopardizes the capacity of future generations to meet their basic needs and raises concerns on ecosystem stability and functioning.

FIGURE 1: **STATUS OF WORLD'S SOILS**



Source: FAO, 2011A

Therefore, sustainable soil management is necessary for guaranteeing food security, as well as for maintaining or improving other ecosystem-provided goods and services (FAO, 2017a). According to FAO-Save and Grow, the definition of soil health is *"the capacity of soil to function as a living system. Healthy soils maintain a diverse community of soil organisms that help to control plant disease, insect and weed pests form beneficial symbiotic associations with plant roots, recycle essential plant nutrients, improve soil structure with positive effects for soil water and nutrient holding capacity, and ultimately improve crop production. A healthy soil also contributes to mitigating climate change by maintaining or increasing its carbon content"* (FAO, 2011b).

1.2 Agronomic importance of livestock manure

Lack of soil organic matter (SOM) is one of the most common deficiencies in degraded soils, and SOM is the main indicator of soil quality and health (Lehman *et al.*, 2015). The presence of sufficient SOM supports crop production and ecosystem stability by improving water and nutrient retention, nutrient cycling, carbon transformation, soil biodiversity, soil structure and soil aggregation (Wolf and Snyder, 2003). As also stated by the recent FAO Voluntary Guidelines on Sustainable Soil Management (VGSSM), the adoption of agricultural practices that build and retain SOM are therefore an important pillar of sustainable crop production (FAO, 2017a). The supply of manure to agricultural soils is an ancient practice and a well-tested strategy to increase SOM, replenish basic plant nutrients, improve yield response to fertilizers and to restore soil productivity in degraded areas (Rufino *et al.*, 2007; Schröder, 2005; Bogaard *et al.*, 2013; Nezomba *et al.*, 2015).

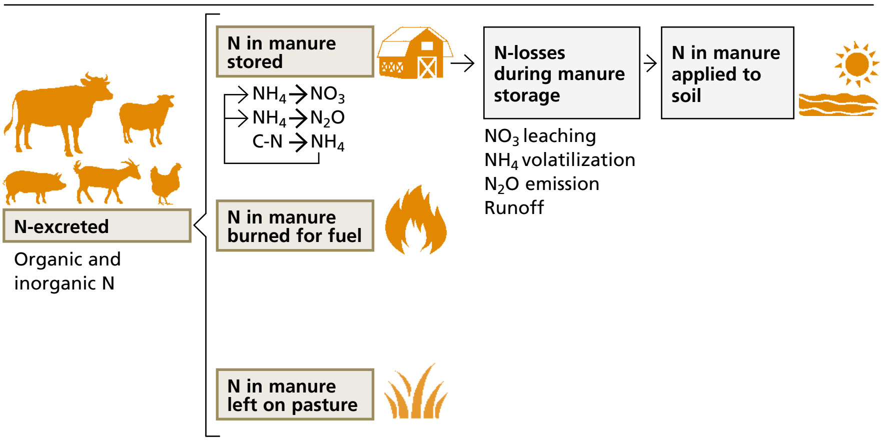
At the same time, excessive manure applications and inefficient manure storage practices can have detrimental effects on the environment at multiple scales, such as the contamination of water and soil resources at local and regional levels, and the emissions of greenhouse gases (GHG) at a global level (Sutton *et al.*, 2011a; Tubiello *et al.*, 2013). Thus while the recycling of livestock manure within agricultural systems is necessary to improve and maintain soil health, its efficient management is also important to reduce environmental impacts associated with farming activities.

1.3 Nitrogen in manure: an essential element to be managed efficiently

Nitrogen (N) is a key component of proteins, therefore, it is not only essential for plants but also a necessary element in a balanced animal diet.

Animals use N for maintenance, metabolic activity, body gain, and milk, meat and egg production. Unused N consumed in feed and feed supplements is excreted via urine and manure (Figure 2). The N content of manure depends primarily on the N content of the feed intake and on the metabolic activity of the animal, which varies according to animal species, sex, breed, age, and on the production system and climatic conditions. Manure may be excreted directly to fields, such as in grazed systems, or applied fresh to fields after collection from barns, yards or animal houses. Manure may also be collected and/or treated in various storage systems for later applications to fields, or destined to other uses such as being burnt for fuel, or used for feed in aquaculture. Manure storage and management choices will further determine the final N composition of treated manure. Manure applied to soils or left on pasture enriches the soil nutrient pools and contributes to the build-up of SOM. However, N is extremely reactive and mobile in soils and subject to loss via different pathways such as leaching, run off and gaseous losses, which all pose a serious threat to natural resources and the environment. For instance, nitrate (NO_3^-) leaching to ground water resources can cause eutrophication or excessive NO_3^- loads in drinking water, which is harmful to human health. Furthermore nitrous oxide (N_2O) is a potent GHG with a 100-year Global Warming Potential (GWP) 298 times stronger than that of CO_2 (IPCC, 1996).

FIGURE 2: **GRAPHIC REPRESENTATION OF THE DIFFERENT ITINERARIES OF PROCESSES INVOLVED IN MANURE-N PRODUCTION.**



1.4 Importance of manure-N statistics

Considering the importance of N for crop production, its wide scale use, and the negative environmental effects caused by unsustainable N management, quantification and monitoring of N flows and inputs are critical for effective agronomic and environmental planning. Accurate and reliable data and statistics on synthetic fertilizer and livestock manure use, as well as on their amount and nutrient composition of manures, are therefore necessary for detailed and multi-scale accounting of nutrient inputs and flows in agricultural systems.

To this end, FAO currently collects and analyses country-level statistics on the production and consumption of the three main synthetic fertilizer agricultural nutrients, nitrogen (N), phosphorus anhydride (P_2O_5) and potassium oxide (K_2O). This information is disseminated via the FAOSTAT database with data from 1961 to the present (FAO, 2017b). A comparable dataset of official country statistics on manure nutrients does not exist due to very low response rates of countries to the relevant section in the FAO Fertilizers Questionnaire[1].

Several studies have used different methods at various scales to quantify N inputs from livestock manure and resulted in a wide range of estimates (e.g., Smil, 1999; Van der Hoek *et al.*, 1999; Sheldrick *et al.*, 2003; Green *et al.*, 2004; Siebert, 2005; Bouwman *et al.*, 2005 and 2013; Potter *et al.*, 2010; Liu *et al.*, 2010). This report estimates manure-N inputs using the methodologies of the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National GHG inventories (IPCC, 2006). The IPCC guidelines provide default coefficients, defined at either global or regional level, for a simplified (Tier 1) approach to the assessment of manure applied to soils and pastures. The IPCC guidelines also consider more detailed approaches if national-specific methodologies can be applied to include sub-national details (Tier 2 and Tier 3 methodologies).

Because of the existing gap in the availability of official country data, FAOSTAT currently disseminates analytical estimates of the amounts of livestock manure-N left on pasture or applied to soils using IPCC Tier 1 methodology (FAO, 2018). The FAOSTAT manure-N statistics are computed annually and by animal type for approximately 200 countries and territories covering the period 1961-2016. They are also used as input to compute manure-related greenhouse gas emissions from agriculture. In addition to the FAOSTAT statistics on livestock manure, this report also considers more detailed, country-level information estimated using the Global Livestock Environmental Assessment Model (GLEAM) (Gerber *et al.*, 2013; FAO, 2017c).

[1] See http://www.fao.org/economic/ess/ess-home/questionnaires/en/

1.5 Scope of this report

This report expands the FAOSTAT statistics based on the IPCC Tier 1 default methodology in two ways. Firstly, by focusing the analysis of the Tier 1 regional-level estimates to quantify the amounts of N that are applied to soils via livestock manure at global and regional levels from a N input perspective. Secondly, by providing new data on manure-N application based on Tier 2, country-specific coefficients from the GLEAM model, for the year 2005.

This report therefore aims at providing FAO member countries, academia and the general public with reference information towards a preliminary assessment of manure-N inputs to agricultural soils, at national level, using statistics that are produced with internationally recognised and transparent methodologies. These reference data may subsequently be used by practitioners to evaluate successive national efforts towards the elaboration of more sophisticated statistics useful for national analysis as well as for reporting to international bodies, including the UN Framework Convention on Climate Change (UNFCCC) and the Sustainable Development Goals (SDG) process.

Specifically, this report provides information on:

1. Tier 1 estimates of N input from livestock manure to agricultural area at a regional and global levels over the period 1961-2014;
2. Analysis and comparison of regional and global trends in N inputs from livestock manure and synthetic fertilizers;
3. Complementary Tier 2 methodology data and their possible use to improve the assessment of N input from livestock manure by countries and other users.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Methodology

This report applies the methodology developed by IPCC, the internationally accepted guidelines used by countries for reporting their national GHG inventories to the UNFCCC. The IPCC methodology was developed to ensure that the national statistics formulated under its guidance, and reported internationally, are transparent, complete, consistent, comparable and accurate. This methodology was developed through an extensive process involving the synthesis of published literature and the integration of expert knowledge of thousands of authors worldwide, and formally approved by more than 150 member countries of the IPCC Bureau (FAO, 2015b).

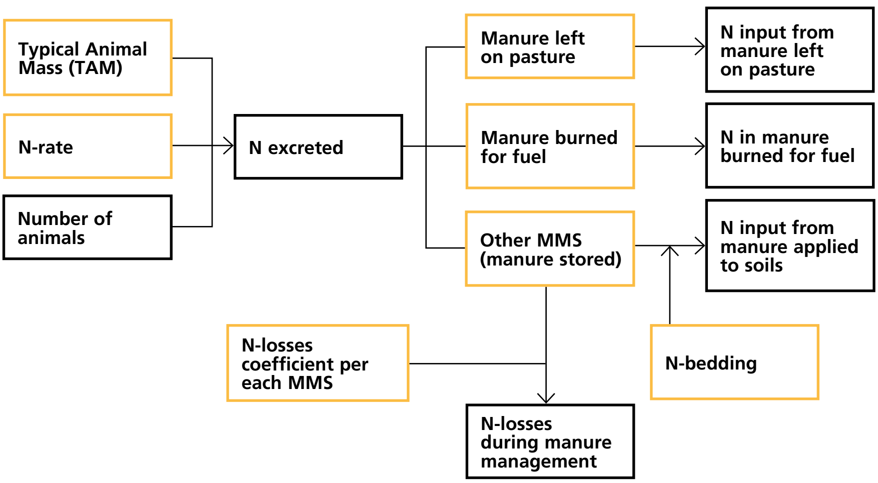
An important feature of the IPCC guidelines is its tier structure, allowing for the compilation of statistics as a function of national capacity. The IPCC guidelines Tier 1 default approach uses standard equations and default coefficients with regional or global applicability. The Tier 2 approach is similar to Tier 1, but with emission factors and other parameters which are specific to the country or production system. The Tier 3 approach involves more sophisticated models and detailed statistics, such as emission factors at a sub-national level (IPCC, 2006). In general, IPCC encourages countries to select more detailed, higher tier methods for those categories that have a significant influence on the country's total inventory of GHG (IPCC, 2006).

The IPCC guidelines provide a complete Tier 1 national-level methodology for the national-level estimation of livestock manure-N which is excreted, treated and applied to soils. The following section describes in detail how these IPCC guidelines have been applied in FAOSTAT in order to produce Tier 1 statistics on livestock manure-N within its Livestock Manure database, including information on manure management, manure applied to soils, and manure left on pasture (FAO, 2018). The additional section describes the set of Tier 2 coefficients used in the estimation of manure dynamics at country level, which was based on GLEAM developed at FAO (FAO, 2017c).

2.1 Tier 1 Approach

The IPCC Tier 1 methodology is used in FAOSTAT to estimate the amount of manure-N available for application in agriculture. It uses a modular approach that involves the amount of animal manure-N excreted, manure-N left on pastures by grazing animals, manure-N treated in MMSs and manure-N available for application to soils. Figure 3 provides a summary description of the process. Further information is also available online via FAOSTAT metadata (FAO, 2018) and a guidance manual for countries compiling national GHG inventories for agriculture (FAO, 2015b).

FIGURE 3: **FLOW DIAGRAM FOR MANURE N FROM LIVESTOCK USED AS FERTILIZER.** Orange boxes determined by default IPCC Tier 1 coefficients.



The quantification of manure-N is performed using Equation 1 and 2.

EQUATION 1

N input from manure applied to soils

$$N_{MS\_Avb(T)} = \sum_{S} [N_{(T)} x Nex_{(T)} x MS_{(S,T)} x (1 - Frac_{Loss(S,T)})] + [N_{(T)} x MS_{SolidStorage(T)} x N_{bedding\_SolidStorage(T)}]$$

Source: Equation 10.34, Vol. 4, IPCC Guidelines 2006

Where:

$N_{MS\_Avb(T)}$	Amount of managed manure nitrogen available for application to soils and for other uses for animal category T, kg N yr^{-1}
$N_{(T)}$	Number of heads of animal category T, heads yr^{-1} (from FAOSTAT)
$Nex_{(T)}$	Annual N excretion for animal category T, kg N animal^{-1} yr^{-1} (Equation 10.30, Vol. 4, IPCC Guidelines 2006)
$MS_{(S,T)}$	Fraction of manure treated in each system S for animal category T (%) (Tables from 10A-4 to 10A-9, Vol. 4, IPCC Guidelines 2006, for cattle, swine, and for some buffaloes; Table 4.7, Vol 2, Revised IPCC Guidelines 1996, for other animals)
$Frac_{Loss(S,T)}$	Fraction of managed manure nitrogen for livestock category T that is lost in each system S (%) (Tables 10.22, Vol. 4, IPCC Guidelines 2006)
$MS_{SolidStorage(T)}$	Fraction of manure treated in Solid Storage for animal category T (Tables from 10A-4 to 10A-9, Vol. 4, IPCC Guidelines 2006, for cattle, swine, and for some buffaloes; Table 4.7, Vol 2, Revised IPCC Guidelines 1996, for other animals)
$N_{bedding\_SolidStorage(T)}$	Amount of nitrogen from bedding for solid storage MS for animal category T, kg N animal^{-1} yr^{-1} (Values for bedding reported in page 10.66, Vol. 4, IPCC Guidelines 2006)
T	Species/category of livestock
S	Manure management system (Tab.1)

The N excretion rate per animal, NexT, (Annex III.A) is obtained by multiplying default N excretion rate -expressed as kg N per kg animal mass per year- by default values of average animal mass, provided by animal category and region. See FAO (2015b) for further details on coefficients and animal category considered.

The portion fraction of manure treated in each MMS is estimated using default IPCC values for each of the categories given in Table 1. Losses due to the MMSs are computed using default IPCC values. Further losses due to the use of treated manure as feed, fuel or for construction were not computed for lack of available statistics.

TABLE 1: IPCC MANURE MANAGEMENT SYSTEMS (MMS)s

1.	Daily Spread	**9.**	Composting in vessel
2.	Solid Storage	**10.**	Composting – Static pile
3.	Dry Lot	**11.**	Composting – Intensive windrow
4.	Liquid/Slurry	**12.**	Composting – Passive windrow
5.	Uncovered anaerobic lagoon	**13.**	Poultry manure with litter
6.	Pit storage below animal	**14.**	Poultry manure without litter
7.	Anaerobic digester	**15.**	Aerobic treatment
8.	Cattle and Swine deep bedding		

EQUATION 2

N input from manure left on pasture

$$F_{PRP(T)}=[(N_{(T)}xNex_{(T)}xMS_{PRP(T)}]+\frac{[N_{(T)}xNex_{(T)}xMS_{BurnedForFuel(T)}]}{2}$$

Source: Adapted Equation 11.5, Vol.4, IPCC Guidelines 2006[2]

Where:

$F_{PRP(T)}$	Amount of animal manure N left on pastures for animal category T, kg N yr^{-1}
$N_{(T)}$	Number of heads of animal category T, heads yr^{-1} (from FAOSTAT)
$Nex_{(T)}$	Annual N excretion for animal category T, kg N $animal^{-1}$ yr^{-1} (Equation 10.30, Vol. 4, IPCC Guidelines 2006)
$MS_{PRP(T)}$	Fraction of total annual N excretion for each livestock species/ category T that is deposited on pasture, range and paddock (%) (Tables from 10A-4 to 10A-9, Vol. 4, IPCC Guidelines 2006, for cattle, swine, and for some buffaloes; Table 4.7, Vol 2, Revised IPCC Guidelines 1996, for other animals4, IPCC Guidelines 2006)
$MS_{BurnedForFuel(T)}$	Fraction of total annual N excretion for each livestock species/ category T that is burned for fuel (%) (Tables from 10A-4 to 10A-9, Vol. 4, IPCC Guidelines 2006, for cattle, swine, and for some buffaloes; Table 4.7, Vol 2, Revised IPCC Guidelines 1996, for other animals, IPCC Guidelines 2006)
T	Species/category of livestock

[2] The equation was modified in order to take into account that on average, the dung burned as fuel contains only 50 percent of the N excreted, while the remaining 50 percent is contained in urine which stays in the field (IPCC 2006 Vol.4, Ch.10, page 10.58)

2.2 Tier 2 Approach

The Tier 2 dataset presented in this report was estimated using the same equation structure described above for Tier 1 (Figure 3; equations 1 and 2), but using specific IPCC Tier 2 coefficients derived from GLEAM. GLEAM is a spatially explicit model based on a Life Cycle Assessment (LCA) approach that was developed to estimate GHG emissions of livestock products and to identify mitigation options (Gerber *et al.*, 2013; FAO, 2017c). Figure 4 expands the concepts illustrated previously in Figure 3, as the N-excretion rates calculated in GLEAM are a function of the animal diet and metabolic activity of the animals parameterized against a set of country-specific observations. It should be noted that the application of GLEAM to generate Tier 2 coefficients is one of many different approaches that could be used towards this scope. Therefore, these coefficients will be referred as Tier 2-GLEAM coefficients in the reminder of this report.

GLEAM takes the total number of livestock from FAOSTAT, and disaggregates the national herd into cohorts (Table 2), taking also into account different production systems, depending on available information on animal fertility and mortality rates, growth and replacement rates.

TABLE 2: **LIVESTOCK CATEGORIES AND COHORTS IN GLEAM**

LIVESTOCK CATEGORIES					
CATTLE[a]	BUFFALO[a]	GOAT[a]	SHEEP[a]	CHICKEN	SWINE
Adult	**Adult**	**Adult**	**Adult**	**Adult**	**Adult**
cow	female	female	female	female	female
bull	male	male	male	male	male
Calves[b]	**Calves[b]**	**Kids[b]**	**Lambs[b]**	**Chicks[b]**	**Piglets[b]**
Slaughter	**Slaughter**	**Slaughter**	**Slaughter**	**Slaughter**	**Slaughter**
female	female	female	female	female	female
male	male	male	male	male	male
Replacement	**Replacement**	**Replacement**	**Replacement**	**Replacement**	**Replacement**
male	male	male	male	male	male
female	female	female	female	female	female

[a] Different parameters were considered for meat or dairy specialized herds; [b] At birth.

Once the structure of the herd is defined, GLEAM estimates a feed basket for each animal class or production system. Gross energy requirements are calculated as a function of energy requirements for maintenance, activity, lactation, work, pregnancy, growth and production using IPCC 2006 (Vol. 4, Equation 10.16) and other sources (NRC, 1998; Sakomura, 2004; Opio *et al.*, 2013). Data on the feed basket, gross energy requirements, energy content, N content and digestibility of feed ration is used to calculate the dry matter intake and N-intake. N-excretion rates are computed as the balance between N retention, calculated by considering milk or egg production, weight gain and the average N content of the relative tissues, and N-intake. It is important to note that all of these coefficients are referenced to 2005.

With the above in mind in terms of how the relevant Tier 2-GLEAM coefficients are calculated, the amounts of available manure-N are computed with equations 1 and 2 defined above, with some slight modifications. Specifically, equation 1 for estimating the amount of treated manure available for soil application is used by assuming zero bedding as this information is not available in GLEAM. Furthermore, with reference to equation 1 above, the following specific coefficients were obtained at Tier 2 from GLEAM:

$\mathbf{Nex_{(T)}}$	Annual N excretion for animal category T, kg N animal^{-1} yr^{-1} (Annex III.A)
$\boldsymbol{MS_{(S,T)}}$	Share of manure treated in system S, for animal category T (%) (Annex III.B)
$\mathbf{Frac_{Loss(T)}}$	Weighted average fraction of managed (stored) manure nitrogen for livestock category T that is lost in all the MMSs (%) (Annex III.C)

Specifically, for each country, the N-excretion coefficients were extracted from GLEAM as a weighted average among all animal cohorts for each species and then multiplied by the total number of animals to obtain the total amount of manure-N excreted per animal species on an annual basis. Secondly, information on MMSs (Table 3) from GLEAM was used to generate Tier 2-GLEAM values to replace the Tier 1 default factors. GLEAM uses country-specific data on the allocation of manure to each MMSs, which are obtained from data sources such as national inventories, literature and expert knowledge. Concerning the percentage of N lost for each MMS, GLEAM also uses Tier 1 coefficients. The coefficients for the amount of N lost per animal in the country per each species presented in the Annex III.C were extracted from GLEAM as a weighted average due to the sub-national spatial differences in MMSs.

TABLE 3: MANURE MANAGEMENT SYSTEMS IN GLEAM

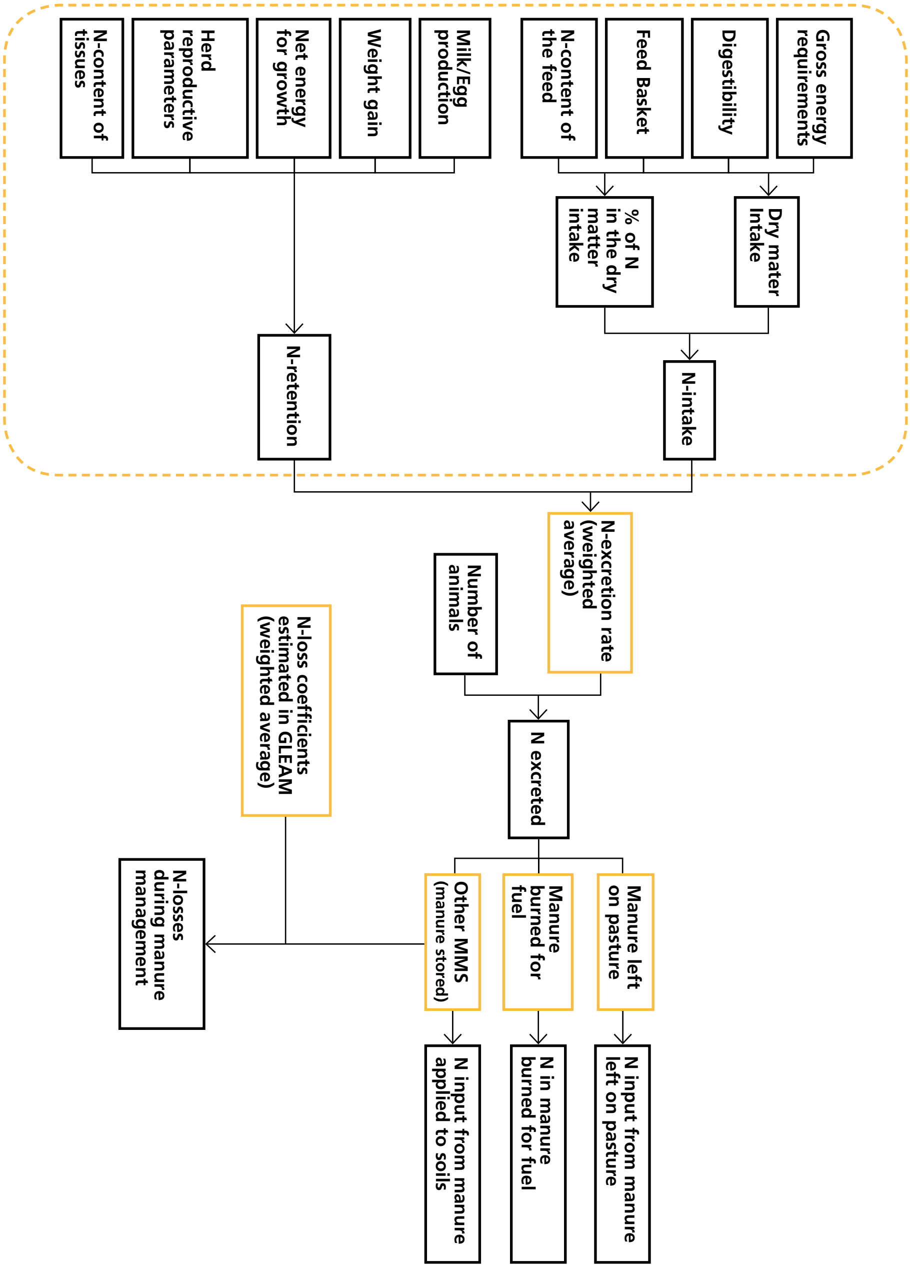
MMS	Cattle	Buffaloes	Sheep	Goats	Swine	Chickens
Pasture, range and paddocks	x	x	x	x	x	x
Daily spread	x	x	x	x	x	x
Solid storage	x	x	x	x	x	x
Dry lot	x	x	x	x	x	x
Liquid/Slurry	x	x	x	x	x	x
Uncovered anaerobic lagoon	x	x	x	x	x	x
Pit storage below animal confinements						x
Anaerobic digester					x	
Burned for fuel	x	x				
Poultry manure with litter						x

The total amount of manure N left on pastures was estimated using equation 2 above, but without corrections for urine retention in soils and amounts of manure burned, since these were already explicitly computed in GLEAM. With specific reference to equation 2, the following Tier2-GLEAM coefficient value was derived directly from the GLEAM model:

$MS_{PRP(T)}$	Share of total annual N excretion for each livestock species/category T that is deposited on pasture, range and paddock (%) (Annex III.B)

Finally, both the Tier 1 and the Tier 2-GLEAM estimates were computed using the livestock number statistics currently available in FAOSTAT (stocks) in order to avoid possible bias differences between the two approaches merely due to the use of different livestock numbers.

FIGURE 4: FLOW DIAGRAM FOR MANURE N FROM LIVESTOCK USED AS FERTILIZER. ORANGE BOXES INDICATE USE OF TIER 2-GLEAM COEFFICIENTS. The dashed orange box is a schematic illustration of part of the animal emissions module in GLEAM.



2.3 Uncertainties and limitations

The methodologies used to produce the FAO estimates in this report have several advantages, including their ease of applicability by all countries as a first step to build a core set of data for quantifying manure-N input over time and space (FAO, 2015b; Caro *et al.*, 2014). However, a number of limitations should be noted.

Some limitations related to the use of the Tier 1 approach that have been extensively discussed in the literature (e.g. Tubiello *et al.*, 2013; Ogle *et al.*, 2013; FAO, 2015b) as well as within the IPCC Guidelines (IPCC, 2006) are summarized below.

Tier 1 methods provide generic coefficients for estimating critical processes such as N excretion rates, MMS types and related N losses. Most of these coefficients are based on research in developed countries and in a limited number of developing countries. Although they were agreed through IPCC expert consultation as a means to facilitate comparability among countries, these coefficients do not necessarily capture (i) the heterogeneity of animals and production systems and (ii) the animal-soil-N dynamics in cropping and livestock systems of many developing countries.

IPCC Tier 1 coefficients are fixed reference values. This implies that while they may correctly represent underlying biophysical processes, they would not capture possible changes in agricultural management over time (e.g. adjustments in livestock diets, animal breeds, manure storage facilities and manure allocation at country level). A key consequence of using the default IPCC coefficients is that the temporal variation observed in the estimated manure statistics merely mirrors changes in the underlying livestock populations.

The IPCC Tier 2 approach used in GLEAM is meant to improve the representativeness of the coefficients through detailed country-specific information regarding N excretion rates, share of manure left on pasture and that applied to soils, and the percentage of N losses during manure storage. As Tier 2 methodologies require more detailed information, they are better able to capture the effects of changes in management practices (Wilkes, 2017). Experimental measurements of the N cycle are difficult however, resulting in uncertainty of coefficients and often wide uncertainties in national statistics. This affects both Tier 1 and Tier 2 approaches. This report does not offer a detailed quantification and analysis of those uncertainties concerning manure-N estimates.

Concerning manure allocation, the IPCC methodology strictly separates manure-N applied to soils from that left on pastures by grazing animals. This assumption may not be well-suited to many developing countries where livestock is often fed crop residues and left to graze on cropland. As a result, part of the manure-N which is actually applied to soils can be incorrectly allocated to pasture in both datasets (Rufino *et al.*, 2006 and 2011).

Livestock population data may also represent a source of uncertainty due to extrapolation imputation of data on livestock population in FAOSTAT for some countries and in certain years when official data are lacking.

Finally, this report does not cover the analysis of current use or availability of N from manure. It may happen that the manure is spatially too disperse or too concentrated to be optimally used. For instance, the concentration of livestock production often means that the manure produced by animals exceeds the absorptive capacity of the local area, and therefore manure becomes a waste product rather than a resource. Notwithstanding, such analysis falls beyond the scope of this report.

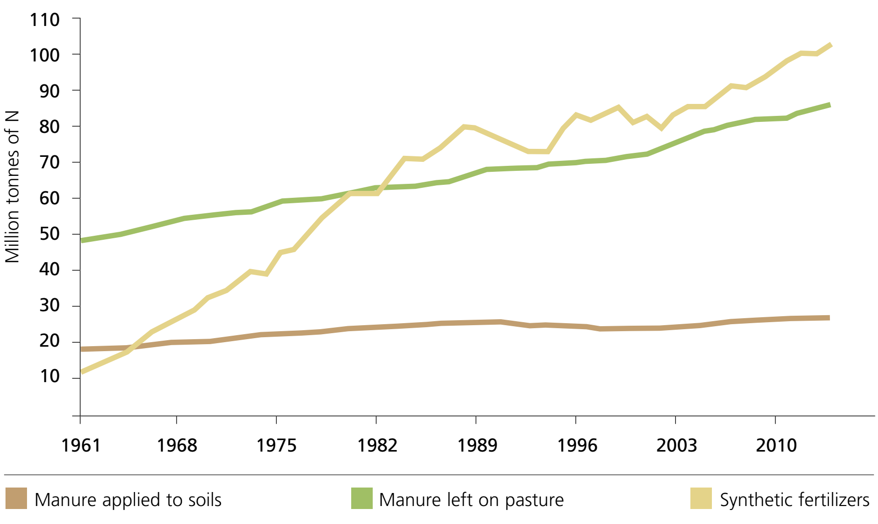
Results

3.1 Global Manure Availability (Tier 1)

This section presents the results of an analysis based on Tier 1 FAOSTAT estimates of manure-N inputs to agricultural area and a comparison with fertilizer-N inputs over the period 1961-2014 (FAO, 2017b, 2018).

Global manure production and use increased globally, and in most regions, from 1961 to 2014 (Figure 5) as a result of the increased livestock population numbers. Specifically, stocks of *Cattle, Buffaloes, Sheep and Goats* increased by 60 percent over this period, while *Swine* increased by about 140 percent. *Poultry* was the livestock category which recorded the highest increase in population numbers, with roughly a five-fold increase over the last fifty years.

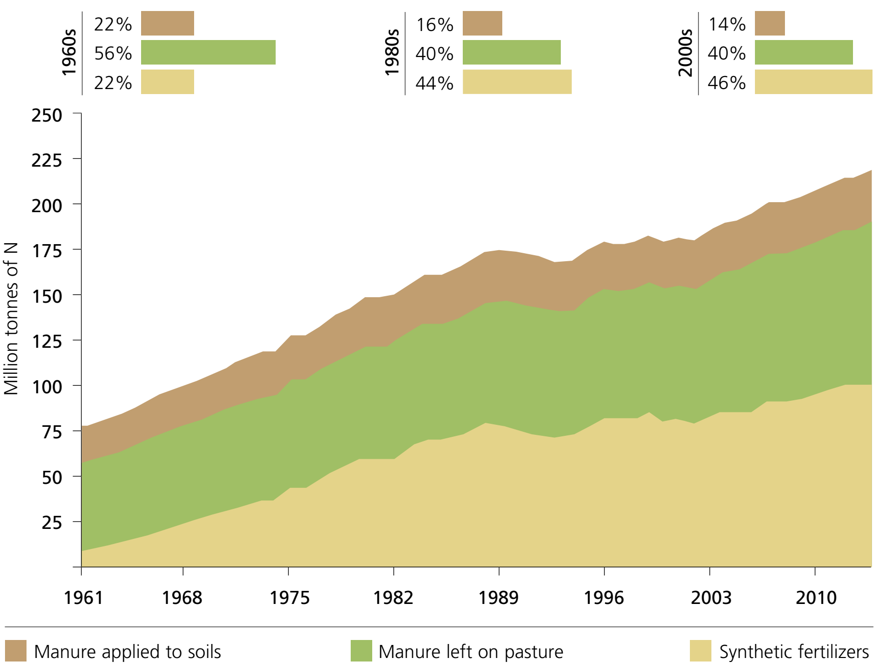
FIGURE 5: GLOBAL N INPUTS FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961 - 2014.



Global manure production from all livestock increased from 66 to 113 million tonnes of N (+71 percent) from 1961-2014, with manure applied to soils increasing from 18 to 28 million tonnes of N, and N input from manure left on pasture increasing from 48 to 85 million tonnes of N (Figure 5). It is worth noting that N input from mineral and chemical fertilizers (referred hereafter as synthetic fertilizers) grew considerably over the same period, with more than a seven-fold increase from 12 to 102 million tonnes of N. As a result, synthetic fertilizer-N inputs to soils were comparable to inputs from livestock manure in 2014 while only accounting for one-sixth of the N input from livestock manure in 1961. Furthermore, excluding manure-N left on pastures, the use of synthetic fertilizer-N was four times larger than livestock manure-N applied to soils in 2014.

The relative contributions of livestock manure and synthetic N sources have profoundly changed over the period 1961- 2014 (Figure 6).

FIGURE 6: **CUMULATIVE GLOBAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014.** Bar charts represent decadal average shares for 1960s, 1980s and 2000s.



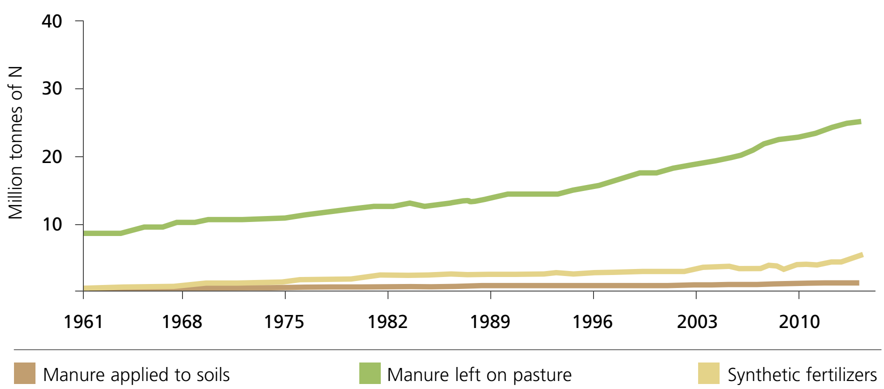
The total N input to soils (synthetic fertilizer + livestock manure)[3] was 78 million tonnes of N in 1961, of which around 80 percent was from livestock manure (averaged over the 1960s). By the 1980s, total N input to soils had nearly doubled to 150 million tonnes of N per year while the share of manure-N decreased to 56 percent, mainly due to the large increase in use of synthetic fertilizers in this period (Figure 5). Growth in livestock manure N inputs to soils matched that of synthetic fertilizers over the next two decades and by 2014 livestock manure still contributed more than half of the total input (or about 215 million tonnes of N per year).

3.2 Manure availability by region (Tier 1)

3.2.1 Africa

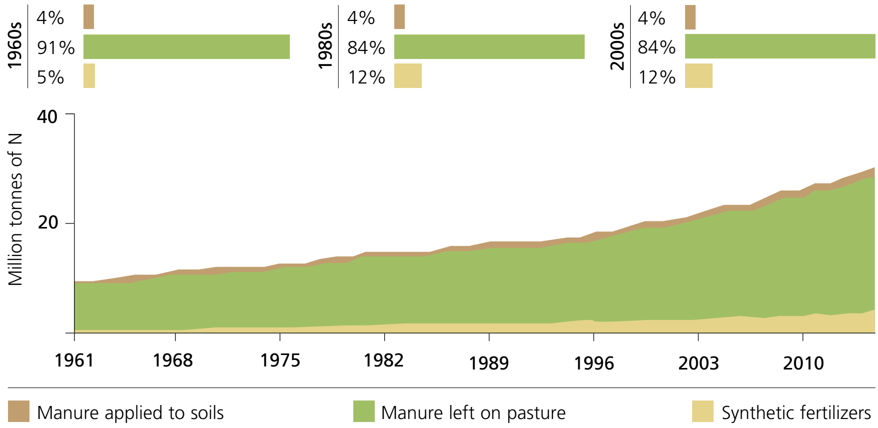
In Africa, the application rates of manure-N increased threefold from about 9 million tonnes of N in 1961 to 26 million tonnes of N in 2014 (Figures 7 and 8) and synthetic N-fertilizer use showed an approximate 10–fold increase over the study period. Despite the large increase in use, absolute amounts of synthetic fertilizer-N inputs were the lowest among all regions over the study period and N input from livestock manure was by far the largest source of N inputs to African soils. Livestock manure represented over 90 percent of total N inputs in the 1960s and about 87 percent in 2014.

FIGURE 7: **AFRICA: REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014**



[3] In this report total N input refers to the sum of synthetic N fertilizers and livestock manure-N. Other N input (e.g. N-fixation, atmospheric deposition, other organic fertilizers) are not taken into account. This should be considered when analyzing the data and particularly the shares of synthetic N fertilizer and manure-N presented in this chapter.

FIGURE 8: AFRICA: CUMULATIVE REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014. Bar charts represent decadal average shares (not cumulative) for 1960s, 1980s and 2000s.



3.2.2 Americas

The total N input in the Americas increased from 21 million tonnes of N to 53 million tonnes of N from 1961-2014 (Figures 9 and 10). The N input from manure deposited on pasture and manure applied to soils increased steadily, but manure-N left on pasture was the main input for the period considered. Synthetic fertilizer-N inputs increased by more than 6-fold over the study period due to factors such as the expansion of agricultural lands and availability and subsidies of fertilizers. Due to the increase in synthetic N fertilizer applications, the share of manure-N inputs (left on pasture + applied to soils) decreased over the study period from over 75 percent in the 1960s to 60 percent in 2000s.

FIGURE 9: AMERICAS: REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014.

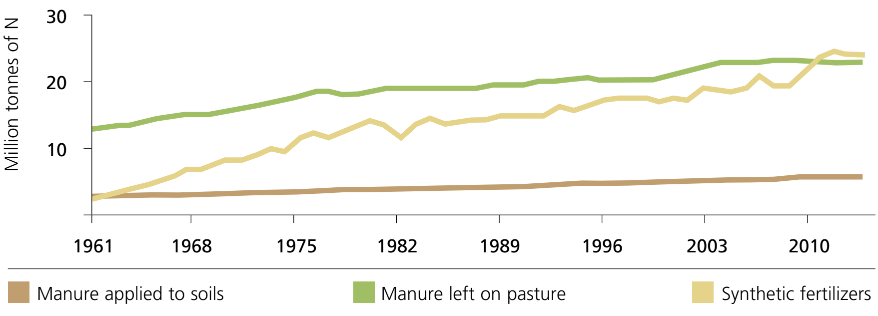
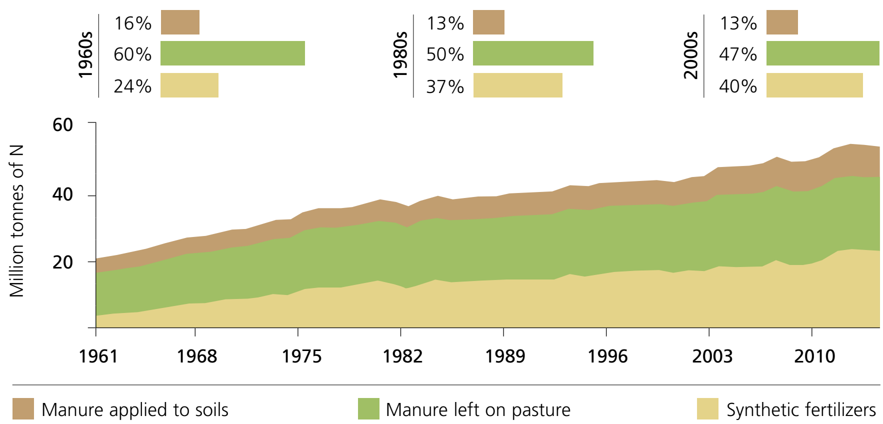


FIGURE 10: AMERICAS: CUMULATIVE REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014. Bar charts represent decadal average shares for 1960s, 1980s and 2000s.



Sub-regional analyses showed marked differences between North America and Latin America, reflecting the sharply different agriculture sector of the two sub regions. Over the study period, North America represented 44 percent of total N use in the region in 1961 and 41 percent in 2014 (data not shown). Importantly, in North America synthetic fertilizers already contributed more than 40 percent of the total N applied in 1961, a share that grew up to 70 percent in 2014. Conversely, the share of livestock manure left on pasture decreased from 36 percent to 12 percent as the share of manure applied to soils which dropped from 24 percent to 18 percent over the same period.

Livestock manure, especially the component left on pasture, was the dominant N input in Latin America in 1961 and continued to grow over the study period. This is mainly due to the extensive livestock systems that characterize this region. As a consequence, livestock manure accounted for 11 million tonnes of N in 1961 (96 percent of the total input, of which 84 percent was manure left on pasture) and doubled throughout the study period reaching 23 million tonnes in 2014 (73 percent of the total N input of which 61 percent was manure left on pasture). Synthetic fertilizers only accounted for 0.4 million tonnes of N in 1961 (4 percent of the total N input) and increased substantially, accounting for 8.5 million tonnes in 2014 (27 percent of the total N input).

3.2.3 Asia

Asia is the region with the largest agricultural area. The total N input was 18.6 million tonnes of N in 1961 (Figures 11 and 12) which was comparable with the amount of N applied in the Americas in the 1960s. Manure deposited on pasture was the main source of N input (61 percent of the total N input) in the 1960s, followed by manure applied to soils (20 percent of the total N input) and synthetic fertilizers (19 percent of the total N input).

FIGURE 11: **ASIA: REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014.**

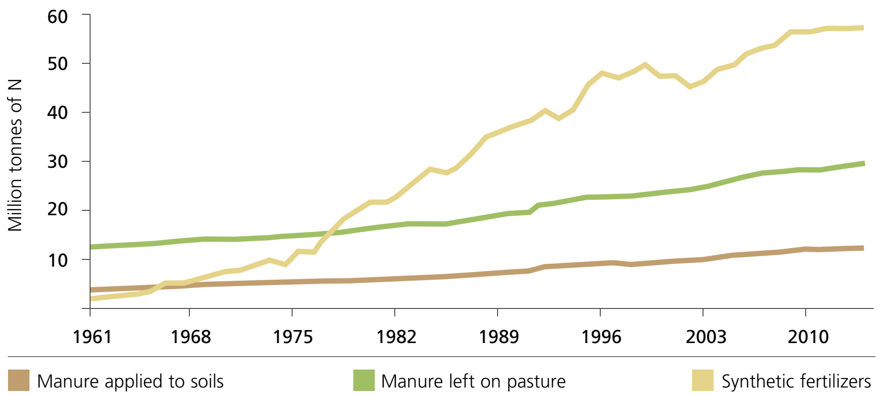
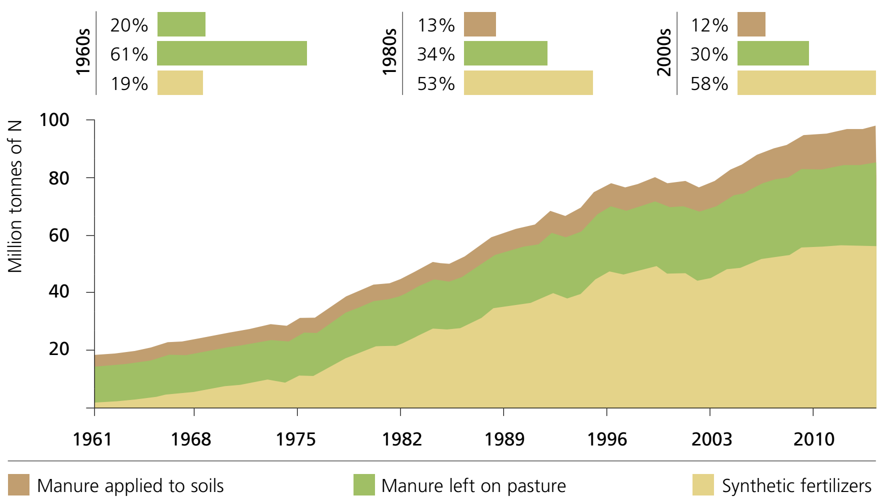


FIGURE 12: **ASIA: CUMULATIVE REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014.** Bar charts represent decadal average shares for 1960s, 1980s and 2000s.



Manure-N inputs continued to increase in the period considered but at a lower rate than synthetic fertilizer-N inputs. Manure-N applied to soils increased from 4 million tonnes of N in 1961 to about 12 million tonnes of N in 2014 while the N input from manure left on pasture increased by 140 percent, from 12 million tonnes of N in 1961, and reaching 29 million tonnes of N in 2014. Despite such growth, the share of the respective N inputs from livestock manure deposited on pasture and applied to soils decreased significantly to 34 percent and 13 percent in the 1980s, and to 30 percent and 12 percent in the 2000s, respectively. This was due to a 26-fold increase in synthetic fertilizer use over the study period that was supported by fertilizers subsidies, and in 2014 synthetic fertilizers accounted for 56.7 million tonnes of N and represented almost 60 percent of total N inputs.

3.2.4 Europe

Trends in organic and inorganic N inputs in Europe are presented in Figures 13 and 14. In the 1960s, the total N input was about 23 million tonnes and comparable with values from Asia, despite the smaller agricultural area. Compared to other regions, manure-N applied to soils was significantly larger than the amount left on pasture, with 40 percent (about 10 million tonnes of N) and 27 percent (about 7 million tonnes of N) of the total N input, respectively. During the period 1961-2014, synthetic fertilizer-N use increased from 33 percent (about 5 million tonnes of N) of the total in the 1960s to about 55 percent by the 1980s in a trend similar to those observed in other regions. Europe, however, is the only region showing a marked decrease in fertilizer N inputs from the 1980s to the 1990s.

FIGURE 13: EUROPE: REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014.

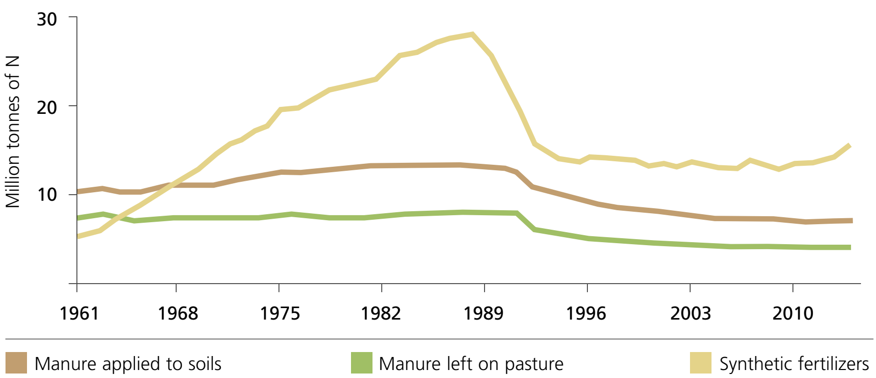
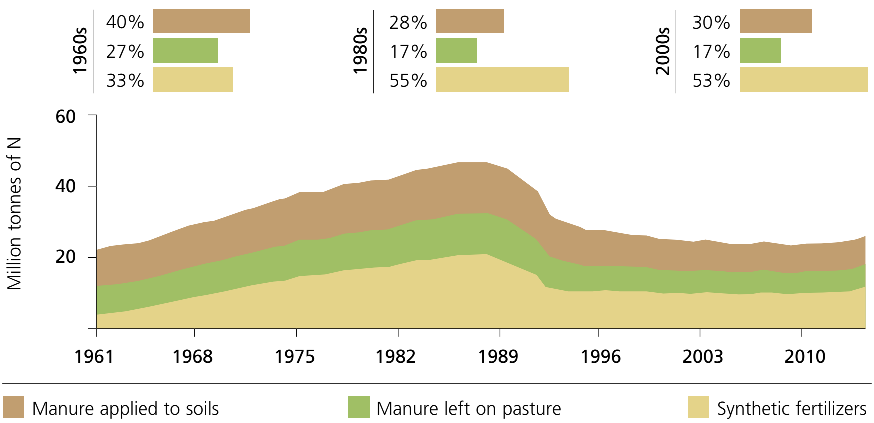


FIGURE 14: **EUROPE: CUMULATIVE REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014.** Bar charts represent decadal average shares for 1960s, 1980s and 2000s.



The reason for this decrease could be due to the EU nitrate directive that led to tight limitations in nutrient use (Sutton *et al.*, 2011a). These trends were re-enforced by the collapse of the Soviet Union and its economy, including agricultural production. As a result, from 1992 to 2014, use of synthetic fertilizers dropped by nearly 50 percent, while applications and availability of manure-N decreased by over 30 percent. Indeed, Europe is also the only region analysed where the share of synthetic fertilizers dropped, albeit only slightly, from the 1980s to the 2000s, from 55 percent to 53 percent of total N inputs. In 2014 about 4 million tonnes of N, 7 million tonnes of N and 15 million tonnes of N were applied via manure left on pasture, manure applied to soils and synthetic fertilizers, respectively.

3.2.5 Oceania

Manure left on pasture was the main source of N input over the entire period (Figures 15 and 16), with a share of over 70 percent and accounting for 5.4 million tonnes of N in 1961, and 4.3 million tonnes of N in 2014. This is a direct reflection of the extensive livestock production in this region. Conversely, N input from manure applied to soils represented only 2-4 percent of the total N input, about 0.1 million tonnes of N in 1961 and 0.2 million tonnes of N 2014, of the total N input. Share of total N inputs from synthetic fertilizers increased from 2 percent to 19 percent, from about 0.04 million tonnes of N in 1961 to 1.75 million tonnes of N in 2014.

While the use of nitrogenous fertilizers increased almost steadily throughout the period considered, the N from manure left on pasture started to drop in the 1990s and in the 2000s, with the contribution of each N source changing considerably. The manure left on pasture remained the main N source but its share decreased significantly (from 96 percent to 77 percent). The share of N input from synthetic fertilizers increased considerably and reached 19 percent of the total N input while the manure applied to soils increased over the study period, but remained below 5 percent.

FIGURE 15: OCEANIA: REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014.

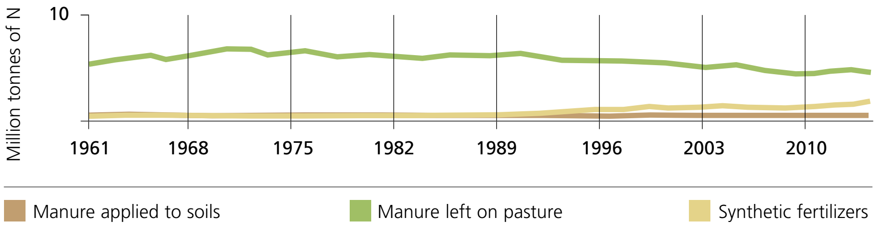
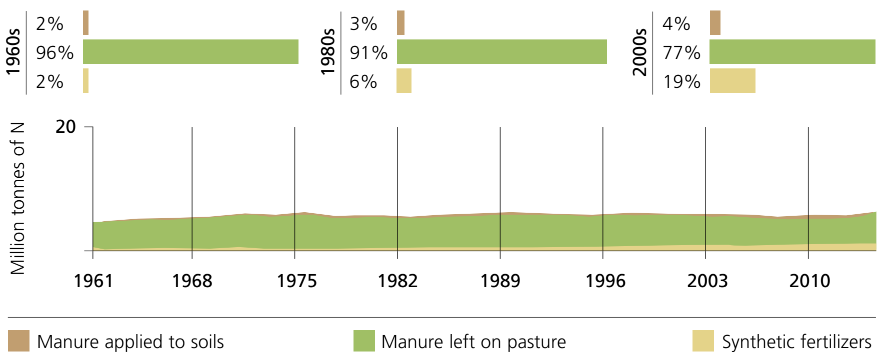


FIGURE 16: OCEANIA: CUMULATIVE REGIONAL N INPUT FROM LIVESTOCK MANURE AND SYNTHETIC FERTILIZERS, 1961-2014. Bar charts represent decadal average shares for 1960s, 1980s and 2000s.



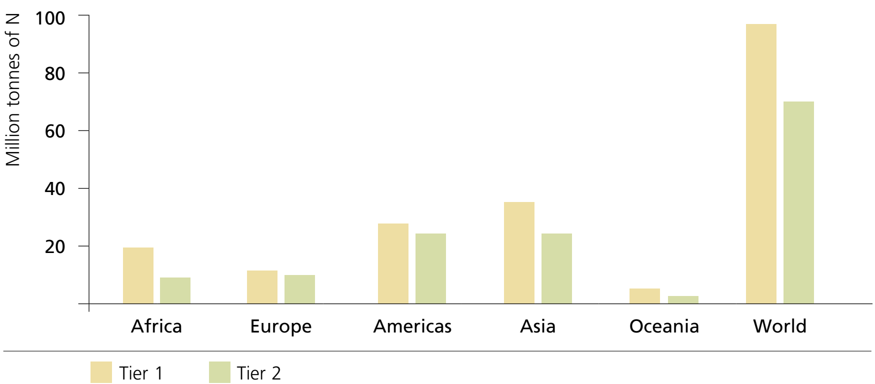
3.3 Comparing IPCC Tiers

The GLEAM estimates of N inputs from livestock manure differed from the Tier 1 results, both at global and regional levels (Figure 17). In the year used for comparison (2005), at a global level, total N input from livestock manure estimated by Tier 1 was about 97 million tonnes of N, while Tier 2-GLEAM estimates were 29 percent lower, at about 69 million tonnes of N. Furthermore, it was found that Tier 1 estimates were consistently higher than Tier 2 across all regions. Regional differences between the two approaches were most pronounced in Africa (about 19 vs 9 million tonnes of N; 53 percent), Oceania (about 5 vs 3 million tonnes of N, 40 percent) while they were smaller for Asia (about 35 vs 25 million tonnes of N; 28 percent) and Europe (about 11 vs 8 million tonnes of N, 27 percent). For Americas, the estimates were comparable for Tier 1 and Tier 2 (about 27 vs 25 million tonnes of N, 7 percent).

The above differences are important and will be discussed below, taking into account that this analysis is limited to livestock species common to both approaches (cattle, buffaloes, chickens, sheep, goats and swine). FAOSTAT contains estimates for additional, locally relevant species such as asses, camels, ducks, horses, llamas, mules and turkeys. These species will not be considered in the following analysis as they contribute very little to the N input[4].

The analysis presented in this section will focus on the comparison of total manure-N inputs, and on the manure allocation between pastures and soils.

FIGURE 17: **N INPUT FROM LIVESTOCK MANURE ESTIMATED AT TWO IPCC TIERS, 2005.** The graph refers to the common FAOSTAT-GLEAM livestock species.



[4] The N-input from manure (left on pasture + applied to soils) of those livestock species accounted for 4.6 million tonnes of N in 1961 and 6.5 million tonnes of N in 2014.

More substantial differences between the two Tiers were found at the regional level and for the separate components of manure left on pasture and manure applied to soils, especially in Africa and Asia (See Annex I, II and Table 4). For instance, of the 97 million tonnes manure-N estimated globally with the Tier 1 approach, manure-N left on pasture is roughly three times that of manure applied to soils. Conversely, in Tier 2-GLEAM approach, the manure-N left on pasture and that applied to soils are more similar, with the former being only one quarter higher than the latter. The most notable differences were found in Africa. In this region, Tier 1 approach estimates of manure-N left on pasture were some 18 times larger than amounts of N applied to soils, while in Tier 2-GLEAM the two manure allocations have similar absolute amounts. Furthermore, in Asia, Tier 2-GLEAM estimates of the amount of manure-N left on pasture were about 40 percent lower than those for the N applied to soils, whereas for Tier 1 these estimates were 140 percent higher. These observed differences were due to different coefficients specifying the split of total manure application between soils and pastures (See Annex III). As discussed in the methodology section, the default Tier 1 IPCC methodology is particularly weak in capturing manure dynamics in mixed systems. This is the case in Africa where a good portion of the manure-N left on pasture is in practice applied to soils when animals are allowed to graze on cropland after harvest.

Additional differences in Tier method results are discussed in the analysis of results by livestock category.

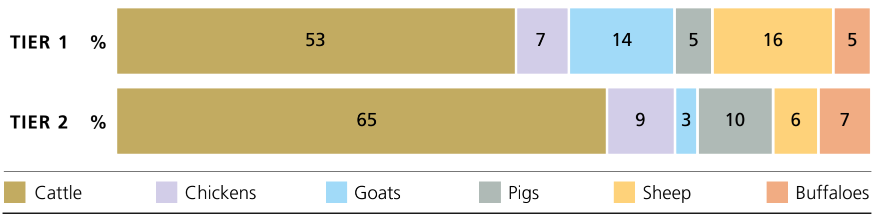
TABLE 4: **GLOBAL DIFFERENCES IN MANURE ESTIMATES BETWEEN FROM THE TWO TIER APPROACHES, DISAGGREGATED BY REGION, 2005.** Data are reported in million tonnes of N.

TOTAL	APPLIED TO SOILS		LEFT ON PASTURE		TOTAL APPLIED	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Africa	1	3.5	18.4	5.2	19.4	8.6
Europe	7.1	5.7	4.0	2.6	11.2	8.5
Americas	5.4	7.0	21.1	17.6	26.6	24.6
Asia	10.2	14.8	24.6	10.2	34.8	25.0
Oceania	0.2	0.1	5.0	2.7	5.3	2.8
WORLD	24.0	31.1	73.1	38.6	97.3	69.5

3.4 Global and regional manure-N estimates by livestock species

The contribution of different animal species categories to the production of manure was also investigated to explain additional differences in results between the two Tier approaches (Figure 18 and Table 5). At the aggregate level, the relative share between species differed as shown in Figure 18. Cattle had a smaller share of total N input in Tier 1 calculations as compared to those of Tier 2-GLEAM (53 percent vs 65 percent), while sheep and goats had a higher share in Tier 1 than in Tier 2-GLEAM (30 percent vs 9 percent). Swine manure share estimated using Tier 1 was half that of Tier 2-GLEAM.

FIGURE 18: **SHARE OF TOTAL N INPUT FROM ANIMAL MANURE BY LIVESTOCK CATEGORY, ESTIMATED WITH TWO IPCC TIERS.**



The discussion below will focus on cattle, the major component of the total share, as well as on the major sources of discrepancy in the two Tier estimates, particularly sheep and goats.

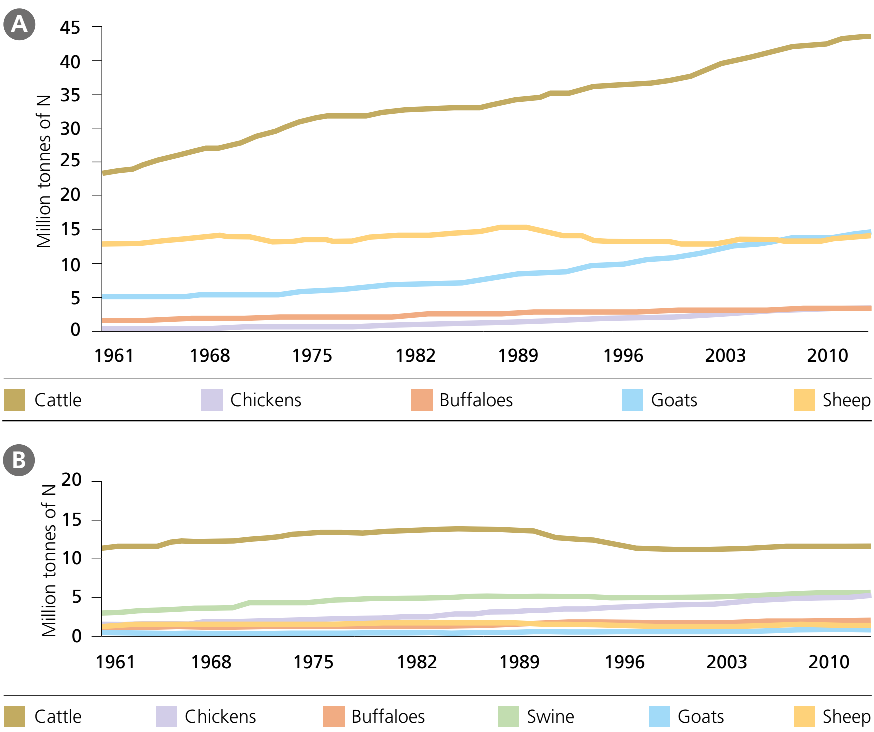
TABLE 5: **GLOBAL DIFFERENCES BETWEEN TIER APPROACHES, BY LIVESTOCK SPECIES, 2005.** Data are reported in million tonnes of N.

WORLD	APPLIED TO SOILS		LEFT ON PASTURE		TOTAL APPLIED	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Cattle	11.2	16.6	40.7	28.7	51.9	45.2
Buffaloes	1.6	2.0	3.2	2.5	4.9	4.6
Sheep	1.2	0.8	13.7	3.3	14.9	4.2
Goats	0.5	0.7	12.8	1.5	13.3	2.3
Swine	5.0	6.7	0	0.2	5.0	6.9
Chickens	4.4	4.1	2.8	2.0	7.2	6.2
TOTAL	23.9	30.9	73.2	38.2	97.2	69.4

3.4.1 Cattle and Buffaloes

Over the period of analysis, 1961-2014, the amount of cattle manure-N left on pasture increased by 85 percent worldwide while cattle manure-N applied to soils decreased sharply during the 1990s, and increased again, if only slightly, in the early 2000s (Figure 19). This trend is linked with the underlying livestock population statistics, which in FAOSTAT showed increases in cattle numbers in most regions (not shown) except for Europe, where cattle numbers decreased significantly after 1998. By contrast, significant increases in manure-N production were observed both in Africa and Asia (roughly 50 percent and 100 percent, respectively). In the analysis, of these graphs, especially for cattle, it should be considered that the variation in manure-N left on pasture or applied to soils of each livestock category is influenced by the underlying population of the Tier 1 livestock sub-categories (e.g. dairy cattle vs other cattle) which have specific excretion rates and manure allocation coefficients.

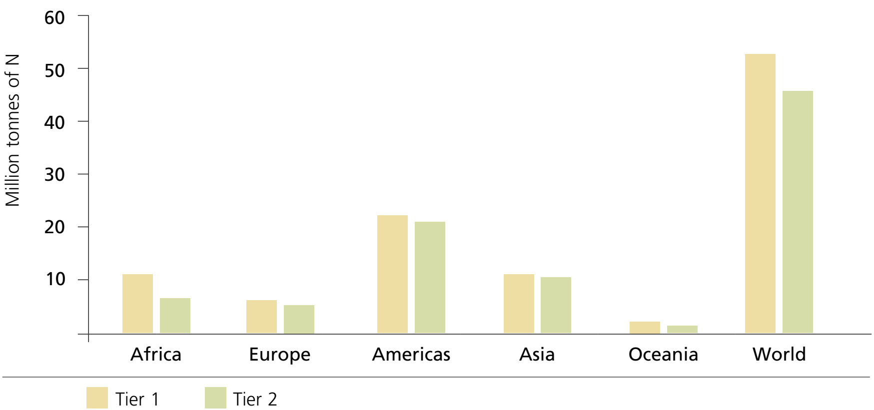
FIGURE 19: **TOTAL N INPUT OF ANIMAL MANURE BY LIVESTOCK SPECIES, 1961-2014, IPCC TIER 1.** A) Manure left on pasture; B) Manure applied to soils.



For instance, increases in non-dairy cattle population in Western Europe or in Latin America likely results in increased amounts of manure-N left on pasture and reductions in manure-N applied to soils. This explains the different trends of manure-N applied to soils and left on pasture from the same livestock category and why those values do not mirror exactly the fluctuation in total livestock population.

In 2005, cattle provided more than half of the total manure-N input (manure-N applied to soil + manure-N left on pasture) worldwide, or 52 million tonnes of N (Tier 1) and 46 million tonnes of N (Tier 2-GLEAM), as shown in Figure 20 and Table 5. The Americas and Asia contributed the largest share of the total cattle manure-N input, 40 percent and 20 percent respectively. The difference in estimates of manure-N was specifically marked in Africa with Tier 1 being 68 percent higher than Tier 2-GLEAM and leading to high discrepancies in global estimates.

FIGURE 20: **N INPUT FROM CATTLE MANURE ESTIMATED AT TWO IPCC TIERS, 2005.**



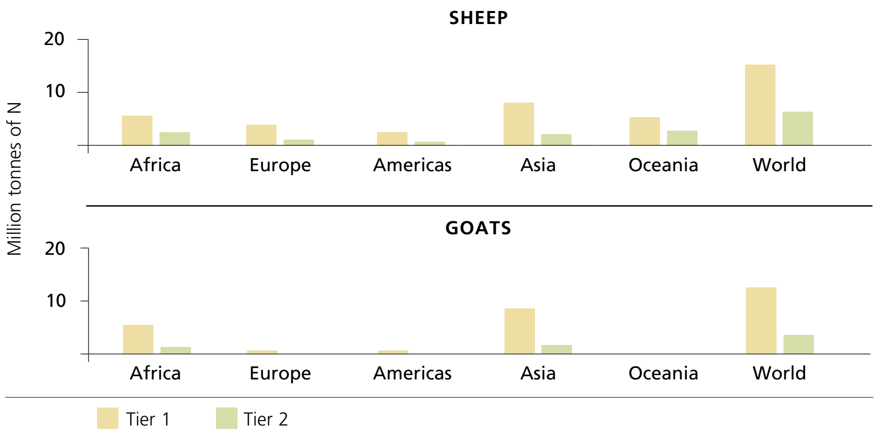
Looking at the estimations of manure-N left on pasture and applied to soils, separately, some substantial differences were found for cattle manure left on pasture and applied to soils, both globally and regionally, and especially in Africa and Asia (See Annexes I and II). Globally, Tier 1 estimates of cattle manure left on pasture were as roughly four times that of cattle manure applied to soils, whereas Tier 2-GLEAM estimates of manure left on pasture were slightly less than double to that applied to soils. Similar to the aggregated analysis for all animal species, the largest discrepancy was found for Africa. As for the previous analysis at global aggregate level, such discrepancies were explained by large differences in the underlying coefficients used between different Tier approaches for allocating manure between pasture, MMSs and soils.

Buffalo manure had a minor contribution to the estimated global manure-N inputs during the period 1961-2014, with Asia producing over 95 percent of the inputs. The two-Tier approaches gave similar estimates for total buffalo manure produced, except for Africa where Tier 1 estimates were 62 percent higher than those of Tier 2-GLEAM.

3.4.2 Sheep and Goats

Sheep and goats are the species which showed the largest differences between the datasets of the two Tier approaches. In 2005, Tier 1 and Tier 2-GLEAM manure-N input estimates for goats were 13 million tonnes of N and 2 million tonnes of N, and 15 million tonnes of N and 4 million tonnes of N for sheep, respectively (Figure 21).

FIGURE 21: **N INPUT FROM SHEEP AND GOAT MANURE ESTIMATED FOR TWO IPCC TIERS, 2005.**



Of these amounts, and across Tiers, about three-quarters were estimated as manure-N left on pasture for goats, while for sheep the amount varied by region.

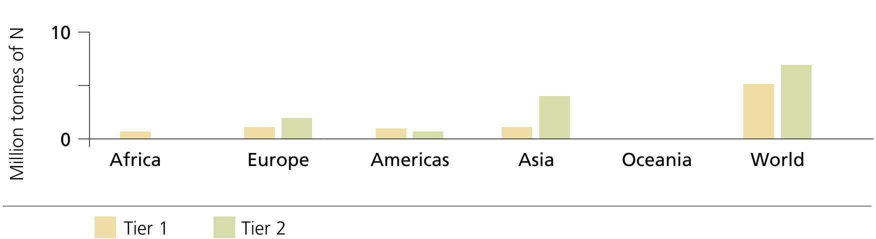
For goat manure-N, the differences between Tier approaches are mainly explained by Africa and Asia (which represent about 90 percent of stocks of this livestock species), whereas for sheep manure-N differences are more distributed across regions, although Africa and Asia still accounted for 50 percent of the difference. The reason for such large differences in estimates between Tiers are due to N excretion coefficients values. IPCC Tier 1 values range between 10-20 kg N animal^{-1} year^{-1} compared to typical values of 1-5 kg N animal^{-1} year^{-1} specified in Tier 2-GLEAM (See Annex III A). These differences between coefficients for the two Tier methods are directly reflected in the differences observed in manure-N production.

3.4.3 Swine

The global N input to soils from swine manure was about 10 percent of that of cattle in 2014. Swine manure-N applied to soils doubled from 1961 to 1986 and continued to rise at a slower rate after this period, reaching 5.6 million tonnes of N in 2014 (Figure 19). The estimates in FAOSTAT show that the swine manure-N applied to European soils rose steadily from 1.3 million tonnes of N in 1961 to a peak of about 2.1 million tonnes of N in 1989 after which time it decreased steadily to 1.6 million tonnes in 2014. Africa and Asia saw a steep and consistent increase in the N applied to soils from swine manure with more than five-fold increases over the study period. In the Americas, the N input from swine manure applied to soils increased at a lesser rate, from 1 to 1.6 million tonnes of N, while in Oceania inputs increased over the study period, however the total tonnage remained very limited.

At the global level the Tier 1 estimates for swine were 27 percent lower than those of Tier 2-GLEAM (Figure 22 and Annex II), contrary to that observed for the other livestock species where Tier 1 estimates were generally higher. Large differences between the two approaches were observed in Africa (Tier 1 was 180 percent higher), Asia (Tier 1 was 53 percent lower) and Oceania (Tier 1 was 39 percent lower), although the former and the latter were measured against a very low absolute amount. Tier 1 estimates for Europe and the Americas were 21 percent lower and 25 percent higher than Tier 2, respectively. Concerning manure-N allocation to pasture and soils, it should be noted that all the swine manure-N is allocated to soils in Tier 1, while Tier 2 also includes the allocation of swine manure-N to pasture.

FIGURE 22: **N INPUT FROM SWINE MANURE ESTIMATED AT TWO IPCC TIERS, 2005.**

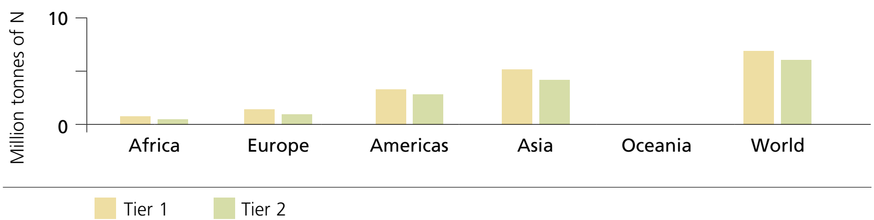


3.4.4 Chickens

Manure-N input to soils and pastures from chickens grew steadily over 1961 to 2014 (Figure 19) with Asia seeing the greatest increases and accounting for about half of the global N input (regional data not shown). In the Americas, the N input from the chicken manure applied to soils showed more than a three-fold increase, increasing from 0.4 million tonnes of N in 1961 to about 1.6 million tonnes of N in 2014. Unlike the other regions considered, the majority of manure-N from chickens in Africa was left on pasture.

The comparison between Tier estimates showed a general agreement at global level with Tier 1 estimates being about 16 percent higher than those of Tier 2-GLEAM.

FIGURE 23: N INPUT FROM CHICKEN MANURE ESTIMATED AT TWO IPCC TIERS, 2005.



Regional agreement between approaches was close in Oceania with Tier 1 being 6 percent higher than Tier 2-GLEAM, and in the Americas with Tier 1 estimates 2 percent higher than those of Tier 2-GLEAM. Tier 1 results were 16 percent and 20 percent higher than Tier 2-GLEAM in Africa and Asia respectively. Europe was the region with the highest differences between Tiers with Tier 1 estimates 39 percent higher than those of Tier 2-GLEAM.

Looking at the estimations of manure left on pasture and applied to soils separately, some additional differences are observed. For instance, in the case of the Americas estimates of the total N input from chicken manure did not differ between the two Tier methodologies, however the results showed differences in allocation to either soil application or retention on pasture. Large differences were also observed in the allocation of manure-N to soils and pasture in Europe and Africa (See Annex II).

3.5 Review of other published global manure-N estimates

Many studies have published estimates of global N input from livestock manure applied to agricultural soils. Table 6 presents a subset relevant to this report.

The range in published estimates of total global livestock manure N inputs to soils over the period 1995-2014 is 55-128 million tonnes of N. The results presented in this report lie within this range. Nevertheless, an accurate comparison is difficult due to the difference in methodologies, reference year and input data used.

Van der Hoek *et al.* (1999) estimated a global total of 102 million tonnes of N of manure-N in 1995 by up-scaling N budgets at different scales (field, farm and region), using FAOSTAT livestock populations and N excretion rates from the literature. Sheldrick *et al.* (2003) estimated a global total of 94 million tonnes of N in 1996 (34 when limited to cropland application) by scaling up N, P and K excretion rates by livestock populations and body weights taken from FAOSTAT, and adjusted for manure allocation and losses during manure storage. Liu *et al.* (2010) estimated a total of 17 million tonnes of N applied to the global cropland in 2000, using coefficients for North America and Europe and default values for other regions.

TABLE 6: PUBLISHED ESTIMATES OF N INPUT FROM LIVESTOCK MANURE.

REFERENCE	MANURE (million tonnes of N)	REFERENCE YEAR
Van der Hoek *et al.* (1999)	102	1995
Smill (1999)[a]	14-22	1995
Sheldrick *et al.* (2004)	94	1996
Green *et al.* (2004)[b]	82	1995
Siebert (2005)	108	1995
Bouwman *et al.* (2005)	44	1970
Bouwman *et al.* (2005)	55	1995
Bowman *et al.* (2013)	92	2000
Potter *et al.* (2010)[c]	128	2007
Liu *et al.* (2010)[a]	17	2000
This study [a] (Tier 1)	25-28	1995-2014
This study (Tier 1)	94-114	1995-2014
This study (Tier 2)	69	2005

Adapted from Potter *et al.* (2010).

[a] Limited to manure applied to soils; [b] Poultry manure not considered; [c] N losses not taken into account

Bouwman *et al.* (2013) calculated some 82 million tonnes of N in livestock manure inputs in 2000. Results from these studies are well aligned with the Tier 1 estimates presented in this report, probably due in part to the comparable approach followed by the authors.

Other studies, such as Potter *et al.* (2010) and Siebert (2005), reported gross N inputs and are therefore difficult to compare with the datasets presented in this report.

More conservative estimates produced by some studies aligned better with the Tier 2-GLEAM findings presented herein. Specifically, Bouwman *et al.* (2005) estimated manure-N inputs of 55 million tonnes of N in 1995 based on a spatial analysis of the global N balance in intensive agricultural systems. Smil (1999) calculated a total of 75 million tonnes of N of manure-N for 1995 (14-22 million tonnes of N when limited to cropland inputs) as part of a global accounting of N flows. The author calculated N excretion rates as the amount of manure excreted per animal multiplied by average N concentration, adjusted according to type of livestock system (traditional or modern) and to different animal body weights across high and low income countries. Green *et al.* (2004) estimated similar global totals based on a spatial study on the global N flows and the differences between pre-industrial and contemporary N fluxes.

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Conclusions

The results of the analysis of the Tier 1 FAOSTAT database for manure-N input estimations presented in this report clearly indicate that livestock manure (applied to soils and left on pasture) represents a substantial component of N inputs to agricultural soils worldwide. Over the last fifty years the global inputs of manure-N increased from 66 million tonnes of N in 1961 to 113 million tonnes of N in 2014. The large amounts of N contained in and available from manure across the globe supports the need for accurate and robust statistics on livestock manure management and use at various scales. This information is necessary to monitor current and future trends in global N-flows, to assess environmental impacts and sustainability issues related to the agriculture sector, and to inform agricultural and environmental planning and policy. This study intends to contribute towards fulfilling this statistical requirement by providing new and critical information on livestock manure-N at national, regional and global levels based on national statistical processes and internationally referenced methodologies.

In recent decades, the combined N input from livestock manure and synthetic fertilizers to agricultural soils (crops and pastures) has increased considerably, accounting globally for 78 million tonnes in 1961 and reaching 215 million tonnes in 2014. While global N inputs to agricultural soils from manure are still larger today than those from synthetic fertilizers, applications of synthetic N fertilizers have increased dramatically in both developed and emerging economies over the last fifty years and are globally the dominant source of N for crop cultivation.

Marked differences exist in amounts and proportions of synthetic fertilizer-N and manure-N applications among regions however. Asia for instance recorded a steep increase in the use of synthetic N sources over the last 50 years, and by 2014 manure-N accounted for only 42 percent of total N inputs (synthetic fertilizer-N plus manure-N). By contrast, in Africa, where fertilizer inputs are often inaccessible for farmers and 40 percent of the soils are degraded, manure-N represents about 90 percent of total N inputs, with a large share being left on pasture and not recycled to cropland.

The large amount of N available in livestock manure at global and regional levels represents an agronomic opportunity, but also a potential threat to the environment.

Developing efficient manure management plans and technological options to recycle N (and other nutrients) available in manure is crucial for the sustainability of global and regional agricultural systems. Efficient recycling of manure can also play a role in optimizing synthetic N application and reversing soil degradation through increasing organic matter in soils. Robust and regional-specific manure-N data are necessary to tailor policy interventions that support the sustainable use and recycling of livestock manure in agriculture. In areas of the world characterized by excessive N inputs for instance, sustainable manure management is necessary to reduce synthetic fertilizer inputs, contribute to balanced nutrients applications and reduce the pressure of agriculture on the environment. Conversely, in regions affected by soil degradation and with low fertilizer application, manure management practices to enhance nutrient recovery and organic matter input to soil should be prioritized to reverse soil degradation and enhance crop production.

Another important aspect of this report is the comparison of the manure-N input estimates obtained from two methodologies, the Tier 1 IPCC and Tier 2-GLEAM methodologies. At the global level, the estimate obtained with the more complex Tier 2-GLEAM approach was about 30 percent lower than the one obtained with the simpler Tier 1 approach. Additionally, important differences between the two approaches were found for some regions (e.g. Africa and Asia) and some animal species (e.g. sheep and goats). This comparison between Tier 1 and Tier 2-GLEAM also indicates for which regions and livestock species there is the need for improved coefficients and estimations. This report therefore represents a preliminary step towards more comprehensive assessments and harmonization of the different methodologies to estimate nutrient inputs from livestock manure to soils.

Finally, the information in this report is intended to provide guidance to countries for adopting practical and suitable methodological approaches towards producing manure-N statistics based on criteria such as national statistical capacity, the data accuracy required, the prevalence and importance of specific animal species, and the types of production systems in which the livestock are raised.

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ANNEXES

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ANNEX I

N inputs from Manure (IPCC Tier 1) and Synthetic Fertilizers

ANNEX II

N inputs from Manure (IPCC Tier 1 and Tier 2) by Region, Year 2005

ANNEX III

Coefficients used to estimate N input from livestock manure

ANNEX I

N inputs from Manure (IPCC Tier 1) and Synthetic Fertilizers

MANURE APPLIED TO SOIL (TONNES OF N)					
LIVESTOCK CATEGORY	1970	1980	1990	2000	2010
Cattle	12 197 360	13 496 182	13 781 130	11 200 071	11 545 936
Buffaloes	1 062 397	1 174 225	1 401 461	1 515 615	1 724 252
Sheep	1 342 183	1 484 837	1 574 645	1 098 435	1 246 060
Goats	195 488	248 296	324 164	418 635	524 698
Swine	3 546 887	4 866 113	5 120 705	4 902 653	5 520 345
Chickens	1 767 416	2 280 017	3 032 503	3 806 513	5 068 009
Ducks	122 897	164 913	261 069	452 746	577 074
Turkeys	300 496	532 464	745 695	747 559	723 937
Horses	99 773	93 799	92 111	81 970	89 883
Asses	23 643	24 132	28 729	26 838	26 571
Mules	5 544	7 026	8 702	7 689	5 406
Camels	15 596	16 819	17 998	17 151	21 157
Llamas	1 385	1 177	1 095	1 257	1 626
TOTAL*	20 681 065	24 390 000	26 390 007	24 277 132	27 074 954

MANURE LEFT ON PASTURE (TONNES OF N)					
LIVESTOCK CATEGORY	1970	1980	1990	2000	2010
Cattle	27 976 137	32 516 803	34 586 406	37 271 083	42 740 399
Buffaloes	2 027 774	2 278 067	2 776 387	3 018 013	3 425 576
Sheep	14 159 789	14 240 441	15 706 286	13 325 689	13 383 799
Goats	5 517 673	6 778 669	8 604 651	10 939 497	13 879 360
Swine	-	-	-	-	-
Chickens	580 734	859 477	1 440 554	2 242 624	3 310 614
Ducks	84 450	119 668	192 721	331 240	426 165
Turkeys	19 572	31 723	40 847	71 947	101 851
Horses	2 346 750	2 296 773	2 355 164	2 229 732	2 306 283
Asses	806 353	813 026	917 553	873 901	911 522
Mules	254 767	269 686	311 609	272 129	221 054
Camels	592 310	642 029	710 347	726 627	953 244
Llamas	137 096	116 556	108 450	124 487	161 010
TOTAL*	54 503 405	60 962 919	67 750 976	71 426 968	81 820 879

SYNTHETIC FERTILIZERS (TONNES OF N)					
TOTAL	1970	1980	1990	2000	2010
	31 756 154	60 775 733	77 175 240	80 786 730	94 855 671

* Values in the tables may not add up due to rounding

ANNEX II

N inputs from Manure (IPCC Tier 1 and Tier 2) by Region, Year 2005

CATTLE	APPLIED TO SOILS (TONNES OF N)		LEFT ON PASTURE (TONNES OF N)		TOTAL APPLIED (TONNES OF N)	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Africa	405 995	2 726 337	10 342 098	3 657 411	10 748 093	6 383 747
Europe	4 447 371	3 172 452	1 999 613	2 090 190	6 446 984	5 262 641
Americas	2 610 538	4 264 445	19 048 424	16 821 098	21 658 962	21 085 544
Asia	3 619 831	6 393 578	7 123 131	4 228 631	10 742 962	10 622 209
Oceania	156 618	24 637	2 143 126	1 853 285	2 299 744	1 877 922
WORLD*	11 240 354	16 581 449	40 656 391	28 650 615	51 896 745	45 232 063

BUFFALOES	APPLIED TO SOILS (TONNES OF N)		LEFT ON PASTURE (TONNES OF N)		TOTAL APPLIED (TONNES OF N)	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Africa	4 569	40 067	165 536	64 690	170 105	104 757
Europe	8 001	6 740	325	644	8 326	7 384
Americas	524	6 851	51 855	49 942	52 379	56 793
Asia	1 608 761	2 012 507	3 023 488	2 432 580	4 632 248	4 445 087
Oceania	-	-	9	-	9	-
WORLD*	1 621 854	2 066 165	3 241 212	2 547 856	4 863 067	4 614 021

SHEEP	APPLIED TO SOILS (TONNES OF N)		LEFT ON PASTURE (TONNES OF N)		TOTAL APPLIED (TONNES OF N)	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Africa	63 665	190 298	3 274 185	614 960	3 337 850	805 258
Europe	333 045	128 328	1 755 388	333 600	2 088 434	461 928
Americas	6 284	71 383	1 044 999	351 296	1 051 282	422 679
Asia	792 793	454 311	4 827 541	1 156 480	5 620 334	1 610 791
Oceania	-	-	2 820 802	888 576	2 820 802	888 576
WORLD*	1 195 787	844 320	13 722 916	3 344 912	14 918 702	4 189 232

GOATS	APPLIED TO SOILS (TONNES OF N)		LEFT ON PASTURE (TONNES OF N)		TOTAL APPLIED (TONNES OF N)	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Africa	84 155	66 103	4 165 651	603 430	4 249 805	669 533
Europe	16 763	27 419	312 593	66 528	329 356	93 948
Americas	6 628	17 828	534 675	110 392	541 304	128 220
Asia	386 226	613 777	7 757 932	756 271	8 144 157	1 370 048
Oceania	-	-	75 536	19 032	75 536	19 032
WORLD*	493 771	725 127	12 846 387	1 555 654	13 340 158	2 280 781

* Values in the tables may not add up due to rounding

SWINE	APPLIED TO SOILS (TONNES OF N)		LEFT ON PASTURE (TONNES OF N)		TOTAL APPLIED (TONNES OF N)	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Africa	352 560	117 209	-	8 721	352 560	125 930
Europe	1 533 748	1 917 852	-	15 330	1 533 748	1 933 182
Americas	1 388 017	1 087 285	-	26 845	1 388 017	1 114 130
Asia	1 731 361	3 512 478	-	195 170	1 731 361	3 707 647
Oceania	34 509	52 930	-	3 415	34 509	56 345
WORLD*	5 040 194	6 687 754	-	249 481	5 040 194	6 937 235

CHICKENS	APPLIED TO SOILS (TONNES OF N)		LEFT ON PASTURE (TONNES OF N)		TOTAL APPLIED (TONNES OF N)	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Africa	105 228	243 641	448 603	235 668	553 831	479 309
Europe	808 704	480 218	12 870	110 125	821 575	590 344
Americas	1 415 792	1 538 031	451 475	288 705	1 867 267	1 826 737
Asia	2 068 410	1 837 388	1 835 882	1 404 563	3 904 291	3 241 951
Oceania	41 387	36 373	1 280	3 774	42 667	40 146
WORLD	4 439 521	4 135 651	2 750 110	2 042 836	7 189 631	6 178 487

WORLD	APPLIED TO SOILS (TONNES OF N)		LEFT ON PASTURE (TONNES OF N)		TOTAL APPLIED (TONNES OF N)	
	Tier 1	Tier 2	Tier 1	Tier 2	Tier 1	Tier 2
Cattle	11 240 354	16 581 449	40 656 391	28 650 615	51 896 745	45 232 063
Buffaloes	1 621 854	2 066 165	3 241 212	2 547 856	4 863 067	4 614 021
Sheep	1 195 787	844 320	13 722 916	3 344 912	14 918 702	4 189 232
Goats	493 771	725 127	12 846 387	1 555 654	13 340 158	2 280 781
Swine	5 040 194	6 687 754	-	249 481	5 040 194	6 937 235
Chickens	4 439 521	4 135 651	2 750 110	2 042 836	7 189 631	6 178 487
TOTAL[11]	24 031 481	31 040 466	73 217 017	38 391 354	97 248 498	69 431 820

[11] These totals refers only to the N input from the selected livestock species. The N input from the manure produced by all the livestock category estimated using the Tier 1 methodology is shown in Annex I

* Values in the tables may not add up due to rounding

ANNEX III

Coefficients used to estimate N input from livestock manure

A. Annual Nitrogen Excretion rates (Nex)

Regional values extracted from the results of the Tier 1 approach in FAOSTAT, and country-specific values extracted from the Tier 2-GLEAM approach

	KG N ANIMAL^{-1} YEAR^{-1}					
	Cattle	Buffalo	Goats	Sheep	Swine	Chicken
AFRICA						
Tier 1	**60.23/ 39.78**[a]	**44.38**	**19.25/ 15.00**[b]	**20.71/ 11.96**[b]	**16.05/ 5.62**[c]	**0.36/ 0.54**[d]
Algeria	23.00		2.42	3.23	12.56	0.63
Angola	32.23		2.85	3.41	8.02	0.39
Benin	32.01		4.34	3.11	12.05	0.54
Botswana	26.66		3.59	3.58	8.91	0.65
Burkina Faso	35.11		2.56	3.26	7.59	0.50
Burundi	26.43		2.11	2.54	6.01	0.38
Cabo Verde					14.26	
Cameroon	30.59		2.57	3.45	8.94	0.50
Central African Republic	34.80		2.70	3.69	10.49	0.57
Chad	33.70		3.21	3.42	11.75	0.56
Comoros	25.95		1.21	1.47		0.72
Congo	29.01		2.71	3.43	7.97	0.45
Côte d'Ivoire	33.55		2.52	2.77	12.78	0.65
Democratic Republic of the Congo	26.26		2.71	3.16	6.05	0.33
Djibouti	27.92		2.64	2.79		
Egypt	24.45	32.82	1.69	2.39	8.17	0.44
Equatorial Guinea	24.33		2.60	3.19	12.19	0.77
Eritrea	28.23		2.66	3.23		0.53
Ethiopia	31.15		2.65	2.77	7.56	0.47
Gabon	32.30		2.64	3.17	6.21	0.35
Gambia	31.02		2.34	3.15	8.57	0.42
Ghana	32.57		2.39	2.71	10.25	0.52
Guinea	32.39		2.67	3.19	15.01	0.72
Guinea-Bissau	29.30		2.10	1.69	14.53	0.66

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a, b, c, d Refer to page 52 footnotes

	KG N ANIMAL^{-1} YEAR^{-1}					
	Cattle	Buffalo	Goats	Sheep	Swine	Chicken
Kenya	35.48		3.55	3.20	7.77	0.50
Lesotho	23.95		3.24	2.53	6.60	0.47
Liberia	30.13		2.41	2.59	9.86	0.52
Libya	27.86		2.35	2.82		0.44
Madagascar	34.12		3.12	3.37	7.84	0.47
Malawi	30.00		2.49	3.02	6.40	0.40
Mali	33.04		2.63	3.35	10.95	0.55
Mauritania	31.97		3.08	3.10	8.04	0.40
Mauritius					5.43	
Mayotte	13.61			1.04		
Morocco	23.78		1.85	2.73	10.18	0.58
Mozambique	36.63		3.44	3.44	8.65	0.53
Namibia	26.47		3.42	2.58	8.48	0.47
Niger	30.97		2.65	3.27	9.85	0.64
Nigeria	28.41		2.08	2.67	10.12	0.51
Réunion					14.67	
Rwanda	28.43		2.26	2.23	6.44	0.46
Saint Helena, Ascension and Tristan da Cunha	14.98		1.21	1.43		
Sao Tome and Principe	26.76		0.95	1.44	16.71	0.74
Senegal	32.22		2.03	3.22	8.54	0.45
Seychelles					3.27	0.27
Sierra Leone	32.56		2.48	2.54	7.80	0.45
Somalia	31.24		2.24	2.93	6.89	0.40
South Africa	41.82		3.80	3.75	8.50	0.45
Sudan	31.17		3.57	4.13		0.46
Swaziland	31.04		3.61	3.08	6.15	0.40
Togo	31.10		2.22	2.75	8.05	0.41
Tunisia	25.82		2.15	2.84	16.64	0.79
Uganda	37.25		2.41	2.92	6.31	0.50
United Republic of Tanzania	37.47		3.07	3.28	8.90	0.50
Western Sahara	17.04			2.03		
Zambia	32.58		3.09	3.69	8.62	0.51
Zimbabwe	33.05		3.80	4.94	9.74	0.55
ASIA						
Tier 1	60.04/ 39.58[a]	44.38	19.25/ 15.00[b]	20.71/ 11.96[b]	4.29/ 2.45[c]	0.36/ 0.54[d]
Brunei Darussalam	27.56	33.03	1.82	1.47	21.69	0.94
Cambodia	29.81	31.44		2.45	11.34	0.52
China, Hong Kong SAR	25.62	33.97		1.31	15.22	
China, mainland	39.95	31.36	2.51	4.03	14.47	0.56
Democratic People's Republic of Korea	29.48		2.73	3.27	17.29	0.63

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[a, b, c, d] Refer to page 52 footnotes

	KG N ANIMAL^{-1} YEAR^{-1}					
	Cattle	Buffalo	Goats	Sheep	Swine	Chicken
Indonesia	30.64	31.76	4.23	3.25	17.89	0.81
Iran (Islamic Republic of)	34.02	42.34	3.37	3.36		0.54
Japan	55.56		2.78	3.39	11.71	0.49
Kazakhstan	54.94	35.09	3.11	4.57	14.34	0.53
Kyrgyzstan	53.53		3.02	4.42	16.29	0.62
Lao People's Democratic Republic	34.12	31.48	3.42	2.38	10.47	0.51
Malaysia	24.72	30.15	4.21	2.90	24.24	0.67
Mongolia	30.68		4.03	4.33	12.75	0.67
Myanmar	29.69	33.91	3.51	3.01	10.88	0.55
Philippines	24.78	27.56	2.71	1.92	19.24	0.62
Republic of Korea	46.36		2.71	3.51	15.29	0.56
Singapore	29.02		2.37	3.68	0.00	0.00
Tajikistan	51.44		3.28	5.00	22.68	0.90
Thailand	24.59	26.67	1.70	2.49	14.68	0.57
Timor-Leste	32.05	33.46	3.59	3.17	17.52	0.70
Turkmenistan	51.76		2.99	5.26	22.56	0.61
Uzbekistan	53.38		2.88	4.72	24.27	0.68
Viet Nam	29.10	29.45	3.17	2.79	13.09	0.54

EASTERN EUROPE						
Tier 1	70.26/ 49.95[a]	44.38	17.99/ 14.02[b]	15.93/ 9.20[b]	10.04/ 30.22[c]	0.36/ 0.54[d]
Albania	42.47		5.09	4.81	18.86	0.70
Armenia	44.56		4.17	4.28	12.93	0.48
Azerbaijan	46.84	48.59	3.06	3.72	15.60	0.53
Belarus	47.05		7.21	4.07	19.51	0.88
Bosnia and Herzegovina	42.55	52.67	4.72	4.81	16.51	0.68
Bulgaria	48.46	52.76	4.83	4.34	19.35	0.59
Croatia	44.94		5.71	4.80	18.34	0.59
Cyprus	37.69		3.66	4.02	19.04	0.56
Czech Republic	55.56		7.35	4.47	18.93	0.50
Estonia	64.12		6.00	4.68	19.11	0.59
Georgia	42.12	45.75	3.19	4.04	14.35	0.53
Hungary	59.86		4.52	4.10	16.36	0.49
Latvia	61.34		6.61	4.44	17.44	0.62
Lithuania	62.07		6.65	4.53	17.93	0.64
Montenegro	42.77		4.72	4.78	21.65	0.56
Poland	48.68		5.36	4.24	17.45	0.46
Republic of Moldova	47.40		4.49	4.24	19.46	0.79
Romania	44.64	45.57	4.26	4.52	15.51	0.62
Russian Federation	44.95	45.50	4.86	4.07	19.26	0.58
Serbia	42.98		4.72	4.78	18.57	0.65
Slovakia	56.47		5.03	4.21	19.14	0.51

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[a, b, c, d] Refer to page 52 footnotes

	KG N ANIMAL^{-1} YEAR^{-1}					
	Cattle	Buffalo	Goats	Sheep	Swine	Chicken
Slovenia	48.69		5.08	4.70	16.46	0.41
The former Yugoslav Republic of Macedonia	43.12			4.81	17.30	0.60
Turkey	34.41	39.06	3.47	4.01	17.81	0.55
Ukraine	49.63		6.14	4.54	19.80	0.65
INDIAN SUBCONTINENT						
Tier 1	**47.18/ 13.65[a]**	**34.46**	**19.25/ 15.00[b]**	**20.71/ 11.96[b]**	**4.29/ 2.45[c]**	**0.36/ 0.54[d]**
Afghanistan	35.38		3.95	4.24		0.52
Bangladesh	31.97	32.44	2.96	2.52	12.11	0.36
Bhutan	33.54	41.14	3.02	3.81	12.61	0.45
India	34.47	40.57	2.71	2.75	15.41	0.68
Nepal	29.99	38.98	2.67	4.28	13.06	0.42
Pakistan	34.94	43.33	2.71	3.31		0.54
Sri Lanka	28.46	36.96	3.52	2.31	22.13	0.58
LATIN AMERICA						
Tier 1	**70.08/ 40.08[a]**	**44.38**	**19.25/ 15.00[b]**	**20.71/ 11.96[b]**	**16.05/ 5.62[c]**	**0.36/ 0.54[d]**
Antigua and Barbuda					20.42	
Argentina	46.78	54.07	4.23	4.87	25.05	0.63
Bahamas	38.64		3.79	4.43	21.31	0.47
Barbados					7.88	
Belize	34.95		3.25	4.52		0.54
Bolivia (Plurinational State of)	46.40		3.69	5.06	20.69	0.83
Brazil	43.50	52.75	3.05	5.00	16.74	0.69
British Virgin Islands					12.76	0.00
Cayman Islands					19.55	
Chile	45.96		3.74	5.70	21.53	0.58
Colombia	44.26	52.51	3.37	4.84	14.36	0.57
Costa Rica	44.57		2.92	4.44	15.46	0.63
Cuba	27.63		2.88	3.27	12.55	0.47
Dominica	39.94		3.65	5.01	23.39	0.80
Dominican Republic	32.83		3.00	4.10	16.37	0.26
Ecuador	43.14		3.26	3.82	16.90	0.81
El Salvador	35.91		2.70	3.93	14.34	0.52
Falkland Islands (Malvinas)					20.44	
French Guiana	35.54		3.42	4.91	12.62	0.44
Grenada					24.66	0.63
Guadeloupe	33.43		1.31	1.86	11.85	0.63
Guatemala	35.33	46.57	3.23	4.31	14.07	0.55
Guyana	42.23		3.19	4.67	14.88	0.62
Haiti	33.02		2.50	3.81	13.37	0.51

[a, b, c, d] Refer to page 52 footnotes

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	KG N ANIMAL^{-1} YEAR^{-1}					
	Cattle	Buffalo	Goats	Sheep	Swine	Chicken
Honduras	40.53		3.18	4.50	16.12	0.64
Jamaica	32.15		4.44	4.33	18.13	0.71
Martinique	34.99		2.93	4.13	11.92	0.53
Mexico	41.87		3.30	4.24	12.91	0.54
Montserrat					25.36	
Netherlands Antilles	36.50		3.31	4.50	18.84	0.35
Nicaragua	45.01		3.16	4.12	13.28	0.52
Panama	35.65		3.10	4.78	14.41	0.55
Paraguay	42.22		3.38	4.87	27.13	0.68
Peru	46.05		3.49	4.10	14.05	0.56
Puerto Rico	34.62		3.29	4.46	13.90	0.69
Saint Kitts and Nevis					6.98	
Saint Lucia	35.13		2.48	3.37	19.79	0.27
Saint Vincent and the Grenadines	29.29		1.63	2.85	14.32	0.58
Suriname	36.69		3.25	4.76	14.84	0.51
Trinidad and Tobago					13.43	
United States Virgin Islands					12.66	
Uruguay	42.54		3.52	5.82	15.21	0.54
Venezuela (Bolivarian Republic of)	44.87	53.72	3.54	5.02	14.02	0.55
MIDDLE EAST						
Tier 1	70.26/ 49.88[a]	44.38	19.25/ 15.00[b]	20.71/ 11.96[b]	16.05/ 5.62[c]	0.36/ 0.54[d]
Bahrain	34.29		2.80	3.66		0.31
Iraq	30.88		3.31	3.81		0.47
Israel	73.85		3.79	4.34	17.71	0.54
Jordan	37.50		3.16	4.04		0.71
Kuwait	34.52		3.44	3.96		0.39
Lebanon	36.50		3.75	4.28	21.17	0.72
Occupied Palestinian Territory	30.81		3.65	4.19		0.51
Oman	30.29		3.95	4.30		0.38
Qatar	31.37		3.70	4.31		0.11
Saudi Arabia	42.11		3.34	3.97	0.00	0.47
Syrian Arab Republic	31.07	45.13	2.89	3.74		0.52
United Arab Emirates	30.75		3.65	4.31		0.44
Yemen	31.54		3.06	3.86		0.50
NORTHERN AMERICA						
Tier 1	97.00/ 44.02[a]	44.38	6.32/ 4.93[b]	7.44/ 4.29[b]	7.05/ 17.34[c]	0.36/ 0.55[d]
Canada	52.30	58.10	5.23	6.47	13.04	0.72
Saint Pierre and Miquelon						0.85
United States of America	61.37		6.21	6.48	10.70	0.74

[a, b, c, d] Refer to page 52 footnotes

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	KG N ANIMAL^{-1} YEAR^{-1}					
	Cattle	Buffalo	Goats	Sheep	Swine	Chicken
OCEANIA						
Tier 1	**80.30/ 60.23**[a]	**44.38**	**19.95/ 15.55**[b]	**20.00/ 11.55**[b]	**8.71/ 30.22**[c]	**0.36/ 0.54**[d]
American Samoa					18.77	
Australia	48.24		5.34	6.30	12.25	0.69
Cook Islands					19.18	
Fiji					25.19	
French Polynesia					23.57	
Guam					18.52	
Kiribati					17.06	
Micronesia (Federated States of)					18.32	
New Caledonia	41.57		4.50	5.43	25.13	0.37
New Zealand	55.01		6.02	6.30	12.30	0.70
Niue					24.59	
Papua New Guinea	41.54		4.39	5.43	28.10	0.78
Samoa					26.16	
Solomon Islands	41.54				25.17	0.39
Tonga					19.82	
Tuvalu					26.36	
Vanuatu	41.54		4.50		29.81	0.78

	Cattle	Buffalo	Goats	Sheep	Swine	Chicken
WESTERN EUROPE						
Tier 1	**105.12/ 50.59**[a]	**44.38**	**17.99/ 14.02**[b]	**15.05/ 8.69**[b]	**9.31/ 30.35**[c]	**0.36/ 0.63**[d]
Austria	62.26		6.59	5.59	20.84	0.47
Belgium	60.96		4.14	5.35	13.31	0.47
Denmark	60.13			5.43	20.19	0.62
Finland	67.33		4.11	4.17	19.01	0.55
France	59.01		7.57	5.57	14.68	0.58
Germany	66.81		6.02	5.24	20.73	0.43
Greece	49.79		5.00	5.15	19.01	0.47
Iceland					19.01	0.63
Ireland	58.95		5.06	4.61	18.65	0.63
Italy	52.28	58.81	4.56	5.25	17.83	0.48
Liechtenstein	58.67		4.19	5.39	16.87	
Luxembourg	60.92		4.38	6.93	18.95	0.53
Malta	49.73		6.70	5.22	17.17	0.48
Netherlands	65.18		3.66	5.14	16.49	0.47
Norway	62.31		6.90	4.48	19.01	0.66
Portugal	54.17		5.31	4.94	21.43	0.46
Spain	47.61		6.80	4.87	17.62	0.46
Sweden	68.17			4.41	20.22	0.58
Switzerland	63.40		6.57	5.49	19.00	0.60
United Kingdom	61.60				18.73	0.64

[a] N-excretion rates for Dairy cows / Other cattle
[b] N-excretion rates for Developed Countries / Developing Countries
[c] N excretion rates for Market swine / Breeding swine
[d] N excretion rates for Layers / Broilers

B. Manure uses

Regional values extracted from the results of the Tier 1 approach in FAOSTAT, and country-specific values extracted from the Tier 2-GLEAM approach

	(% OF TOTAL MANURE AVAILABLE)																	
	MANURE BURNT FOR FUEL						MANURE LEFT ON PASTURE						STORED					
	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken
AFRICA																		
Tier 1	**6/3[a]**	**0**	**0**	**0**	**0**	**0**	**83/95[a]**	**96**	**99**	**99**	**0**	**81**	**10/2[a]**	**4**	**2**	**2**	**100**	**19**
Algeria	0	0	0	0	0	0	45	0	50	50	4	37	55	100	50	50	96	63
Angola	0	0	0	0	0	0	63	0	92	89	5	40	37	100	8	11	95	60
Benin	0	0	0	0	0	0	57	0	95	95	5	43	43	100	5	5	95	57
Botswana	20	0	0	0	0	0	54	0	95	95	5	43	26	100	5	5	95	57
Burkina Faso	0	0	0	0	0	0	45	0	95	95	4	34	55	100	5	5	96	66
Burundi	0	0	0	0	0	0	29	0	61	75	4	37	71	100	39	25	96	63
Cabo Verde	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Cameroon	0	0	0	0	0	0	54	0	90	93	5	46	46	100	10	7	95	54
Central African Republic	0	0	0	0	0	0	72	0	95	95	5	48	28	100	5	5	95	52
Chad	0	0	0	0	0	0	56	0	95	95	5	44	44	100	5	5	95	56
Comoros	0	0	0	0	0	0	26	0	89	88	0	41	74	100	11	12	100	59
Congo	0	0	0	0	0	0	57	0	95	95	4	35	43	100	5	5	96	65
Côte d'Ivoire	0	0	0	0	0	0	61	0	95	95	5	45	39	100	5	5	95	55
Democratic Republic of the Congo	0	0	0	0	0	0	44	0	89	87	4	50	56	100	11	13	96	50
Djibouti	20	0	0	0	0	0	57	0	50	50	0	0	23	100	50	50	100	100
Egypt	0	0	0	0	0	0	45	51	50	50	4	16	55	49	50	50	96	84
Equatorial Guinea	0	0	0	0	0	0	43	0	95	95	5	48	57	100	5	5	95	52
Eritrea	18	0	0	0	0	0	41	0	85	92	0	37	41	100	15	8	100	63
Ethiopia	5	0	0	0	0	0	31	0	77	65	4	37	64	100	23	35	96	63
Gabon	0	0	0	0	0	0	50	0	95	95	4	39	50	100	5	5	96	61
Gambia	0	0	0	0	0	0	41	0	95	95	5	39	59	100	5	5	95	61
Ghana	0	0	0	0	0	0	52	0	95	95	4	43	48	100	5	5	96	57
Guinea	0	0	0	0	0	0	53	0	95	95	5	46	47	100	5	5	95	54
Guinea-Bissau	0	0	0	0	0	0	52	0	95	95	5	45	48	100	5	5	95	55
Kenya	8	0	0	0	0	0	37	0	84	78	4	35	55	100	16	22	96	65
Lesotho	0	0	0	0	0	0	25	0	50	50	4	42	74	100	50	50	96	58
Liberia	0	0	0	0	0	0	40	0	95	94	4	39	60	100	5	6	96	61
Libya	0	0	0	0	0	0	66	0	50	50	0	21	34	100	50	50	100	79
Madagascar	15	0	0	0	0	0	48	0	95	94	4	40	37	100	5	6	96	60
Malawi	18	0	0	0	0	0	33	0	92	92	4	36	48	100	8	8	96	64
Mali	0	0	0	0	0	0	53	0	95	95	5	45	47	100	5	5	95	55
Mauritania	0	0	0	0	0	0	61	0	50	50	5	35	39	100	50	50	95	65
Mauritius	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100

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[a] N-excretion rates for Dairy cows / Other cattle

	(% OF TOTAL MANURE AVAILABLE)																	
	MANURE BURNT FOR FUEL						MANURE LEFT ON PASTURE						STORED					
	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken
Mayotte	0	0	0	0	0	0	40	0	0	95	0	0	60	100	100	5	100	100
Morocco	0	0	0	0	0	0	42	0	50	50	4	33	58	100	50	50	96	67
Mozambique	19	0	0	0	0	0	40	0	94	95	4	48	41	100	6	5	96	52
Namibia	20	0	0	0	0	0	49	0	95	95	4	42	31	100	5	5	96	58
Niger	0	0	0	0	0	0	61	0	94	95	5	45	39	100	6	5	95	55
Nigeria	0	0	0	0	0	0	42	0	95	95	3	26	58	100	5	5	97	74
Réunion	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Rwanda	0	0	0	0	0	0	31	0	65	55	4	35	69	100	35	45	96	65
Saint Helena, Ascension and Tristan da Cunha	0	0	0	0	0	0	25	0	50	50	0	0	75	100	50	50	100	100
Sao Tome and Principe	0	0	0	0	0	0	40	0	88	95	5	41	60	100	12	5	95	59
Senegal	0	0	0	0	0	0	46	0	95	95	4	42	54	100	5	5	96	58
Seychelles	0	0	0	0	0	0	0	0	0	0	4	9	100	100	100	100	96	91
Sierra Leone	0	0	0	0	0	0	41	0	95	95	4	35	59	100	5	5	96	65
Somalia	20	0	0	0	0	0	53	0	50	50	4	40	27	100	50	50	96	60
South Africa	12	0	0	0	0	0	38	0	87	80	4	14	50	100	13	20	96	86
Sudan	0	0	0	0	0	0	56	0	50	50	0	40	44	100	50	50	100	60
Swaziland	14	0	0	0	0	0	31	0	85	76	4	42	55	100	15	24	96	58
Togo	0	0	0	0	0	0	45	0	95	95	4	41	55	100	5	5	96	59
Tunisia	0	0	0	0	0	0	43	0	50	50	5	42	57	100	50	50	95	58
Uganda	1	0	0	0	0	0	39	0	82	84	4	40	60	100	18	16	96	60
United Republic of Tanzania	13	0	0	0	0	0	37	0	91	89	4	37	49	100	9	11	96	63
Western Sahara	0	0	0	0	0	0	75	0	0	50	0	0	25	100	100	50	100	100
Zambia	19	0	0	0	0	0	50	0	93	95	4	36	31	100	7	5	96	64
Zimbabwe	19	0	0	0	0	0	39	0	94	89	4	37	43	100	6	11	96	63

ASIA																		
Tier 1	**7/2[a]**	**5**	**0**	**0**	**0**	**1**	**20/50[a]**	**50**	**95**	**83**	**0**	**44**	**73/48[a]**	**45**	**5**	**17**	**101**	**55**
Brunei Darussalam	0	0	0	0	0	0	27	25	50	95	2	48	73	75	50	5	98	52
Cambodia	0	0	0	0	0	0	32	25	0	95	4	41	68	75	100	5	96	59
China, Hong Kong SAR	0	0	0	0	0	0	25	25	0	65	0	0	75	75	100	35	100	100
China, mainland	1	2	0	0	0	0	26	29	50	56	3	23	73	69	50	44	97	77
Democratic People's Republic of Korea	0	0	0	0	0	0	25	0	50	50	5	21	75	100	50	50	95	79
Indonesia	0	0	0	0	0	0	28	25	50	92	2	47	72	75	50	8	98	53
Iran (Islamic Republic of)	20	18	0	0	0	0	53	29	50	50	0	22	27	52	50	50	100	78
Japan	0	0	0	0	0	0	72	0	95	83	0	0	28	100	5	17	100	100
Kazakhstan	16	16	0	0	0	0	33	34	50	50	2	25	50	50	50	50	98	75

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[a] N-excretion rates for Dairy cows / Other cattle

	(% OF TOTAL MANURE AVAILABLE)																	
	MANURE BURNT FOR FUEL						MANURE LEFT ON PASTURE						STORED					
	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken
Kyrgyzstan	17	0	0	0	0	0	36	0	50	51	2	31	48	100	50	49	98	69
Lao People's Democratic Republic	0	0	0	0	0	0	49	25	50	95	4	45	51	75	50	5	96	55
Malaysia	0	0	0	0	0	0	27	25	50	95	3	24	73	75	50	5	97	76
Mongolia	14	0	0	0	0	0	36	0	50	50	2	36	50	100	50	50	98	64
Myanmar	0	0	0	0	0	0	34	43	49	90	4	19	66	57	51	10	96	81
Philippines	0	0	0	0	0	0	25	25	50	94	2	24	75	75	50	6	98	76
Republic of Korea	0	0	0	0	0	0	25	0	50	52	1	0	75	100	50	48	99	100
Singapore	0	0	0	0	0	0	25	0	46	50	0	0	75	100	54	50	100	100
Tajikistan	15	0	0	0	0	0	47	0	50	84	3	44	39	100	50	16	97	56
Thailand	0	0	0	0	0	0	27	26	50	95	0	34	73	74	50	5	100	66
Timor-Leste	0	0	0	0	0	0	35	25	50	87	2	50	65	75	50	13	98	50
Turkmenistan	16	0	0	0	0	0	48	0	50	82	3	24	36	100	50	18	97	76
Uzbekistan	13	0	0	0	0	0	32	0	49	74	3	31	56	100	51	26	97	69
Viet Nam	0	0	0	0	0	0	28	26	49	95	2	33	72	74	51	5	98	67
EASTERN EUROPE																		
Tier 1	**0**	**0**	**0**	**0**	**0**	**0**	**18/ 20**[a]	**29**	**92**	**73**	**0**	**1**	**82/ 80**[a]	**71**	**8**	**27**	**100**	**99**
Albania	0	0	0	0	0	0	13	0	72	79	2	29	87	100	28	21	98	71
Armenia	4	0	0	0	0	0	33	0	50	76	2	23	64	100	50	24	98	77
Azerbaijan	1	10	0	0	0	0	26	50	49	74	2	29	73	39	51	26	98	71
Belarus	0	0	0	0	0	0	24	0	24	24	1	29	76	100	76	76	99	71
Bosnia and Herzegovina	0	0	0	0	0	0	12	12	72	79	2	39	88	88	28	21	98	61
Bulgaria	0	0	0	0	0	0	13	13	49	45	2	21	87	87	51	55	98	79
Croatia	0	0	0	0	0	0	12	0	72	79	2	21	88	100	28	21	98	79
Cyprus	3	0	0	0	0	0	33	0	50	94	3	9	64	100	50	6	97	91
Czech Republic	0	0	0	0	0	0	11	0	49	45	0	0	89	100	51	55	100	100
Estonia	0	0	0	0	0	0	0	0	100	100	0	0	100	100	0	0	100	100
Georgia	2	6	0	0	0	0	29	40	50	57	2	29	69	54	50	43	98	71
Hungary	0	0	0	0	0	0	8	0	40	40	2	0	92	100	60	60	98	100
Latvia	0	0	0	0	0	0	41	0	43	42	2	9	59	100	57	58	98	91
Lithuania	0	0	0	0	0	0	40	0	60	60	2	11	60	100	40	40	98	89
Montenegro	0	0	0	0	0	0	12	0	72	79	0	15	88	100	28	21	100	85
Poland	0	0	0	0	0	0	12	0	10	50	0	0	88	100	90	50	100	100
Republic of Moldova	0	0	0	0	0	0	12	0	49	0	0	37	88	100	51	100	100	63
Romania	0	0	0	0	0	0	13	13	92	73	2	26	87	87	8	27	98	74
Russian Federation	0	0	0	0	0	0	22	28	18	18	2	23	78	72	82	82	98	77
Serbia	0	0	0	0	0	0	12	0	72	79	1	25	88	100	28	21	99	75
Slovakia	0	0	0	0	0	0	12	0	49	45	0	0	88	100	51	55	100	100
Slovenia	0	0	0	0	0	0	12	0	46	68	2	0	88	100	54	32	98	100

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[a] N-excretion rates for Dairy cows / Other cattle

	(% OF TOTAL MANURE AVAILABLE)																	
	MANURE BURNT FOR FUEL						MANURE LEFT ON PASTURE						STORED					
	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken
The former Yugoslav Republic of Macedonia	0	0	0	0	0	0	12	0	0	79	2	24	88	100	100	21	98	76
Turkey	4	13	0	0	0	0	34	57	50	89	0	0	62	29	50	11	100	100
Ukraine	0	0	0	0	0	0	22	0	100	100	3	23	78	100	0	0	97	77
INDIAN SUBCONTINENT																		
Tier 1	**51/ 53[a]**	**55**	**0**	**0**	**0**	**1**	**27/ 22[a]**	**19**	**95**	**83**	**0**	**44**	**21/ 26[a]**	**26**	**5**	**17**	**100**	**55**
Afghanistan	20	0	0	0	0	0	42	0	50	91	0	28	38	100	50	9	100	72
Bangladesh	20	20	0	0	0	0	20	22	48	95	5	38	60	58	52	5	95	62
Bhutan	20	20	0	0	0	0	21	20	50	52	2	36	59	60	50	48	98	64
India	20	20	0	0	0	0	20	40	49	94	3	18	60	40	51	6	97	82
Nepal	20	20	0	0	0	0	20	28	50	64	2	37	60	52	50	36	98	63
Pakistan	20	20	0	0	0	0	25	33	49	92	0	26	55	48	51	8	100	74
Sri Lanka	20	20	0	0	0	0	20	20	49	94	3	10	60	60	51	6	97	90
LATIN AMERICA																		
Tier 1	**0**	**0**	**0**	**0**	**0**	**0**	**36/ 99[a]**	**99**	**99**	**100**	**0**	**42**	**64/ 1[a]**	**1**	**1**	**0**	**101**	**58**
Antigua and Barbuda	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Argentina	0	0	0	0	0	0	91	81	94	90	3	12	9	19	6	10	97	88
Bahamas	0	0	0	0	0	0	60	0	89	92	3	35	40	100	11	8	97	65
Barbados	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Belize	0	0	0	0	0	0	89	0	94	94	3	12	11	100	6	6	97	88
Bolivia (Plurinational State of)	0	0	0	0	0	0	84	0	83	78	3	39	16	100	17	22	97	61
Brazil	0	0	0	0	0	0	84	81	94	95	2	19	16	19	6	5	98	81
British Virgin Islands	0	0	0	0	0	0	0	0	0	0	1	0	100	100	100	100	99	100
Cayman Islands	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100
Chile	0	0	0	0	0	0	53	0	92	68	0	0	47	100	8	32	100	100
Colombia	0	0	0	0	0	0	69	73	87	88	4	19	31	27	13	12	96	81
Costa Rica	0	0	0	0	0	0	47	0	78	79	3	23	53	100	22	21	97	77
Cuba	0	0	0	0	0	0	85	0	92	94	3	27	15	100	8	6	97	73
Dominica	0	0	0	0	0	0	75	0	95	95	3	39	25	100	5	5	97	61
Dominican Republic	0	0	0	0	0	0	70	0	90	83	3	0	30	100	10	17	97	100
Ecuador	0	0	0	0	0	0	58	0	80	78	3	43	42	100	20	22	97	57
El Salvador	0	0	0	0	0	0	66	0	92	93	3	10	34	100	8	7	97	90
Falkland Islands (Malvinas)	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
French Guiana	0	0	0	0	0	0	89	0	95	95	3	26	11	100	5	5	97	74
Grenada	0	0	0	0	0	0	0	0	0	0	3	28	100	100	100	100	97	72
Guadeloupe	0	0	0	0	0	0	95	0	95	95	3	30	5	100	5	5	97	70

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[a] N-excretion rates for Dairy cows / Other cattle

	(% OF TOTAL MANURE AVAILABLE)																	
	MANURE BURNT FOR FUEL						MANURE LEFT ON PASTURE						STORED					
	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken
Guatemala	0	0	0	0	0	0	73	79	80	79	3	21	27	21	20	21	97	79
Guyana	0	0	0	0	0	0	65	0	93	95	3	47	35	100	7	5	97	53
Haiti	0	0	0	0	0	0	80	0	85	93	3	37	20	100	15	7	97	63
Honduras	0	0	0	0	0	0	68	0	90	0	3	27	32	100	10	100	97	73
Jamaica	0	0	0	0	0	0	91	0	94	95	3	22	9	100	6	5	97	78
Martinique	0	0	0	0	0	0	84	0	95	95	3	29	16	100	5	5	97	71
Mexico	0	0	0	0	0	0	78	0	80	72	1	0	22	100	20	28	99	100
Montserrat	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Netherlands Antilles	0	0	0	0	0	0	50	0	95	95	3	13	50	100	5	5	97	87
Nicaragua	0	0	0	0	0	0	65	0	91	83	3	23	35	100	9	17	97	77
Panama	0	0	0	0	0	0	82	0	92	93	3	16	18	100	8	7	97	84
Paraguay	0	0	0	0	0	0	93	0	94	95	3	25	7	100	6	5	97	75
Peru	20	0	0	0	0	0	38	0	68	56	3	21	42	100	32	44	97	79
Puerto Rico	0	0	0	0	0	0	69	0	95	94	3	30	31	100	5	6	97	70
Saint Kitts and Nevis	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Saint Lucia	0	0	0	0	0	0	89	0	71	71	3	0	11	100	29	29	97	100
Saint Vincent and the Grenadines	0	0	0	0	0	0	55	0	73	73	3	27	45	100	27	27	97	73
Suriname	0	0	0	0	0	0	91	0	93	95	3	40	9	100	7	5	97	60
Trinidad and Tobago	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
United States Virgin Islands	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Uruguay	0	0	0	0	0	0	87	0	94	95	3	21	13	100	6	5	97	79
Venezuela (Bolivarian Republic of)	0	0	0	0	0	0	85	81	94	94	3	15	15	19	6	6	97	85
MIDDLE EAST																		
Tier 1	**17**	**42**	**0**	**0**	**0**	**0**	**80/79**[a]	**20**	**100**	**100**	**0**	**71**	**5.0**	**38**	**0**	**0**	**100**	**29**
Bahrain	1	0	0	0	0	0	29	0	44	50	0	0	70	100	56	50	100	100
Iraq	6	0	0	0	0	0	39	0	49	50	0	25	55	100	51	50	100	75
Israel	4	0	0	0	0	0	34	0	50	95	3	0	62	100	50	5	97	100
Jordan	5	14	0	0	0	0	39	61	50	50	0	29	56	25	50	50	100	71
Kuwait	10	0	0	0	0	0	51	0	50	50	0	37	39	100	50	50	100	63
Lebanon	4	0	0	0	0	0	32	0	50	50	3	31	64	100	50	50	97	69
Occupied Palestinian Territory	2	0	0	0	0	0	30	0	0	0	0	0	68	100	100	100	100	100
Oman	18	0	0	0	0	0	71	0	50	50	0	29	11	100	50	50	100	71
Qatar	12	0	0	0	0	0	56	0	50	50	0	0	32	100	50	50	100	100
Saudi Arabia	9	0	0	0	0	0	47	0	50	50	0	20	44	100	50	50	100	80
Syrian Arab Republic	10	18	0	0	0	0	49	71	50	50	0	11	41	11	50	50	100	89
United Arab Emirates	9	0	0	0	0	0	49	0	50	50	0	26	42	100	50	50	100	74
Yemen	5	0	0	0	0	0	38	0	50	50	0	29	56	100	50	50	100	71

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[a] N-excretion rates for Dairy cows / Other cattle

	(% OF TOTAL MANURE AVAILABLE)																	
	MANURE BURNT FOR FUEL						MANURE LEFT ON PASTURE						STORED					
	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken
NORTHERN AMERICA																		
Tier 1	**0**	**0**	**0**	**0**	**0**	**0**	**10.8/ 81.5[a]**	**0**	**92**	**88**	**0**	**1**	**89.3/ 18.6[a]**	**16**	**8**	**12**	**100**	**99**
Canada	0	0	0	0	0	0	43	17	56	64	0	0	57	83	44	36	100	100
Saint Pierre and Miquelon	0	0	0	0	0	0	0	0	0	0	0	50	100	100	100	100	100	50
United States of America	0	0	0	0	0	0	35	0	49	45	0	0	65	100	51	55	100	100
OCEANIA																		
Tier 1	**0**	**0**	**0**	**0**	**0**	**0**	**76/ 91[a]**	**100**	**100**	**100**	**0**	**3**	**25/ 9[a]**	**0**	**0**	**0**	**100**	**97**
American Samoa	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Australia	0	0	0	0	0	0	99	0	100	100	0	3	1	100	0	0	100	97
Cook Islands	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Fiji	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
French Polynesia	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Guam	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Kiribati	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Micronesia (Federated States of)	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
New Caledonia	0	0	0	0	0	0	100	0	100	100	5	36	0	100	0	0	95	64
New Zealand	0	0	0	0	0	0	95	0	100	100	0	5	5	100	0	0	100	95
Niue	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Papua New Guinea	0	0	0	0	0	0	100	0	100	100	5	42	0	100	0	0	95	58
Samoa	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Solomon Islands	0	0	0	0	0	0	100	0	0	0	5	37	0	100	100	100	95	63
Tonga	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Tuvalu	0	0	0	0	0	0	0	0	0	0	5	0	100	100	100	100	95	100
Vanuatu	0	0	0	0	0	0	100	0	100	0	5	43	0	100	0	100	95	57
WESTERN EUROPE																		
Tier 1	**0**	**0**	**0**	**0**	**0**	**0**	**20/ 32[a]**	**0**	**96**	**87**	**0**	**2**	**80/ 68[a]**	**99**	**4**	**13**	**100**	**98**
Andorra	0	0	0	0	0	0	63	0	0	79	0	0	37	100	100	21	100	100
Austria	0	0	0	0	0	0	10	0	37	63	0	0	90	100	63	37	100	100
Belgium	0	0	0	0	0	0	44	0	37	63	0	0	56	100	63	37	100	100
Denmark	0	0	0	0	0	0	5	0	0	73	0	0	95	100	100	27	100	100
Finland	0	0	0	0	0	0	25	0	33	33	0	0	75	100	67	67	100	100
France	0	0	0	0	0	0	44	0	0	70	0	0	56	100	100	30	100	100
Germany	0	0	0	0	0	0	15	0	32	54	0	0	85	100	68	46	100	100
Greece	0	0	0	0	0	0	9	0	100	72	0	0	91	100	0	28	100	100
Iceland	0	0	0	0	0	0	0	0	0	0	0	0	100	100	100	100	100	100

>>>

[a] N-excretion rates for Dairy cows / Other cattle

	(% OF TOTAL MANURE AVAILABLE)																	
	MANURE BURNT FOR FUEL						MANURE LEFT ON PASTURE						STORED					
	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken	Cattle	Buffalo	Goats	Sheep	Pig	Chicken
Ireland	0	0	0	0	0	0	62	0	100	92	0	0	38	100	0	8	100	100
Italy	0	0	0	0	0	0	5	3	90	90	0	0	95	97	10	10	100	100
Liechtenstein	0	0	0	0	0	0	20	0	37	63	2	0	81	100	63	37	98	100
Luxembourg	0	0	0	0	0	0	48	0	60	60	0	0	52	100	40	40	100	100
Malta	0	0	0	0	0	0	8	0	72	79	2	16	92	100	28	21	98	84
Netherlands	0	0	0	0	0	0	21	0	37	63	0	0	79	100	63	37	100	100
Norway	0	0	0	0	0	0	29	0	60	60	0	0	71	100	40	40	100	100
Portugal	0	0	0	0	0	0	51	0	80	80	0	0	49	100	20	20	100	100
Spain	0	0	0	0	0	0	41	0	72	83	0	0	59	100	28	17	100	100
Sweden	0	0	0	0	0	0	30	0	0	60	0	0	70	100	100	40	100	100
Switzerland	0	0	0	0	0	0	20	0	20	69	0	9	81	100	80	31	100	91
United Kingdom	0	0	0	0	0	0	48	0	96	96	0	0	52	100	4	4	100	100

[a] N-excretion rates for Dairy cows / Other cattle

C. Net N change (loss) during manure storage[a]

Regional values extracted from the results of the Tier 1 approach in FAOSTAT, and country-specific values extracted from the Tier 2-GLEAM approach

	LOSS CHANGE (%)					
	NET Cattle	N Buffalo	N Goat	N Sheep	N Swine	N Chicken
AFRICA						
Tier 1	**13.08/ 20.0[a]**	**33.8**	**0**	**3.7**	**5.8/ 0.3[c]**	**0**
Algeria	25	0	34	34	44	42
Angola	33	0	29	25	49	44
Benin	31	0	37	36	48	42
Botswana	30	0	33	33	44	38
Burkina Faso	26	0	34	34	8	48
Burundi	43	0	22	24	50	48
Cabo Verde	0	0	0	0	46	0
Cameroon	37	0	28	34	48	39
Central African Republic	38	0	41	41	50	39
Chad	30	0	33	33	44	37
Comoros	44	0	27	33	0	49
Congo	39	0	41	41	50	47
Côte d'Ivoire	33	0	40	40	50	44
Democratic Republic of the Congo	43	0	28	25	50	39
Djibouti	32	0	34	34	0	0
Egypt	24	36	34	34	44	49
Equatorial Guinea	42	0	42	42	50	41
Eritrea	33	0	23	27	0	44
Ethiopia	40	0	22	21	49	48
Gabon	34	0	42	42	49	47
Gambia	29	0	34	34	45	41
Ghana	29	0	38	39	49	44
Guinea	34	0	38	38	48	43
Guinea-Bissau	28	0	33	37	45	37
Kenya	35	0	22	21	48	55
Lesotho	46	0	23	23	50	46
Liberia	36	0	41	37	51	47
Libya	23	0	34	34	0	50
Madagascar	32	0	34	33	47	42
Malawi	33	0	27	28	45	46
Mali	30	0	34	34	44	34
Mauritania	26	0	34	34	45	46
Mauritius	0	0	0	0	47	0
Mayotte	42	0	0	42	0	0
Morocco	25	0	35	35	45	45
Mozambique	26	0	31	33	45	33

[a, b, c] Refer to page 65 footnotes

	LOSS CHANGE (%)					
	NET	N	N	N	N	N
	Cattle	Buffalo	Goat	Sheep	Swine	Chicken
Namibia	31	0	34	34	44	36
Niger	26	0	30	31	44	36
Nigeria	31	0	37	35	45	62
Réunion	0	0	0	0	51	0
Rwanda	38	0	22	22	50	53
Saint Helena, Ascension and Tristan da Cunha	55	0	22	23	0	0
Sao Tome and Principe	34	0	18	42	50	46
Senegal	30	0	34	34	44	38
Seychelles	0	0	0	0	38	54
Sierra Leone	34	0	42	42	50	51
Somalia	28	0	34	34	44	40
South Africa	43	0	26	26	46	51
Sudan	24	0	35	35	0	43
Swaziland	31	0	24	20	47	39
Togo	32	0	39	38	49	43
Tunisia	24	0	34	34	44	39
Uganda	33	0	24	24	50	47
United Republic of Tanzania	28	0	27	25	47	47
Western Sahara	34	0	0	34	0	0
Zambia	32	0	27	34	45	46
Zimbabwe	30	0	30	26	45	41

ASIA						
Tier 1	33.8/ 38.3[a]	36.4	0	0	19.0/ 19.0[b]	1.4
Brunei Darussalam	40	42	22	42	51	40
Cambodia	40	40	0	39	50	44
China, Hong Kong SAR	47	45	0	32	50	0
China, mainland	47	43	22	23	51	62
Democratic People's Republic of Korea	52	0	22	23	51	61
Indonesia	42	45	22	36	50	42
Iran (Islamic Republic of)	30	31	34	34	0	42
Japan	56	0	14	14	57	56
Kazakhstan	41	53	22	22	46	63
Kyrgyzstan	41	0	22	22	50	59
Lao People's Democratic Republic	39	39	22	42	51	42
Malaysia	39	41	22	39	50	49
Mongolia	42	0	22	22	51	53
Myanmar	35	39	20	34	48	48
Philippines	42	40	22	42	50	39
Republic of Korea	51	0	22	23	60	59

[a, b, c] Refer to page 65 footnotes

	LOSS CHANGE (%)					
	NET	N	N	N	N	N
	Cattle	Buffalo	Goat	Sheep	Swine	Chicken
Singapore	54	0	21	23	0	0
Tajikistan	30	0	16	22	46	42
Thailand	40	40	22	42	49	53
Timor-Leste	42	43	22	32	50	39
Turkmenistan	42	0	16	22	35	60
Uzbekistan	35	0	18	22	43	54
Viet Nam	41	40	22	42	49	46
EASTERN EUROPE						
Tier 1	**31.2/ 23.1**[a]	**0**	**0**	**0**	**32.3/ 28.0**[b]	**0**
Albania	36	0	16	16	39	45
Armenia	32	0	18	23	46	57
Azerbaijan	36	46	18	22	26	52
Belarus	35	0	17	17	48	44
Bosnia and Herzegovina	40	47	16	16	39	39
Bulgaria	36	48	16	16	39	46
Croatia	40	0	17	16	39	46
Cyprus	25	0	15	31	45	45
Czech Republic	34	0	16	16	51	46
Estonia	38	0	0	0	21	50
Georgia	36	48	20	23	48	53
Hungary	35	0	16	16	47	47
Latvia	35	0	16	16	38	50
Lithuania	37	0	17	17	38	47
Montenegro	40	0	16	16	37	48
Poland	35	0	17	17	50	42
Republic of Moldova	40	0	16	9	21	41
Romania	36	48	16	17	43	45
Russian Federation	35	49	16	16	46	50
Serbia	40	0	16	16	39	44
Slovakia	40	0	16	16	39	46
Slovenia	42	0	17	16	39	47
The former Yugoslav Republic of Macedonia	40	0	0	16	39	46
Turkey	28	41	16	26	45	49
Ukraine	34	0	0	0	39	46
INDIAN SUBCONTINENT						
Tier 1	**21.8/ 6.2**[a]	**6.2**	**0**	**0**	**23.3/ -9.5**[b]	**1.4**
Afghanistan	31	0	15	30	0	42
Bangladesh	36	36	21	40	51	45
Bhutan	38	51	22	23	50	47

[a, b, c] Refer to page 65 footnotes

	LOSS CHANGE (%)					
	NET	N	N	N	N	N
	Cattle	Buffalo	Goat	Sheep	Swine	Chicken
India	31	33	16	34	45	50
Nepal	38	43	20	25	49	45
Pakistan	28	32	15	32	0	42
Sri Lanka	37	41	22	41	50	52

LATIN AMERICA						
Tier 1	22.6/ 0[a]	0	0	0	8.3/ -0.9[b]	0
Antigua and Barbuda	0	0	0	0	50	0
Argentina	40	40	33	29	50	49
Bahamas	31	0	20	27	47	44
Barbados	0	0	0	0	49	0
Belize	41	0	35	34	52	50
Bolivia (Plurinational State of)	47	0	25	24	52	43
Brazil	39	43	33	38	51	48
British Virgin Islands	0	0	0	0	10	0
Cayman Islands	0	0	0	0	54	0
Chile	30	0	29	23	51	48
Colombia	39	47	26	28	52	54
Costa Rica	34	0	19	25	52	52
Cuba	34	0	33	35	52	58
Dominica	32	0	42	42	52	46
Dominican Republic	34	0	31	27	52	54
Ecuador	42	0	26	25	52	42
El Salvador	32	0	24	28	49	53
Falkland Islands (Malvinas)	0	0	0	0	48	0
French Guiana	41	0	42	42	52	52
Grenada	0	0	0	0	43	50
Guadeloupe	42	0	42	42	53	53
Guatemala	41	44	25	25	52	52
Guyana	35	0	30	41	52	40
Haiti	37	0	17	34	52	46
Honduras	39	0	30	3	52	49
Jamaica	39	0	38	40	52	48
Martinique	35	0	42	42	53	55
Mexico	43	0	24	22	49	54
Montserrat	0	0	0	0	46	0
Netherlands Antilles	32	0	42	42	48	63
Nicaragua	35	0	26	16	51	48
Panama	42	0	30	36	52	51
Paraguay	42	0	36	40	52	56
Peru	48	0	23	23	51	47
Puerto Rico	35	0	40	37	52	47

[a, b, c] Refer to page 65 footnotes

	LOSS CHANGE (%)					
	NET	N	N	N	N	N
	Cattle	Buffalo	Goat	Sheep	Swine	Chicken
Saint Kitts and Nevis	0	0	0	0	51	0
Saint Lucia	37	0	7	7	53	50
Saint Vincent and the Grenadines	44	0	24	24	53	59
Suriname	42	0	28	41	52	44
Trinidad and Tobago	0	0	0	0	51	0
United States Virgin Islands	0	0	0	0	47	0
Uruguay	37	0	37	42	52	53
Venezuela (Bolivarian Republic of)	39	43	34	36	52	50
MIDDLE EAST						
Tier 1	28.8/ 8[a]	0	0	0	11.0/ 11.0[b]	0
Bahrain	33	0	34	38	0	51
Iraq	26	0	34	35	0	46
Israel	24	0	15	34	44	46
Jordan	26	0	34	34	0	40
Kuwait	26	0	34	34	0	39
Lebanon	27	0	36	36	44	42
Occupied Palestinian Territory	35	0	0	0	0	0
Oman	28	0	34	34	0	48
Qatar	25	0	34	34	0	52
Saudi Arabia	26	0	34	34	0	43
Syrian Arab Republic	26	33	34	34	0	51
United Arab Emirates	25	0	34	34	0	45
Yemen	28	0	34	34	0	41
NORTHERN AMERICA						
Tier 1	39.2/ 39.6[a]	0	0	1.2	46.2/ 45.3[b]	3.9
Canada	46	46	17	16	50	45
Saint Pierre and Miquelon	0	0	0	0	0	33
United States of America	42	0	16	16	38	45
OCEANIA						
Tier 1	57.9/ 40.0[a]	0	0	0	43.3/ 43.1[b]	0
American Samoa	0	0	0	0	45	0
Australia	34	0	0	0	54	45
Cook Islands	0	0	0	0	45	0
Fiji	0	0	0	0	45	0
French Polynesia	0	0	0	0	45	0

[a, b, c] Refer to page 65 footnotes

	LOSS CHANGE (%)					
	NET	N	N	N	N	N
	Cattle	Buffalo	Goat	Sheep	Swine	Chicken
Guam	0	0	0	0	45	0
Kiribati	0	0	0	0	45	0
Micronesia (Federated States of)	0	0	0	0	45	0
New Caledonia	0	0	0	0	45	36
New Zealand	50	0	0	0	52	49
Niue	0	0	0	0	45	0
Papua New Guinea	0	0	0	0	45	34
Samoa	0	0	0	0	45	0
Solomon Islands	0	0	0	0	45	35
Tonga	0	0	0	0	45	0
Tuvalu	0	0	0	0	45	0
Vanuatu	0	0	0	0	45	34

WESTERN EUROPE						
Tier 1	35.1/ 24.1[a]	31.9	0	1.2	30.6/ 29.3[b]	0.3
Austria	38	0	17	17	50	47
Belgium	43	0	16	17	50	46
Denmark	42	0	0	17	50	45
Finland	40	0	16	16	31	46
France	39	0	16	17	50	49
Germany	41	0	16	17	50	49
Greece	34	0	0	17	33	45
Iceland	0	0	0	0	31	45
Ireland	44	0	0	16	31	47
Italy	39	48	17	17	52	52
Liechtenstein	40	0	17	17	34	0
Luxembourg	42	0	17	16	33	45
Malta	34	0	16	16	35	47
Netherlands	42	0	16	16	32	47
Norway	42	0	17	17	31	46
Portugal	45	0	16	16	45	45
Spain	40	0	17	16	33	40
Sweden	42	0	0	16	31	40
Switzerland	40	0	16	17	31	32
United Kingdom	31	0	17	16	45	46

[a] Net loss change values refers to the proportional change in N content between manure excreted in the MMSs and manure applied to soil. In the case of Tier 1 values were calculated using FAOSTAT estimations, which include N inputs from bedding in the MMS. As a consequence the N-bedding can partially or fully compensate the N lost during manure storage. The few extreme cases where the net loss change is negative indicate that the N input from bedding is higher than the N losses and therefore the manure-N applied to soils is higher than the N excreted in the MMSs. In the case of Tier 2, bedding is not taken into account and therefore the values of net loss change simply refers to the N losses during manure management extracted from GLEAM as weighted average.

[b] Percentage of N stored for Dairy cows / Other cattle

[c] Percentage of N stored for Market Swine / Breeding Swine

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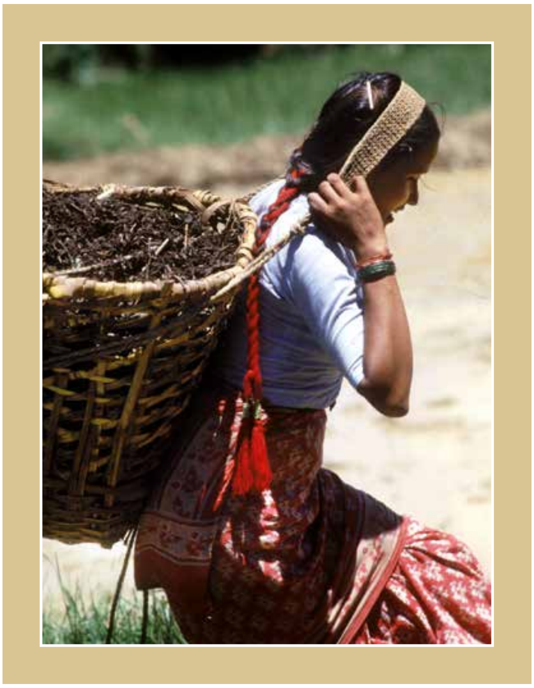

The global agricultural sector today faces the double challenge of feeding a growing population while preserving the underlying natural resources of land, water and air. In the meantime, already a third of the world's soils are degraded.

Soil and nutrient management techniques aimed at restoring soil health will therefore be essential to meeting these challenges. Agricultural statistics on nutrient use in agriculture provide a useful tool for countries to measure progress towards achieving these national and global development goals. This report presents the relevant statistics available at FAO to this end, and demonstrates how they can be used for a nutrient input analysis at a national, regional and global level. The data include FAOSTAT chemical and mineral fertilizers statistics integrated with estimates of livestock manure from the FAOSTAT and the Global Livestock Environmental Assessment Model.

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Nitrogen inputs to agricultural soils from livestock manure
New statistics

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