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Agenda item 13: Common methodologies on estimation techniques for the National Baseline Budget (NBB) of pollutants related to:

- **a) Non-point source releases from agriculture**
- **b) Point source releases from aquaculture**
- **c) Non-point source releases from catchment runoffs**

Guideline on estimation techniques and applied methodologies for non-point source releases from agriculture

UNEP/MAP
Athens, 2021

Note by the Secretariat

The LBS Protocol requires in its Article 13 (para 2) the Contracting Parties to submit reports which shall include *inter alia*: (i) data resulting from pollutants' monitoring and (ii) quantities of pollutants discharged from their territories. For this purpose, the National Baseline Budget of pollutants (NBB) was agreed by the Contracting Parties as "the monitoring tool" to track progress, on a five-yearly basis, of loads of released pollutants. To assist the Countries in this mandate, updated NBB guidelines were developed in 2015 (UNEP(DEPI)/MED WG.404/7).

COP21 (Napoli, Italy, 2-5 December 2019), mandated MED POL in its Programme of Work for the biennium 2020-2021 to develop new Technical Guidelines for estimating National Baseline Budget of Pollutants (NBB) providing methodologies on estimation techniques for releases from non-point sources (catchment runoffs and agriculture) and aquaculture; thus strengthening the reporting capacities of the Contracting Parties to Barcelona Convention for sector of activities under LBS Protocol (Annex I).

To this aim, this guidance document was developed with a focus on agricultural activities. It serves to further expand the capacity of reporting for the upcoming 5th NBB Reporting Cycle scheduled for the biennium 2024-2025, as well as ensure further streamlining with (e)PRTR methodologies. This new guideline is expected to facilitate also the collection of data for monitoring the implementation of the Regional Plan for Agriculture to be developed in the biennium 2022-2023.

This guidance document was reviewed and approved in the Meeting on Evaluation of Implementation of National Action Plans and Assessments, and Tools to estimate pollutants loads from diffuse sources which was held on 22-23 April 2021. The meeting participants agreed to submit the updated document to the Meeting of the MED POL Focal Points for their consideration and final approval.

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List of Abbreviations / Acronyms

BOD	Biological oxygen demand
CH4	Methane
CLRTAP	Convention on Long Range Transboundary Air Pollution
CO	Carbon Monoxide
CO2	Carbon Dioxide
COD	Chemical Oxygen Demand
DEFRA	Department for the Environment, Food and Rural Affairs (UK)
EC	European Commission
EEA	European Environment Agency
EIIP	Emissions Inventory Improvement Program (US)
EMEP	European Monitoring and Evaluation Programme
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations Rome
GHG	Greenhouse gas
GIS	Geographic Information System
HABs	Harmful algal blooms
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
LBS	Land Based Sources
MEDPOL	Convention on Protection of the Mediterranean Sea
N	Nitrogen
NH_3	Ammonia
NMVOC	Non-Methane Volatile Organic Compounds
N_2O	Nitrous Oxide
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NOx	Oxides of Nitrogen
NPI	National Pollutant Inventory (Australia)
NPRI	National Pollutant Release Inventory (Canada)
OECD	Organization for Economic Cooperation and Development
P	Phosphorus
PRTR	Pollutant Release and Transfer Registers
TFEIP	Transboundary Air Pollution Task Force on Emission Inventories and Projections
TN	Total Nitrogen
TP	Total Phosphorus
UNFCCC	United Nations Framework Convention on Climate Change
UNITAR	United Nations Institute for Training and Research
WHO	World Health Organization
WISE	World Inventory of Soil Emission Potentials

1. Introduction

1. Following the 21st Meeting of the Contracting Parties to the Barcelona Convention COP21 (held in Napoli, Italy, 2-5 December 2019)[1] and the adoption of Decision IG.24/14,[2] the Programme of Work mandated MED POL Programme to develop/update technical guidelines addressing estimation techniques of pollutant releases from non-point (diffuse) sources (agriculture, catchments runoff) as well as from aquaculture (point source).

2. To achieve this mandate, this guidance document was developed. It elaborates on techniques and applied methodologies for estimating non-point (diffuse) source emissions to air and releases to water and land from activities classified under the **agricultural sector** including, but not limited to, releases of pollutants listed in Annex I to the LBS Protocol.

3. The scope of this guidance document covers the following:
   a. Characteristics of non-point sources emissions to air and releases to water and land from farming of animals as NBB/PRTR sector of activity; and

   b. Release estimation methods and techniques for non-point sources including pollutants, overview of approaches for emission estimations for non-point sources releases; their accuracy and uncertainties as well as quality control/quality assurance (QC/QA).

4. The non-point (diffuse) sources addressed in this guidance document include:

   a. Farming animals, especially those generated by enteric fermentation, manure management, feed management (silage leachate) and field burning of agricultural waste (dead animals); and

   b. Agriculture Crop Production Sectors pertinent to NBB sector of activities and as well as, where applicable for PRTRs including use of fertilizers, use of pesticides, manure application and field burning of agricultural waste (i.e., biomass including crops, dead or damaged trees and other plant material) for the Mediterranean region.

5. Bearing in mind that estimation methodologies for non-point sources of pollutions are quite complex and usually depend on processes and pathways where the scientific information is scarce, the methodology to develop this document consisted of an extensive literature review conducted systematically in a stepwise approach with a focus on the following topics summarized below:

   a. Available information on characteristics of emissions and releases/discharges of pollutants from agricultural non-point sources to air, water and land from agriculture generated by the processes of enteric fermentation, manure and feed management, field burning of agricultural waste (livestock mortalities and biomass) and use of fertilizers and pesticides;

   b. Available information on different approaches, methods and techniques recommended for use in current inventories and technical reports to estimate emissions for non-point (diffuse) sources to air and releases/discharges to water and land;

   c. Peer reviewed research papers describing methodologies and techniques proposed to estimate emissions and releases from the above non-point (diffuse) sources; as well as

   d. Potential issues and drawbacks regarding accuracy and uncertainty associated with the proposed estimation methods, techniques and approaches.

6. The guidelines will complement the NBB/PRTR Methodology for reporting of non-point sources of pollution under NBB/PRTR data calls as well as will serve to facilitate the monitoring of

[1] https://www.unenvironment.org/unepmap/events/meeting/21st-meeting-contracting-parties-convention-protection-marine-environment-and
[2] https://wedocs.unep.org/bitstream/handle/20.500.11822/31712/19ig24_22_2414_eng.pdf

implementation of the Regional Plans for Agriculture and Aquaculture (to be developed in the biennium 2022-2023). It is expected that the newly proposed techniques for estimation of pollution loads to air, water and land will enable the generation of compatible data to evaluate the effectiveness of adopted measures in the National Action Plans and the Regional Plans for Agriculture and Aquaculture.

7. Finally, this document presents to the Contacting Parties to Barcelona Convention an extensive bibliography and supplemental information containing recommendations for further sources of information and peer reviewed research papers which investigated emissions and releases in Mediterranean region (Annex I, Appendices A to E).

2. Legal basis of the NBB guidance document

8. The Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities (the LBS Protocol) is one of the six Barcelona Convention Protocols. It was adopted on 17th May 1980 by the Conference of Plenipotentiaries of the Coastal States of the Mediterranean Region and entered into force on 17th June 1983.[3] This original Protocol was modified by amendments adopted on 7th March 1996 (UNEP(OCA)/MED IG.7/4)[4] and recorded as the "Protocol for the Protection of the Mediterranean Sea against Pollution from Land-Based Sources and Activities". It entered into force on 18th May 2006.[5]

9. The LBS Protocol requires the Contracting Parties to submit reports which shall include inter alia: (i) data resulting from monitoring and (ii) quantities of pollutants discharged from their territories (Article 13, para 2).[6] For this purpose, the National Baseline Budget of pollutants (NBB) was agreed by the Contracting Parties as "the monitoring tool" to track progress, on a five-yearly basis, of discharged loads of pollutants reflecting the effectiveness of measures taken to reduce and prevent pollution from LBS.

10. To assist the Countries in this mandate, updated NBB guidelines were developed in 2015 (UNEP(DEPI)/MED WG.404/7 Annex IV, Appendix B, Page 11).[7] However, these updated NBB guidelines, do not offer means by which pollutants from non-point (diffuse) sources can be estimated. This point was discussed at the Regional Meeting on Reporting of Releases to Marine and Coastal Environment from Land Based Sources and Activities and Related Indicators, which was held in Tirana, Albania on 19-20 March 2019.[8] During the Meeting it was highlighted that reporting of diffuse sources can be only undertaken based on estimation techniques and emission factors which may vary on national and regional levels of each country. Therefore, the recommendation was made to support the Contracting Parties to complement the National Baseline Budget/Pollution Release and Transfer Registers (NBB/PRTRs) methodology with estimation techniques for diffuse sources related to agriculture and as well as aquaculture (UNEP/MED WG.462/8).

3. Characteristics of non-point (diffuse) sources and pollutants from agriculture

11. A detailed information regarding the substances that need to be reduced and eliminated from the land-based pollution sources are identified and listed in the LBS Protocol, Article 5, Annex I[9]. The MEDPOL PRTR Implementation Guide (UNEP/MED WG.473/12)[10] provides a list of sectors of activities (Annex I) and List of Pollutants (Annex II) which are mandatory for NBB reporting.

12. Pollutants discharges are dispersed from numerous sources which are broadly classified as:

[3] https://www.informea.org/en/treaties/land-based-sources-protocol
[4] https://wedocs.unep.org/handle/20.500.11822/3016
[5] https://wedocs.unep.org/bitstream/handle/20.500.11822/7096/Consolidated_LBS96_ENG.pdf?sequence=5&isAllowed=y
[6] https://wedocs.unep.org/bitstream/handle/20.500.11822/3016/96ig7_4_lbsprotocol_eng.pdf?sequence=1&isAllowed=y
[7] https://wedocs.unep.org/bitstream/handle/20.500.11822/5481/1/15wg417_inf6_eng.pdf
[8] file:///C:/Users/aleks/AppData/Local/Temp/19wg462_08_Meeting%20Report.pdf
[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:21983A0312(01)
[10] https://wedocs.unep.org/bitstream/handle/20.500.11822/28072/19wg473_12_eng.pdf

a. Point (end of a pipe) pollution discharges and
b. Non-point (diffuse) pollution sources

13. Both point and non-point discharges may originate from a variety of sources, including: municipal wastewater treatment facilities (largely sewage consisting of human wastes), onsite residential septic systems (containing human wastes, detergents, other organic wastes from food households; septic systems drainage (leachate) fields), industrial (chemical, organic, and thermal wastes), urban and suburban runoff from parking lots, commercial buildings and houses (roofs and gardens), construction sites, golf-courses and roads, and agricultural [2-4].

14. Agricultural non-point (diffuse) pollution sources include surface and subsurface runoff from livestock operations (animal wastes, animal production areas such are barnyards, feedlots and composting piles) and cropping systems (pesticides and fertilizers applications), their field level interactions (both temporal and spatial) and climate (storm frequency and hydrology, temperature) [2-7]. Therefore, estimating pollution loadings and controlling this type of contamination is very complex and requires integration of scientific, technological and socio-economic factors [3-4].

15. The major types of non-point (diffuse) source emissions from agriculture-related activities include use of pesticides, herbicides, and fungicides; excess manure production; burning of waste biomass; and combustion emissions from use of tractors, harvesters and other motorized equipment, and heating of greenhouses [5]. The main criteria air pollutants comprise carbon monoxide (CO), Ozone (O_3), particles, nitrogen dioxide (NO_2), sulphur dioxide (SO_2) [1][6]. Types of pollutants commonly included in inventories on discharges to water include nutrients (total N and total P); other inorganic pollutants (e.g., metals); organic pollutants (e.g., POPs); suspended particles; and indicators such as BOD, COD, TOC, salinity. A full list of PRTRs containing RETs can be found in the OECD's Resource Centre for PRTRs[11]. Based on OECD Compendiums [1][6] Table 5.1 provides an updated summary of pollutants originating from other non-point (diffuse) sources associated with Farming of Animals and Agriculture NBB Sectors:

Table 2.1: Summary of pollutants originating from agriculture non-point (diffuse) sources

Sources		**Process**	**Pollutants**		
Sector	**Subsector**		**air**	**water**	**land**
Farming of Animals (NBB) Intensive livestock production (PRTR)	Other from non-point (diffuse) sources	Enteric fermentation	*CH_4*, CO_2		
		Manure management	*CH_4, N_2O, NH_3, NO_x, volatile organic compounds (VOCs)*	*Nutrients, pathogens, BOD, TC or COD, emerging contaminants (veterinary antibiotics etc.)*	Nutrients, pathogens, BOD, TC or COD, emerging contaminants (veterinary antibiotics etc.)
		Silage leachate	volatile organic compounds (VOCs), NH_3, NO_x, CH_4, CO_2	*BOD, TC or COD, TSS, nutrients, pathogens, veterinary antibiotics*[6]	BOD, TC or COD, TSS, nutrients, pathogens, veterinary antibiotics
		Field burning and disposal of livestock mortalities	CO_2, CH_4, N_2O, NH_3, NO_x, volatile organic compounds (VOCs)	BOD, TC or COD, TSS	BOD, TC or COD, TSS

[11] http://www.prtr-rc.fi/

Sources		Process	Pollutants		
Sector	Subsector		air	water	land
Agriculture	Other from crop production non-point (diffuse) sources	Biomass burning	*CO_2, CH_4, N_2O, NH_3, NO_x, volatile organic compounds (VOCs)*	BOD, TC or COD, TSS, nutrients	BOD, TC or COD, TSS, nutrients
		Fertilizer application	Air emissions from the equipment including NH_3, NO_x, CO_2	N, P and potassium (K), sulfur (S), magnesium (Mg), calcium (Ca), zinc (Zn), copper (Cu)	N, P, K, S, Mg, Ca, Zn, Cu
		Pesticide application	*Air emissions*from the equipment	Various insecticides, herbicides, rodenticides, and fungicides.	Various insecticides, herbicides, rodenticides, and fungicides.
		Manure spreading and land application	*Air emissions* from the equipment and from the soil	N, P, minerals, emerging contaminants (veterinary antibiotics)	N, P, minerals, emerging contaminants (veterinary antibiotics)

16. Detailed characteristics and emissions from Enteric Fermentation; Manure Management; Silage Leachate; Field burning of agricultural waste (disposal of livestock mortalities); Crop Production including use of fertilizers; use of pesticides; and biomass burning are presented in Annex I of this document.

4. Non-point/diffuse Sources Pollution Inventories

17. Estimation techniques for non-point (diffuse) sources require different types of data and approaches compared to point sources of pollutants. Sources of information may include statistical data on economic activities, demographic data, remote sensing data, emission factors and engineering data, while tools may include geographical information systems (GIS) and computer models (e.g., hydrology/water flow models, transportation models and others). In the case of agriculture, the parameters could include the size and composition of cultivated area, the quantity of pesticide or fertilizer use and the locations where these chemicals are applied. In this manner, one can perform a reasonable estimate of aggregate emissions arising from non-point or diffuse sources of certain pollutants starting from simple, known parameters that are readily measured or obtained for each source type.

18. Overview of approaches for air, water and land inventories for estimating emissions from non-point (diffuse) sources to air from agriculture as well as additional information and references on Non-point/diffuse sources pollution inventories are provided in Annex II.

4.1 Inventories on air emissions

19. The OECD Resource Compendiums of PRTR release estimation techniques [1][6] provide detailed summary of air emission inventories. These inventories have developed over several decades and methodologies for estimating emissions from non-point sources in these inventories are well established. National inventories (such as greenhouse gas inventories) tend to be used to monitor trends and progress towards emissions reduction strategies, to support national or state policy development, and may be used for broad scale modelling [1]. An important characteristic of air emission inventories is that they include extensive underlying data sets [1]. Greenhouse gas (GHG) inventories are closely linked to the requirements of UN Framework Convention on Climate Change (UNFCCC) [7]. Another international convention, the UNECE Convention on Long-Range

Transboundary Air Pollution (CLRTAP), the US and Canada, provides information on spatial aggregation of emissions [8]. The convention covers emissions to air of acidifying compounds, particles, metals and persistent organic compounds and involves scientific coordination led by the European Monitoring and Evaluation Programme (EMEP). EMEP collects emission data, measures air and precipitation quality and models atmospheric transport and deposition of air pollutants. These data are used to evaluate the quantity and significance of transboundary fluxes (changes to air pollutant composition and concentrations) and any areas that exceed critical loads and threshold levels [8].

4.2 Inventories on discharges to water

20. Given the magnitude of eutrophication globally [2], the inventories on discharges to water from non-point (diffuse) sources typically involve the estimation of nutrient loads entering inland or marine waters. Nutrients are normally represented by estimates of total nitrogen and phosphorous loads (g or kg/d), calculated by multiplying daily flow (m^3/d) with daily nutrient concentration (g/m^3). As summarized in the OECD Compendium [1], the estimation of pollutant export rates (releases) is often linked with mathematical modelling of pollution impacts on receiving waters using catchment runoff models. Other indicators that are not chemical species are usually included in the model, for example, biological oxygen demand, suspended solids and bacteriological agents. Driven by growing awareness of their impacts and reporting requirements, other pollutants, such as metals and organic chemicals, are becoming addressed. The atmospheric contribution of some of these pollutants, most notably nitrogen, is often included in the catchment modelling. This reflects an important connection between inventories of emissions to air and releases to water [1].

4.3 Inventories on discharges and emissions to land

21. Agriculture non-point (diffuse) sources that can result in emissions to soil include manure management, silage leachate, field burning of animal carcasses, fertilizer use, pesticide use and biomass burning. However, to date, most of the non-point (diffuse) sources inventories are focused on emissions to air or releases to water [1].

22. Disposal or placement of waste that can potentially lead to the contamination of soil are prohibited by law [1][6]. Berlin Ecologic Institute [9] recently provided a comprehensive 462-page update Inventory and Assessment of soil protection policy instruments in EU Member States. The World Inventory of Soil Emission Potentials (WISE) project (1991-2016)[12, 13] generated a range of world databases of soil property estimates (point and grid-based) to support environmental studies at a global scale including soil vulnerability to pollution, soil carbon stocks and change, and soil gaseous emission potentials.

5. Release Estimation Methods and Techniques for Non-Points (Diffuse)

23. Techniques used to estimate releases from non-point (diffuse) agriculture sources are divided into (i) non-point sources from farming of animals and intensive livestock production and (ii) non-point sources from crop production. These are discussed below:

5.1 Summary of techniques used to estimate releases from non-point (diffuse) sources from farming of animals and intensive livestock production

24. Techniques used to estimate releases from non-point (diffuse) agriculture sources from farming animals and livestock production have been described in several guidance documents [1] [5-6][10]. The IPCC guidelines [10] provide a thorough description of steps to define categories and subcategories of livestock, and choice of methods. They also highlight that collecting data on livestock

[12] https://www.isric.org/explore/wise-databases
[13] https://www.isric.org/projects/world-inventory-soil-emission-potentials-wise

characterization (livestock species, animal population) should be performed as a good practice to support emissions estimates.

25. In the following sections, techniques for estimation of emissions and releases to air, water and land are presented for:

a. Emissions from the enteric fermentation to air;
b. Releases from manure management to air, water and land;
c. Releases from silage leachate (proposed for the first time, further to an extensive literature performed for that purpose in this document);
d. Emissions from agricultural burning from disposal of livestock mortalities[14];
e. Emissions from agricultural biomass burning[14].

5.1.1 Techniques used to estimate methane releases from Enteric Fermentation to Air

26. According to the OECD Compendium [1] the general approach to estimate CH4 emissions from livestock is to multiply the number of animals by an emissions factor. Thus, the basic formula is:

$$CH_4\ Emissions = N_T\ (Number\ of\ Animals) * CH_4\ Emissions\ Factor \qquad \text{(Equation 5.1)}$$

27. Therefore, the three key steps to estimate methane emissions for livestock are to: a) Collect animal population and animal characteristics data; b) Estimate the emissions factor for the animal type; and c) Multiply the emission factor estimate by the population to get the total CH_4 emission estimate for the population. The emissions factors are an estimate of the amount of CH_4 produced (kg) per animal. There are two methods by which to estimate emissions factors:

a. The Tier 1 method relies on the default emissions factors in the IPCC Guidelines and requires data on the number of animals only [1]. The latest refinement of the IPCC Guidelines [58] suggests that for estimating number of animals for a growing population on the territory, the updated equation should be used:

$$N_T = Days\_Alive * \frac{NAPA}{365} \qquad \text{(Equation 5.2)}$$

where:

N_T = the number of head of livestock species per category within a given country (equivalent to annual average population); *NAPA* = number of animals produced annually.

b. The Tier 2 method involves collecting feed and animal data to calculate the emissions factor. According to [1] using the Tier 2 method, uncertainty in the emissions factors is generally lower because these emissions factors are based on country-specific conditions.

28. Wolf et al [11] updated information for cattle and swine by region, based on reported changes in animal body mass, feed quality and quantity, milk productivity, and management of animals and manure. They used this updated information to calculate new livestock methane emissions factors for enteric fermentation in cattle, and for manure management in cattle and swine.

29. The IPCC Refinement to the 2006 IPCC Guidelines [10] provides a detailed description of methane emissions from enteric fermentation in section 10.3, consisting of three steps:

Step 1: Divide the livestock population into subgroups and characterize each subgroup as described in Section 10.2 of the Guidelines [10].
Step 2: Estimate emission factors for each subgroup as kilograms of CH_4 per animal per year.

[14] To date, all Inventories used term “field burning of agricultural waste”. We propose separating this process and emissions/releases from agricultural burning from disposal of livestock mortalities (d) and biomass burning (e).

Step 3: Multiply the subgroup emission factors by the subgroup populations to estimate subgroup emission, and sum across the subgroups to estimate total emission.

30. They suggest that Tier 3 method should be used by countries for which livestock emissions are particularly important and which may wish to incorporate additional country-specific information in their estimates. Tier 3 approach could employ the development of sophisticated models that consider diet composition in detail, concentration of products arising from ruminant fermentation, seasonal variation in animal population or feed quality and availability, and possible mitigation strategies. Many of these estimates would be derived from direct experimental measurements. However, the guidelines highlighted that is recommended that Tier 3 method should be subjected to a wide degree of international peer review to ensure that they improve the accuracy and / or precision of estimates.

Comments on reliability

31. The OECD Compendium [1] summarized main points regarding reliability of methods proposed above. They pointed out that because the emission factors for Tier 1 are not based on country-specific data, they may not represent accurately the livestock characteristics for each country. As a result, they may make emissions factors highly uncertain. In the Tier 2, the primary source of uncertainty emissions factors are the livestock characteristics, because these data are dependent on the methods used to collect the data for each country.

32. Sources of further information are provided in Annex III, Appendix A.

5.1.2 Techniques used to estimate emissions and releases from manure management

33. According to the OECD Compendium [1] the process of estimating emissions from manure management involves the following five steps:

Step 1: Determine whether housed livestock in the study region may be an important source of emissions, assuming ammonia and/or greenhouse gases are included in the inventory;
Step 2: Determine the availability of activity data including livestock numbers for different classes of animals, geographic distribution, i.e., location of farms, and other information about waste management practices, feed intake, etc.;
Step 3: Based on available data, resources and inventory objectives, decide on the most suitable methodology;
Step 4: Collect the necessary data and estimate emissions for each animal type then sum for each pollutant;
Step 5: Spatially and temporally disaggregate as required.

5.1.2.1 Emissions to Air

34. IPCC Guidelines 2006 [12] and 2019 Refinement of IPCC Guidelines 2006 [10] provide the most comprehensive description of techniques and methods to estimate emissions to air from manure management.

Methane emissions

35. IPCC Guidelines [12][10] recommended the following four as a good practice for estimating methane emissions from manure:

Step 1: Collect population data from the Livestock Population Characterization as described in IPCC Guidelines, Annex I, Appendix B.
Step 2: Use default values or develop country-specific emission factors for each livestock subcategory in terms of kilograms of methane per animal per year.
Step 3: Multiply the livestock subcategory emission factors by the subcategory populations to estimate subcategory emissions, and sum across the subcategories to estimate total emissions by primary livestock species.
Step 4: Sum emissions from all defined livestock species to determine national emissions.

36. The updated IPCC Guidelines [10] recommend the use of the following equation for CH_4 emissions estimate (Tier 1):

where: $$CH_{4(mm)} = \left[\sum_{T,S,P} \left(N_{(T,P)} \bullet VS_{(T,P)} \bullet AWMS_{(T,S,P)} \bullet EF_{T,S,P} \right) / 1000 \right] \quad \text{(Equation 5.3)}$$

$CH_{4(mm)}$ – CH_4 emissions from Manure Management in the country, kg CH_4 yr^{-1}
$N_{(T, P)}$ = number of head of livestock species/category T in the country, for productivity system P, when applicable
$VS_{(T, P)}$ = annual average volatile solids (VS) excretion per head of species/category T, for productivity system P, when applicable in kg VS $animal^{-1}$ yr^{-1} (calculated by Equation 5.3),
$AWMS_{(T, S, P)}$ = fraction of total annual VS for each livestock species/category T that is managed in manure management system S in the country, for productivity system P, when applicable; dimensionless,
$EF_{(T, S, P)}$ = emission factor for direct CH_4 emissions from manure management system S, by animal
species/category T, in manure management system S, for productivity system P, when applicable g CH_4 kg VS^{-1}
S = manure management system[15]
T = species/category of livestock
P = high productivity system or low productivity system for use in advanced Tier 1a – omitted if using a simple Tier 1 approach.

37. Volatile solids (VS) are the organic material in livestock manure and consist of both biodegradable and nonbiodegradable fractions. VS excretion rates can be calculated as:

$$VS_{(T,P)} = \left(VS_{rate(T,P)} \bullet \frac{TAM_{T,P}}{1000} \right) \bullet 365 \quad \text{(Equation 5.4)}$$

where:

VS (T, P) = annual VS excretion for livestock category T, for productivity system P (when applicable), kg VS $animal^{-1}$ yr^{-1}
VS rate (T, P) = default VS excretion rate, for productivity system P (when applicable), kg VS (1000 kg animal $mass)^{-1}yr^{-1}$
TAMT, P = typical animal mass for livestock category T, for productivity system P (when applicable), kg $animal^{-1}$.

N2O Emissions from manure management

38. IPCC Guidelines 2006 [12] and 2019 [10] provide a comprehensive description of the principles of N flow, methods to estimate the N_2O produced, directly and indirectly, during the storage and treatment of manure before it is applied to land or otherwise used for feed, fuel, or construction purposes in Chapter 10.5. The approach is based on N excretion, emission factors for N_2O emissions, as well as volatilization and leaching factors. This section also discusses the connection between IPCC N_2O reporting and NH_3 and NO_x reporting required for UNECE countries.

39. The IPCC 2019 [10] provides a thorough description of Tiers 1-3 and five steps for calculating direct N2O emissions from Manure Management. They recommend the use of the following equation:

$$N_2O_{D(mm)} = \left[\sum_{S} \left[\sum_{T,P} \left(\left(N_{(T,P)} \bullet Nex_{(T,P)} \right) \bullet AWMS_{(T,S,P)} \right) + N_{cdg(s)} \right] \bullet EF_{3(S)} \right] \bullet \frac{44}{28} \quad \text{(Equation 5.5)}$$
w

[15] https://lpelc.org/manure-collection-and-handling-systems/

N_2O D(mm) = direct N2O emissions from Manure Management in the country, kg N2O yr-1
N (T, P) = number of head of livestock species/category T in the country, for productivity system P, when applicable
Nex (T, P) = annual average N excretion per head of species/category T in the country, for productivity system P, when applicable in kg N animal-1 yr-1
N = annual N input via co-digestate in the country, kg N yr-1, where the system (s) refers exclusively to anaerobic digestion
AWMS (T, S, P) = fraction of total annual N excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless; to consider productivity class P, if using a Tier 1a approach
EF3(S) = emission factor for direct N_2O emissions from manure management system S in the country, kg NO-N/kg N in manure management system S
S = manure management system
T = species/category of livestock
P = productivity class, high or low, to be considered if using the Tier 1a approach
44/28 = conversion of N_2O-N(mm) emissions to N_2O(mm) emissions

40. To estimate the indirect N_2O emissions due to volatilization of N in forms of NH3 and NOx (N_2OG (mm)) from manure management, the IPCC Guidelines [10] recommends the following equation:

$$N_2O_{G(mm)} = (N_{volatilization-MMS} \bullet EF_4) \bullet \frac{44}{28}$$ (Equation 5.6a)

where:

N_2OG(mm) = indirect N_2O emissions due to volatilization of N from Manure Management in the country, kg N2O yr-1
$N_{volatilization\text{-}MMS}$ = amount of manure N that is lost due to volatilization of NH3 and NOx, kg N yr-1
EF_4 = emission factor for N_2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N_2O-N (kg NH_3-N + NOx-N volatilised)-1 (as per Chapter 11, Table 11.3, ref [58])

41. The indirect N_2O emissions due to leaching and runoff from manure management (N_2OL (mm)) are estimated as following:

$$N_2O_{L(mm)} = (N_{leaching-MMS} \bullet EF_5) \bullet \frac{44}{28}$$ (Equation 5.6b)

where:
$N_2O_{L(mm)}$ … and runoff from manure management in the country, kg N_2O yr^{-1}
$N_{leaching\text{-}MMS}$ = amount of manure nitrogen that is lost due to leaching, kg N yr^{-1}
EF_5 = emission factor for N_2O emissions from N leaching and runoff, kg N_2O-N/kg N leached and runoff (can be found in Annex I, Appendix B, ref [10] Chapter 11, Table 11.3)

42. The choice of emission factors including estimates and calculations of the annual average N excretion rates N ex(T, P) for Tier 2 method, N intake rate for cattle, sheep, goats, swine and poultry, default values for N excretion rates per geographic territory, and other relevant information is discussed in detail in Chapter 10.5.2. of the IPCC Guidelines [10].

5.1.2.2 Release to Water

43. Manure runoff from cropland and pastures or discharging animal feeding operations and concentrated animal feeding operations (CAFOs) often reaches surface and groundwater systems through surface runoff or infiltration, posing a significant threat to water quality. However, current inventories, including the European Inventory of Emissions to Inland Waters [13], the OECD [1][6]

and IPCC Guidelines [10] do not propose any methods to estimate pollution loading (nutrients, pathogens, veterinary antibiotics and other emerging contaminants) from this source.

44. There is a large body of the peer reviewed literature which describes agricultural pollution caused by manure runoff [2][13-22]. The European Inventory of Emissions to Inland Waters [13] suggests that diffuse pollution load is usually calculated by means of coefficients. The coefficients are usually calibrated by means of data from small homogeneous catchments and that further estimates of pollution load can be made using a mass-balance approach on a river basin scale.

45. Malve et al [23] developed an export coefficient model for estimation of diffuse pollution loads in Europe for continental scale modelling. The aim was to provide reasonable estimates across the whole of Europe based on readily accessible datasets, and that would be amenable to application within a gridded model of water quality loadings to surface waters. The export coefficient models for biochemical oxygen demand (BOD), total nitrogen (TN) and total phosphors (TP) were fitted to data from European Union European Environment Agency databases of 79–106 selected river basins around Europe depending on the variable in question. The analysis showed that estimated export coefficients were on a reasonable level with estimates made by other methods within Europe. Furthermore, it was demonstrated that runoff, number of livestock and point load were common factors for BOD, TP and TN loads with runoff as the most important factor; 2) cropland area also contributed to diffuse TN load; 3) average slope steepness and runoff, as a combined factor, had a negative effect on diffuse TP load and 4) lake area reduced diffuse loads because of retention mechanisms in lakes.

46. According to the US EPA Guide of Pollutant Load Estimation Techniques [14], reliable estimates of the pollutant loads (quantity of pollutants delivered from various sources within a watershed) are essential for development of watershed plans to address the identified water quality problems or issues. They use methods developed by Richards [24] who defined a *pollutant load* as “the mass or weight of pollutant transported in a specified unit of time from pollutant sources to a waterbody”, and the loading rate, or flux, as the instantaneous rate at which the load is passing a point of reference on a river, such as a sampling station, and has units of mass/time such as grams/second or tons/day.

47. The US EPA Guide [14] suggests three basic steps for estimating pollutant load:
- measuring water discharge (m^3s^{-1}),
- measuring pollutant concentration (mgL^{-1}), and
- calculating pollutant loads (multiplying discharge times concentration over the time frame of interest).

48. Since the flux varies with time, it is expressed in integral form, as the product of concentration and flow (Equation 5.7).

$$Load = k\int_t c(t)q(t)dt \qquad \text{(Equation 5.7)}$$

where:
k is a constant for converting units
c(t) is the pollutant concentration at time=t, and
q(t) is the water discharge at time=t.

49. Richards [24] pointed out that it is not uncommon for 80 to 90% or more of the annual load to be delivered during the 10% of the time which corresponds with high fluxes. Based on review of evaluative studies of loading approaches, Richards recommended the following approaches: averaging methods (e.g., for monthly or quarterly loads), regression approaches and ratio approaches. Most of the studies showed that ratio approaches performed better than regression and averaging methods [24].

50. The US EPA Guide of National Management Measures to Control Nonpoint Source Pollution from Agriculture [14] provides a detailed description of load estimation models including simple methods, Mid-range models, Detailed models, Field-Scale Loading Models and Integrated Modeling Systems. They also describe planning process associated with the model selection, Model Calibration and Validation, Uncertainty in Modelling Predictions, and the use of Geographic Information Systems

(GIS) Technology in Model Applications. The Guide also includes a comprehensive description of water quality monitoring techniques for non-point (diffuse) sources of pollution [25]. It highlights that without current information on water quality conditions and pollutant sources, effects of land-based activities on water quality cannot be assessed, effective management and remediation programs cannot be implemented, and program success cannot be evaluated [25].

51. The National Risk Management Research Laboratory (NRMRL) of the US EPA developed a Risk Management Evaluation (RME) tool to provide information needed to address and plan future research on the environmental impacts of concentrated animal feeding operations (CAFOs). The RME provides a comprehensive description of watershed stressors resulting from CAFO pollution, types of pollutants (e.g., nutrients, pathogens, emerging contaminants), their transport mechanisms to water, air and land and common manure management practices [26]. However, no methods or techniques for estimates of the pollution loading were proposed.

Nutrients

52. USGS [27] estimated Nutrient Inputs from Livestock Manure over 20 years period (1982 to 2001). The estimates were based on county-level livestock population data collected by the Census of Agriculture. The method took into account differences in the life cycles of farm animals (the time from birth to slaughter) during the year, and for nutrient losses in storage, handling, and application of manure. Estimates of nutrient input were made separately for each livestock group. The total mass of nutrients in manure from a livestock group was calculated as the product of the population, the nutrient content of manure, and the number of days in the life cycle.

53. In general, in the USA, nutrient balance assessment on a farm is usually calculated from records of the nutrient-containing materials coming onto the farm (feed, fertilizer, purchased animals) and those leaving the farm in the form or products (milk, meat, eggs, crops, etc.). Balances can be expressed as percentage remaining, lbs/acre remaining or, for dairy farms, as lbs remaining per unit milk produced. Researchers from Cornell University, USA, developed Whole Farm Nutrient Balance Software as a tool for calculating the farm nutrient mass balance. An estimate of the whole farm nutrient balance can also be determined from the density (the number of animal units per surface area) of livestock on the farm [28]. Gross nutrient balances for European countries are computed by Eurostat [29-31].

54. Researchers from the Joint European Research Center developed GREEN-Rgrid, a conceptual statistical regression model to estimate nutrient fluxes into the Mediterranean Sea [32]. The major benefit of this model is that that links nutrient inputs to water quality measurements. It runs on an annual basis on a grid cell size of 5 min (0.083333 degree, about 10 km at the equator) and can be used to estimate total nitrogen (TN) and phosphorus (TP), nitrate (N-NO3) and orthophosphate (P-PO4) from both non-point (diffuse) and point sources. This document contains excellent source of references for nutrient inputs from a variety of diffuse and point sources for the entire Mediterranean Basin.

55. Sources of further information are provided in Annex III, Appendix B.

5.1.2.3 Land

56. Similar to releases to water, current Inventories to do not propose methods for estimating pollutants release from manure to land (either via surface runoff infiltration or direct application to land). The reviewed peer reviewed literature and technical reports suggest that pollutants releases (nutrients, pathogens, veterinary antibiotics and other emerging contaminants) can be estimated by determining their content in the manure, the quantities of manure generated on farm and applied to land [33] [34-39]. Rayne and Aula [37] recently provided a comprehensive review of the impacts of livestock manure on soil health. Eghball et al. [38] pointed out that generally, the amount of a nutrient that is mineralized in manure is a function of manure characteristics, environmental factors, soil properties, and microbial activity. Loyon [39] pointed out that manure type (slurry, farmyard manure, dropping) and the quantities generated on farm depend on the housing type and the stage of animal

rearing. Manure management in the building (drying belt, scrapping, flushing, storage pit, etc.) also affect the quantities of manure to be handled.

5.1.2.4 Comments on reliability Accuracy and uncertainty in calculations

57. The OECD Compendiums [1][6] point out that regarding emissions to air, the use of a simple methodology involving default emission factors for NH3 for each class of animal will be less accurate than a country specific approach that takes account of different farming situations. The also highlight the fact that the uncertainty regarding agricultural emissions of N2O is including emission factors and N excretion is at high levels in general. The available emission factors do not account for the effects of soil type, crops or climate on N_2O formation. The USA EPA [14][25] discusses the importance of model calibration and validation, addressing of uncertainty in modeling approach and field measurement errors.

5.1.3 Techniques used to estimate releases from silage leachate

58. As silage leachate represents the most toxic waste stream on farm, it is very important to estimate pollutants loading rates and releases on water and land. Yet, the literature on this subject is scarce. One of the key reasons is most probably associated with the complexity and costs of equipment and labor for in-situ flow and contaminants monitoring [2][26] [40-44].

59. Based on the literature review in agricultural pollution assessment and control [2] [40-49] we propose the following four steps to estimate releases from silage leachate:

Step 1: Collect relevant data on farm numbers from the Census of Agriculture and Statistics databases for each country[16,17, 18]; Consult the Directorate-General for Agriculture and Rural Development (DG AGRI) and relevant organizations in the country to estimate number of dairy farms (e.g. feed bunks and other areas containing silage heaps).

Step 2: Conduct a comprehensive search of both peer reviewed and gray literature to determine available information on the silage making process in the country (e.g. type of forage, fodder used), nutrient, pathogens, organic matter, veterinary antibiotics (and other emerging contaminants) content of silage and farm practices employed to control runoff from silage.

Step 3: Estimate the amount of surface runoff generated for your country (using literature review and site assessment if feasible, please see equation 5.8).

For example, in Canada, the government of Ontario developed AgriSuite software which can estimate the amount of silo seepage expected from the bunker silos[19] [49].

Step 4: Calculate pollutant loading (equation 5.7) to estimate total discharge from a silage/seepage effluent. The same equation can be used for all parameters listed in Table 2.1.

Step 5: Sum emissions from all defined livestock farms to determine national emissions from this source.

60. Morin [50] provided a good summary of rainfall-runoff relationships. He highlighted that the runoff from a given rainstorm is a function of i) rainfall intensity distribution and sequence, during a particular rainstorm event; ii) soil infiltration rates; and iii) the soil surface storage capacity. He proposed a simple equation to calculate surface runoff of a storm with varying rainfall rates:

$$SR_i = S\ (p_i + SD_i^{-1} - F_i - SD_m) \qquad \text{(Equation 5.8}$$

where:

[16] https://ec.europa.eu/eurostat/statistics-explained/index.php/Farms_and_farmland_in_the_European_Union_-_statistics
[17] https://ec.europa.eu/eurostat/web/agriculture/agri-environmental-indicators
[18] https://feal-future.org/eatlas/en/node/17
[19] http://www.omafra.gov.on.ca/english/nm/nman/agrisuite.htm

R_i= surface runoff (mm) for the time segment
SD_i = surface storage detention (mm) for the time segment
SD_m = maximum storage detention (mm)
F_i = the potential infiltration (mm) of any time segment t_i (mm).

61. Ohana-Levi discussed rainfall-runoff relationships in a Semiarid, Eastern Mediterranean Watershed [51]. In the USA, Wright et al. [41] discussed the challenges of collecting the information on the amount of leachate produced. They pointed out that the amount and concentration of the effluent is partially dependent on rainfall and can be variable from season to season and from day to day depending on crop maturity and harvest conditions. Moreover, nutrient and other pollutant concentrations in silage runoff are variable, likely due to the concentration of silage leachate, storm size, season, and bunker conditions. More recently, Bernardes et al. [48] provided a comprehensive review of unique challenges associated with making silage in hot and cold regions.

62. Sources of further information are provided in Annex III, Appendix C.

5.1.4 Techniques used to estimate emissions and releases from field burning and disposal of livestock mortalities

63. As described earlier, within the EU countries, the incineration (either on or off-farm) is the main disposal route of livestock mortalities. However, other techniques including burial, burning, rendering, composting, anaerobic digestion, and alkaline hydrolysis are also practiced [52].

5.1.4.1 Emissions to Air

64. The UNEP Guidelines on Best Available Techniques (BATs) and Provisional Guidance on Best Environmental Practices (BEPs) relevant to Article 5 and Annex C of the Stockholm Convention on Persistent Organic Pollutants provide a comprehensive overview of the emissions which may originate from the destruction of animal carcasses in Section VI.I. [53]. Airborne emissions from destruction of carcasses consist of nitrogen oxides (NO_x), carbon monoxide (CO), Sulphur dioxide (SO_2), particulate matter, metal compounds, organic compounds and polychlorinated dibenzodioxins (PCDD) and dibenzofurans (PCDF) [53]. The Guidelines highlighted that there is a lack of reliability in data for polychlorinated biphenyls (PCB) and hexachlorobenzene (HCB) emissions. The Guidelines provide recommendations for primary and secondary measures and for destruction of animal carcasses, however, the protocol for determination of the emissions in not given.

65. The UK Department for Environment, Food and Rural Affairs (DEFRA) developed a test protocol to determine emissions of eight pollutants (SO_2, HCl, NOx, TPM, CO, CO_2, dioxins/furans and VOCs) [54]. The method consisted of a comprehensive literature review to determine available information available on the emissions from small incinerators, followed by the site assessment. A protocol to measure emissions from the animal carcass incinerators was developed from reference test methods used for assessing emissions from industrial processes. A full list of protocols for each parameter is provided in Table 1 of the report [98]. In addition, a continuous emission monitoring system (CEMS) was implemented on the site to determine concentrations of NOx, SO_2, CO, CO_2 and O_2 [54].

5.1.4.2 Releases to water and land

66. During carcass disposal processes surface and cooling water, can be contaminated by body fluids, suspended solids, fats and oils. Ash and other by-products from disposal are disposed of to land. However, according to the UNEP Guidelines [53] if waste products are disposed of properly to landfill, they are not anticipated to give rise to large risk of population exposure; the main route for such exposure is thus considered to be emissions to air.

5.2 Summary of Techniques used to Estimate Releases from Non-Point Sources from Crop Production

67. In the following sections, techniques for estimation of emissions and releases to air, water and land are presented for:

a. Emissions due to field burning of agricultural waste (biomass burning);
b. Releases from crop applications for use of fertilizers;
c. Releases from crop applications for use of pesticides.

5.2.1 Field burning of agricultural waste (biomass burning)

68. Biomass (stubble, crop residues, trees and other waste) burning (BB) can represent a significant pollution source, with global, regional and local impacts on air quality, public health and climate, globally.

5.2.1.1 Emissions to Air

69. The UNITAR Guidelines [5] propose that in the case of crop associated burning, the emissions can be estimated as following:

$$E_{AP\,(BB)} = EF\,(_{BT,\,AP}) * BB_{w} \qquad \text{(Equation 5.9)}$$

where:

EAP(BB) = emissions of air pollutant due to biomass burned (kg of air pollutant emissions)
EF (BT, AP) = emission factor specific to biomass type and air pollutant (kg emissions/tonne burned); The necessary emission factors can be obtained from the literature.
BBw = (total tonnes of biomass burned).

70. In a case the primary data is obtained via remote sensing a different emission factor would have to be obtained relating emissions expected from the burning of the vegetation mass in question per unit area burned. This emission factor would have to be multiplied by the total area burned, as indicated by the remote sensing data, using the following equation:

$$E_{AP\,(BB)} = EF\,(_{VT}) * \quad A_{T(BB)} \qquad \text{(Equation 5.10)}$$

where:

EAE (BB) = emissions air emissions due to biomass burned (tonnes of air emissions)
EF (VT) = emission factor specific to vegetation type being burned (tonne air emissions/unit km^2)
AT(BB) = total area of burned biomass (total km^2 burned)

71. The EMEP/EEA air pollutant emission inventory guidebook discusses choice of methods for estimating the emissions and provides comprehensive description of **Tier 1** default approach, **Tier 2** technology-specific approach and **Tier 3** emission modelling and use of facility data [55].

72. The simplest approach (**Tier 1**) is to use a single emission factor for each pollutant representing emission per mass of waste burned. This approach requires input data on the amount of waste per hectare of farmland and the total area and the Guidebook includes Tables with default values for the amount of waste per hectare of arable farmland, and some typical emission factors for dioxins, PAHs, VOCs and NH3/NH4 [1].

73. The OECD Compendium [1] recommends the following steps for the estimates of air emissions from BB:

Step 1: Determine which forms of agricultural burning are relevant to the study region and the extent of available activity data and local fuel loading values, emission factors and other data;
Step 2: Decide which estimation methods to use and collect the data needed;
Step 3: Calculate emissions for each sub-category, then aggregate as required;
Step 4: Spatially and temporally disaggregate as required.

5.2.1.2 Releases to water and land

74. Sundarambal et al. [56] investigated the impact of biomass burning on ocean water quality in Southeast Asia. They reported that atmospheric deposition represents a significant and rising source of nutrients to freshwater and marine ecosystems. It occurs either as "wet deposition" or as "dry deposition" of particles and "gaseous exchange" between the air and water. Blake and Downing [57] provide comprehensive overview and evaluation of direct methods for measuring atmospheric nutrient deposition to inland waters.

5.2.1.3 Comments on reliability

75. The OECD Compendium [1] pointed out that although activity data on the areas of farmland and crop harvests may be quite good in many countries, estimates of waste (residue/crop ratios) from crops are often unreliable. In particular, some emission factors (e.g., dioxins, PAHs in particular) may have a high degree of uncertainty. For the releases to water, Blake and Downing [57] proposed that quantification of contamination of deposition samplers by materials such as insects, plant parts, and bird droppings should be made.

76. Sources of further information are provided in Annex III, Appendix D.

5.2.2 Techniques used to estimate emissions and releases from the use of fertilizers

5.2.2.1 Data on the global chemical fertilizer (nitrogenous, potash, and phosphate fertilizers) consumption per country, measured as the quantity of plant nutrients used per unit of arable land (excluding plant and animal manures) can be found in the agricultural data compiled by the World Bank.[5]

5.2.2.2 Emissions to Air

77. The UNITAR Guidelines [5] and the OECD Compendiums [1][6] provide detailed description of techniques for estimating fertilizer emissions to air. The extent to which NH_3 is emitted to the atmosphere is dependent on the chemical composition, including the concentration of NH_3 of the fertilizer solution, the temperature of the solution, the surface area of the soil that is exposed to the atmosphere, and the resistance of NH_3 transport in the atmosphere.

NH_3 and NO emissions

78. According to the OECD Compendium [1] NH_3 and NO emissions from N fertilizers are estimated using the following **Tier 1** equation:

$$E_{pollutant} = AR_{fertiliser\_applied} \cdot * EF_{pollutant} \qquad \text{(Equation 5.11)}$$

Where:

$E_{pollutant}$ = amount of pollutant emitted (kg a^{-1}),
$AR_{fertiliser\_applied}$ = amount of N applied (kg a^{-1}),
$EF_{pollutant}$ = EF of pollutant (kg kg^{-1}).

79. The equation 5.11 is applied at the national level, using data on the annual national total fertilizer nitrogen use. According to the OECD Compendium [1] **Tier 1** approach above, default NH3 emission factor is derived from a mean of default emission factors for individual N fertilizers weighted

based on their use. The emission factors are reported as 0.05 kg NH3 kg-1 fertilizer applied for NH3 from N fertilizer, is 0.05 kg NH3 kg-1 fertilizer applied, and 0.04 kg kg-1 for NO fertilizer applied, reported as NO2 [1].

CO2 emissions

80. The CO_2 emissions from urea fertilizers are estimated using the following Tier 1 equation:

$$CO_2\text{–}C\ Emission = M * EF \qquad \text{(Equation 5.12)}$$

Where:

CO_2–C Emission = annual C emissions from urea application, tonnes C yr^{-1}
M = annual amount of urea fertilisation, tonnes urea yr^{-1}
EF = emission factor, tonne of C (tonne of urea)$^{-1}$

81. According to the OECD compendium [1] an overall emission factor of 0.20, which is the equivalent to the carbon content of urea on an atomic weight basis, for urea is applied. CO_2– C emissions should be multiplied by 44/12 to convert into CO_2.

82. The CO_2 emissions from additions of carbonate limes to soil are estimated as following (Tier 1):

$$CO_2\text{– C}\ Emission = (M_{Limestone} * EF_{Limestone}) + (M_{Dolomite} * EF_{Dolomite}) \qquad \text{(Equation 5.13)}$$

Where:

CO_2–C Emission = annual C emissions from lime application, tonnes C yr^{-1}
M = annual amount of calcic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), tonnes yr-^{1}
EF = emission factor, tonne of C (tonne of limestone or dolomite)$^{-1}$

83. An overall emission factors of 0.12 and 0.13 are applied for limestone and dolomite, respectively. They represent the equivalents to carbonate carbon contents of the materials. CO_2– C emissions should be multiplied by 44/12 to convert into CO_2 [1].

5.2.2.3 Releases to water and land

84. Fertilizers emissions and releases to water in the European River Basin Districts (RBD) are allocated using JRC's GREEN model for Nutrient-N and Nutrient-P [1] [32][58-59]. Nutrient inputs from agriculture are estimated based on the CORINE Land Cover map[20] and fertiliser rate by NUTS2[21] region and crop type. Activity rates and emission factors are both taken into account in the model calculations. Emissions from agriculture to surface water estimated using this method are then spatially allocated to RBD and their Sub-Units (RBDSU) spatial levels using GIS techniques. Proxy data used for spatial allocation are land use data, fertilizer application rates from the Common Agricultural Policy Regional Impact (CAPRI) model[22], and population statistics [1].

85. In the USA, the USGS [27] performed estimates of nutrient inputs to the land surface from fertilizers, manure and atmospheric deposition for the period 1982–2001 as a part of the National Water-Quality Assessment Program. The methods and techniques used as well as detailed maps are provided in the report [27].

5.2.2.4 Comments on reliability

86. The OECD Compendium [1] summarizes key factors that may affect the reliability of calculations of fertilizer emissions and releases to air, water and land. The compendium points out that as the area of crops under cultivation is probably accurate to better than ± 10 percent in most countries, the emission factor represents the main uncertainty in the emissions calculations for fertilizer.

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[20] CORINE Land Cover map. url: https://land.copernicus.eu/pan-european/corine-land-cover
[21] https://ec.europa.eu/eurostat/web/nuts/background
[22] https://www.capri-model.org/dokuwiki/doku.php?id=capri:concept:spatfert

87. The overall emissions in the NH_3 measurements from mineral fertilizer are about ± 50 percent. For NO emission estimates, the relative 95 percent-confidence interval may vary from -80 percent to +406 percent. Therefore, the overall uncertainty may be a factor of four. Furthermore, for CO_2 emissions from urea or liming, there are uncertainties in the amount of urea or lime applied to soils and in the net amount of carbon from urea or liming that is emitted as CO_2. The emission factors for urea and lime have an uncertainty of -50 percent [1]. There are also uncertainties associated with determination of net amount of carbon added to soils from urea or lime fertilization that is emitted as CO_2.

88. The reliability of activity data depends on the accuracy of fertilizer production, sales, import/export, and/or usage data. Since the import/export and production data have additional uncertainties due to inferences about application, the OECD Compendium [1] suggest that inventory compilers may use a conservative approach and assume that all urea or lime available for application or purchased is applied to soils.

5.2.3 Techniques used to estimate emissions and releases from the use of pesticides

89. Techniques and methodologies to estimate releases from the use of pesticides are described in UNITAR [5] and OECD Guidelines [1][6]. The European Commission established a Pesticides Database which provides thorough information on active substances used in plant protection products, maximum residue levels (MRLs) in food products, and emergency authorizations of plant protection products in Member States [60]. According to the OECD Compendium [1] pesticide emissions are potentially influenced by:

- The way in which a pesticide is applied;
- Whether the application takes place in closed spaces (greenhouses) or fields;
- The vapor pressure of the pesticide involved;
- Additives used with pesticides in order to increase their uptake;
- The meteorological conditions during application; and
- The height of the crop.

90. The compendium highlighted that quantitative data on all the factors noted above are necessary in order to calculate pesticide emissions precisely. However, in practice, this type of data is not available. Moreover, even the information on the methods of pesticides application is rare and unreliable. For this reason, the methodology proposed in the compendium assumes that application takes place under normal field conditions (i.e., no specific measures taken to avoid emissions), with a standard meteorology.

5.2.3.1 Air emissions

91. The UNITAR Guidelines [5] underlined that both the solvent carrier and the active compound usually vaporize and contribute to VOC emissions. However, the VOC content of the formulation can vary substantially from product to product, as pesticides liquid formulations can either be water or solvent based mixtures of the active compound.

92. According to the OECD Compendium [1], the emissions to air from pesticide use can be estimated from the amount of the pesticide applied and an emission factor (EF_{pest_i}) as following:

$$E_{pest} = \Sigma m_{pest\_i} * EF_{pest\_i} \qquad \text{(Equation 5.14)}$$

Where:

E_{pest} = total emission of pesticides (in t a^{-1}),
m_{pest_i} = mass of individual pesticide applied (t a^{-1}),
EF_{pest_i} = Emission Factor (EF) for individual pesticide (kg kg^{-1}).

93. The EFs can be derived from the vapour pressure of the pesticides, which are currently found as the most convenient way to estimate emissions [1].

5.2.3.2 Releases to Water

94. Factors that determine the specific risk of pesticide use on water pollution include [61-62]:

- Active ingredient(s) in the pesticide formulation
- Contaminants that exist as impurities in the active ingredient(s)
- Additives that are mixed with the active ingredient(s) (wetting agents, diluents or solvents, extenders, adhesives, buffers, preservatives, and emulsifiers)
- compounds formed during chemical, microbial, or photochemical degradation of the active ingredient
- Pesticide half-life: The more stable the pesticide, the longer it takes to break down. and the higher its persistence. The half-life is unique to individual products but variable depending on specific environmental and application factors.

5.2.3.3 Releases to Land

95. All pesticides have unique mobility properties, both vertically and horizontally through the soil structure. Residual herbicides applied directly to the soil are designed to bond to the soil structure.

96. Once a pesticide is applied to soil, it will follow one of three pathways: (i) adhering to soil particles (mainly organic matter and clays), (ii) degrading by organisms and/or free enzymes, and (iii) moving through the soil with water. From the physical-chemical data of adsorption, mobility, and degradation obtained in the laboratory, it is possible to predict with a high degree of reliability the behavior of pesticides in the soil [62]. OECD proposed several guidelines including adsorption [63], degradation [64], and leaching [65].

5.2.3.4 Comments on reliability

97. The OECD Compendium [1] pointed out that although the activity data on the areas of farmland and crop harvests may be quite good in many countries, estimates of waste (residue/crop ratios) from crops are often unreliable and as a consequence, some emission factors (e.g., dioxins, PAHs in particular) may have a high degree of uncertainty. The UNITAR Guidelines highlighted that i) in the case of the estimation techniques based on pesticide residue data generated through monitoring programs, their reliability and accuracy will depend on the availability and comprehensiveness of local pesticide monitoring studies [5]. The reliability and accuracy of the estimation techniques based on mathematical models is discussed in previous subsections and [14][16].

98. Sources of further information are provided in Annex III, Appendix E.

6. Conclusions

99. This document provides a comprehensive literature review of techniques and applied methodologies for estimation of non-point (diffuse) source emissions to air and releases to water and land from the animal farming and crop production agricultural sectors including, enteric fermentation, manure management, feed management (silage leachate), field burning of and disposal of livestock mortalities, biomass burning, use of fertilizers and use of pesticides.

100. During the process of desktop research and compilation of information, it became apparent that:

a. Information about emissions to air from the above sources is well documented; and

b. The estimation techniques about releases to water and land from the above agricultural non-point (diffuse) sources is rather limited due to the fact that data collection and estimating of pollution loadings from these pollution sources to water and land is very complex and often requires integration of scientific, technological, socio-economical and educational factors.

101. For the purpose of the document, an extensive peer-reviewed literature was compiled and integrated to assist the Contracting Parties in determination of the most appropriated methods and techniques to estimate potential pollution releases from these non-point sources. An extensive bibliography and supplemental information containing recommendations for further sources of information and peer reviewed research papers particularly relevant to Mediterranean region are presented in Annex III, Appendices A-E, for the further benefit of the Contracting Parties.

102. Apart from integrating the available information for the first time, the additional value of this document is in:

a. Inclusion of silage leachate as a non-point (diffuse) pollution source in the NBB Animal farming/PRTR Intensive livestock production Sector (Table 2.1) and proposed techniques to estimate releases from this source; and

b. Introducing two separate process categories, e.g., “field burning and disposal of livestock mortalities” (Animal farming Sector) and Biomass Burning (Agricultural Sector) instead of a single “burning of agricultural waste” process.

Annex I
Characteristics of Non-point (diffuse) Sources from Agriculture

A. Introduction

1. Characteristics of emissions and releases from the following agricultural processes: (i) Enteric Fermentation; (ii) Manure Management; (iii) Silage Leachate; (iv) Field burning of agricultural waste (disposal of livestock mortalities); (v) Crop Production including use of fertilizers; use of pesticides; and biomass burning are presented in the following sections.

B. Emissions from Enteric Fermentation

2. Enteric fermentation is a natural part of the digestive process in ruminant animals such as cattle, sheep, goats, and buffalo[23]. Microbes resident in the animal's digestive system or rumen, decompose and ferment food, and produce methane (CH4) as a by-product. This CH4 is exhaled or belched and expelled by the animal and accounts for the majority of emissions from ruminants [66-68]. The primary drivers affecting gaseous emissions are the number of animals and the type and quantity of feed consumed. The intensity of enteric methane emissions, and the potential to reduce these emissions, varies greatly across regions and production systems due to different regional conditions, and farming management practices [66]. Moss et al. [69] reported that in the EU, approximately two-thirds of annual regional methane emissions - amounting to some 6.8 million tonnes - have been attributed to enteric fermentation in ruminants. In the New Zealand, where grazing ruminants dominate the agrarian landscape, enterically generated methane accounts for 97.6% of CH4 emissions from the agricultural sector, and 85.6% of all anthropogenic CH4 discharges [67]. Gibbs et al (2001) provided a thorough overview of emissions from enteric fermentation, including methodologies to estimate methane emissions [68]. A comprehensive review of enteric fermentation process, different methods to estimate the emissions from enteric fermentation and their contribution to a global methane budget has been conducted by Thorpe (2009) [67].

C. Emissions and releases from Manure Management

Emissions to Air

3. Manure generated from farming of animals and intensive livestock production contains substantial quantities of inorganic nitrogen (N), carbon (C), and water which are the crucial substrates required for the microbial production of nitrous oxide (N2O) and methane (CH4). These greenhouse gases can be generated and emitted at each stage of the manure management including the livestock buildings, manure storage facilities, manure treatment and manure spreading to land [69-71]. The contribution of manure management to total national agricultural emissions of N2O and CH4 varies, however Chadwick et al [70] highlighted that it can exceed 50% in countries reporting to the UNFCCC.[24] They also provided a comprehensive review of N2O and CH4 emissions at each stage of manure management process [70].

Releases to water and land

4. Animal waste, including manure has serious implications for water quality. The most common pathway for contaminant (nutrients, pathogens, veterinary antibiotics and pathogens) transport is through runoff from open barnyards and feed lots, manure and feed storage units and land application. When applied to land, all contaminants contained in animal manure can travel and get transported and released to water and land via surface water runoff, soil erosion, drainage or leaching [72-74].

[23] Pigs are not included because they are monogastric, meaning they have one major stomach compartment and rely primarily on enzymes for digestion. This is in contrast to ruminants, which have three pre-stomach chambers devoted to fermentation of feedstuffs and an enzymatic stomach as well (https://extension.oregonstate.edu/node/99076/printable/print).

[24] https://unfccc.int/process/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories/submissions-of-annual-greenhouse-gas-inventories-for-2017/submissions-of-annual-ghg-inventories-2009

5. In the last 15 years veterinary medicines (antibiotics, vaccines and hormones), emerged as a new class of agricultural pollutants. Detailed information on these pollutants releases to water and their impact on the ecosystems, human health and the environment globally can be found in the Reports published by the Food and Agriculture Organization (FAO) of the United Nations Rome and joined publication of FAO and the International Water Management Institute (IWMI) [73-74].

Effects on the environment

6. Each of the above-described processes have adverse effects on the environment and human health. For example, the accumulation of nutrients from fertilizers and manure application to land, and animals farming (runoff from manure and feedlots) is a principal cause of nutrient enrichment (eutrophication) of lakes and coastal waters [2][75]. Eutrophication has many detrimental impacts on the environment, health (animal and human) and the economy. These were recently reviewed by Drizo [2] and include: i) intensified growth and production of algae, cyanobacteria (blue-green algae) and aquatic plants, commonly referred to as "harmful algal blooms (HABs)" which results in reducing oxygen content of water and hypoxia, loss of biodiversity, and fish kills; ii) excretion of toxins that may seriously affect human health. For example, the well-known blue-baby syndrome in which high levels of nitrates in water can cause methemoglobinemia; a potentially fatal illness in infants. Moreover, recent studies revealed that most cyanobacteria produce the neurotoxin beta-N-methylamino-L-alanine (BMAA) which was linked with the development of neurodegenerative diseases (Alzheimer's and Parkinson's diseases, and Amyotrophic Lateral Sclerosis (ALS)); and iii) diminishing of potable water supplies, reduction in property values, tourism and recreation leading to considerable economic losses. In addition, there is an increasing evidence that Global Climate Change will promote cyanobacterial growth and intensify algal blooms at much larger scales, further diminishing water availability and potable water supplies [2].

D. Silage Leachate

7. Silage is a type of feed made from green foliage crops which have been preserved by acidification, achieved through fermentation. It is used to feed domesticated livestock, such as cattle, sheep and other ruminants. Silage leachate (effluent) is generated from the moisture that either drains out of forage material (during or after the ensiling process) or from external water that comes into contact with and flows through the silage—or from a combination of both of these sources. It is about 200 times more polluting than raw domestic sewage, and is the most toxic waste streams on farm, containing large concentrations of organic compounds and nutrients [40][76-77]. Gebrehanna et al [76] provide an excellent summary of biochemical characteristics of silage effluent reported in the literature. A typical effluent can contain 12,000-90,000 mg/L biochemical oxygen demand (BOD), 300- 600 mg/L phosphorus (P), 800 to 3,700 mg/L organic N, and 350-700 mg/L ammonium (NH3-N). It also has a very low pH, ranging from 3.5 to 5.5.

E. Field burning of agricultural waste (disposal of livestock mortalities)

8. Animal farming systems generate a significant volume of mortalities that need to be disposed of safely, practically and economically. The most widely utilised methods for disposal of on-farm mortalities have been burial and to a lesser extent, burning. However, the implementation of the European Union (EU) Animal By-Product Regulations (1774/2002)[25] forbade these practices within the EU due to fears that infectious agents may inadvertently enter both the human food and animal feed chains and water pollution. Thus, the main disposal route became incineration (either on or off-farm) [52][78-79]. However, the emissions of gases and particulates resulting from incineration of animal carcasses may contain chemicals and other toxins and create air pollution. Incineration is known to release toxic wastes containing dioxin, mercury, lead, and other harmful substances into the air as waste is burned, to emit particle pollution, to produce toxic ashes, and to contaminate local soil

[25] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32002R1774

and vegetation [52][80]. Gwyther et al. [52] conducted a comprehensive review of the legislation and environmental and biosecurity characteristics of livestock carcass disposal methods.

F. Crop Production

Use of fertilizers

9. Farmers and agricultural producers apply millions of tons of chemical fertilizers and manure to improve crop yields. The global use of fertilizers increased 19-fold in the last century, with global use of P fertilizers increasing from about 873 million tonnes in 1913 to about 16 591 million tonnes of P in the late 1980s [33][81-82]. There is a vast variety in the type and rates of application and many fields may receive a mix of manure/fertilizer types in several applications over a single growing season. For example, grassland fields sometimes receive 10 times more dairy manure volume than fields receiving poultry or swine manure [82][2]. Similar to releases of contaminants from manure (Section 1.1.2.2) when fertilizers are applied to land, the main pathways of contaminants transport and releases to water and land are surface water runoff, soil erosion, drainage and leaching [33][81-82]. The World Bank provides a comprehensive list of data on the global chemical fertilizer (nitrogenous, potash, and phosphate fertilizers) consumption per country, measured as the quantity of plant nutrients used per unit of arable land (excluding plant and animal manures).[26] They also provide information on land surface area [83], percent of arable land and annual fertilizer consumption (kg/ha).[27] Based on World Bank data[26,27], the total annual fertilizer consumption in the Mediterranean region is (12 x 106 tons). Of these, 78.3% is used in France (3 x 106 tons) followed by Turkey (2.8 x 106 tons), Egypt (1.81 x 106 tons) and Spain (1.77 x 106 tons).

Use of pesticides

10. A pesticide is defined as any active substance or mixture used to eradicate unwanted organisms, or pests, including weeds, insects, fungi, bacteria, and rodents. Agriculture accounts for approximately 85 percent of all pesticide use. They are mainly used before or after harvest to protect and preserve crops, orchids and other plants or plant products, and to influence their growth. However, they are also used to suppress pests in confined animal farm operations (CAFOs). Therefore, the main transport and pathways of contaminants (contained in pesticides) releases to water and land are the same as those described for manure and fertilizers (Section 1.1.2) e.g., surface runoff from open lots, soil erosion, drainage and leaching [84-85]. However, unlike manure and fertilizers, pesticides are also applied on crops, fruit, vegetables and other plants and therefore are also transported in a food chain. As most pesticides are potentially toxic to humans causing both acute and chronic health effects, depending on the quantity and ways in which a person is exposed, their overuse represents a high risk to human health [84-86].

11. Pesticide can be applied in both liquid and solid form: as concentrates, solutions, aerosols, and gas; and as dusts, granules, and powders. They are generally categorized on the basis of the type of pest they are primarily designed to target, the main types of pesticides in worldwide use being herbicides (40 percent), insecticides (33 percent), and fungicides (10 percent) [84-85].

12. An extensive database of pesticides uses per area of cropland (kg/ha) for the period 1990 to 2018 has been compiled by FAO.[28] It shows that in Mediterranean region, Malta is the top user (8.6 kg/ha) followed by Italy (5.9 kg/ha) and France (4.4 kg/ha). The EU Pesticides Database [60] assists users to search for information on active substances used in plant protection products, maximum

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[26] World Bank (2021a). Fertilizer consumption (kilograms per hectare of arable land). https://data.worldbank.org/indicator/AG.CON.FERT.ZS, accessed 19th January 2021.
[27] World Bank (2021b). Arable land (% of land area). url: https://data.worldbank.org/indicator/AG.LND.ARBL.ZS, accessed 19th January 2021.
[28] FAOSTAT. Pesticides indicators. url: http://www.fao.org/faostat/en/#data/EP/visualize

residue levels (MRLs) in food products, and emergency authorisations of plant protection products in Member States.

13. The adverse effects of agricultural use of pesticides on water quality, human health and ecology have been documented for the past 25 years [3] [61-62[84-86]. Their effects depend not only on how heavily they are applied, but also on their toxicity and persistence in the environment, their handling, and the exposure of non-target organisms [85]. Pesticide accumulation in water and the food chain, with demonstrated detrimental effects on humans, led to the widespread banning of certain broad-spectrum and persistent pesticides (such as DDT and many organophosphates), but some such pesticides are still used in poorer countries, causing acute and likely chronic health effects [84].

Biomass burning

14. Biomass burning (BB) is a significant air pollution source, with global, regional and local impacts on air quality, public health and climate, globally. Agricultural residues burning emits significant amounts of greenhouse gases (CO2, CH4, CO and hydrocarbons); other gaseous pollutants such as SO2 and NOx; and smoke particles which can carry carcinogenic substances with a wide size distribution [87]. Koppmann et al. [88] and Reid et al. [89-90] made a comprehensive description of biomass-burning particles properties and their emissions impacts on air quality, health and climate. A number of researchers investigated the effects of biomass burning on air pollution in Mediterranean [91-95].

Annex II
Non-point/diffuse sources pollution inventories approach for estimating emissions from non-point (diffuse) sources to air, water and land from agriculture

A. Background

15. Sources of pollution inventories have been long established and documented. Economopoulos and the World Health Organization (WHO) described early approaches for rapid source inventory techniques for assessment of air, land and water pollution, and their use in formulating environmental control strategies nearly three decades ago [96]. UNITAR published Guidance for estimating pollution from non-point (diffuse) source emissions in 1998 [5]. They highlighted that estimation techniques for this type of sources requires different types of data and approaches compared to point sources and may include statistical data on economic activities, demographic data, remote sensing data, emission factors and engineering data; tools may include geographical information systems (GIS) and computer models (e.g., hydrology/water flow models, transportation models and others). The Guidance [5] further suggested to construct appropriate emission factors which are linked to source parameters that are known or easily obtained. For example, in the case of agriculture, the parameters could include the size and composition of cultivated area, the quantity of pesticide or fertilizer use and the locations where these chemicals are applied. In this manner, one can perform a reasonable estimate of aggregate emissions arising from non-point or diffuse sources of certain pollutants starting from simple, known parameters that are readily measured or obtained for each source type.

16. The OECD Resource Compendia of PRTR release estimation techniques provide updated description of aims and uses of emissions inventories [1][6]. The documents underline that while there are many types of inventories in OECD countries, in general, those that include non-point (diffuse) sources are usually not integrated across the environmental media, but relate to a specific environmental medium (i.e., to air, water or land). Additionally, they often apply to smaller geographic regions and are defined by jurisdictional or administrative boundaries, urban airsheds or catchments [1]. The regulatory and community right-to-know generally focus on point source emissions while government planning, policy development and reporting tools usually include both point and non-point sources and may have more restricted pollutant lists than inventories developed for the purposes of community right-to-know [1].

B. Overview of approaches for inventories on non-point (diffuse) source discharges to air from agriculture

17. The LBS Protocol stipulates the Contracting Parties to submit reports containing information on: (i) monitoring data and (ii) quantities of pollutants discharged from their territories (Article 13, para 2). The Contracting Parties agreed on development of NBB for this purpose to serve as “the monitoring tool” and to track progress, on a five-yearly basis, of discharged loads of pollutants reflecting the effectiveness of measures taken to reduce and prevent pollution from LBS. To assist countries, an updated NBB guideline was developed in 2015 (UNEP(DEPI)/MED WG.404/7 Annex IV, Appendix B, Page 11)[7].

18. Air inventories and methodologies for estimating emissions from non-point (diffuse) sources to air are well established and documented [1][5-6][96]. For example, Economopoulos and the WHO [96] suggested system analysis approach which consists of the analysis of existing problems, the identification of the most critical ones, setting of pollution control objectives and development of strategies to meet these objectives. However, their guide does not include approaches for non-point (diffuse) sources.

19. The OECD Compendiums [1][6] provide an exhaustive overview of approaches for air inventories. These inventories highlight the most common generic approaches relevant to non-point source air inventories which include:

- Emission factors (based on test data or surveys of manufacturers);
- Materials balance (assumes that all solvent in a product evaporates);
- Fuel analysis (assumes complete conversion of S to SO2 during combustion); and

- Emission estimation models (empirically derived sets of equations to estimate emissions, e.g., MOVES, COPERT 5).

20. For guidance on survey methods, the Compendia recommend Australian National Pollutant Inventory (NPI) Emission Estimation Technique (EET) manual for Aggregated Emissions from Domestic Lawn Mowing [97]. However, this manual does not discuss nor provide any estimation techniques for emissions caused by agriculture non-point (diffuse) pollution sources and processes listed in Table 5.1. To compile an emission inventory, all relevant sources of the pollutants should be identified and quantified. For further guidance we recommend the following documents:

- The UNECE Convention on Long-range Transboundary Air Pollution Task Force on Emission Inventories and Projections (TFEIP) website[29]. It provides a technical forum and expert network to harmonise emission factors, establish methodologies for the evaluation of emission data and projections and identify problems related to emissions reporting. It also offers the information on various resources and guidance documents are available to assist national emission inventory compilers with development, improvement and reporting of national emission inventories.
- IPCC (2019)[30]. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use, Chapter 10: Emissions from Livestock and Manure Management [10].
- Canada's Air Pollutant Emissions Inventory Report 2020: annex 2. The report describes approaches and methods used for the estimates of NH_3 emissions from Canadian livestock, emissions calculations for annual cattle, sheep, swine and other livestock populations, emissions emitted when synthetic fertilizers are applied for annual and perennial crop production[31].

C. Overview of approaches for inventories on non-point (diffuse) source discharges to water from agriculture

21. Techniques for estimating non-point (diffuse) sources releases to water are generally incorporated into empirical, conceptual and/or physics-based catchment models. Most of these models require spatial data on land use coverage, amount of fertilizer used, livestock numbers are other data [1][6].

22. The US EPA National Management Measures to Control Nonpoint Source Pollution from Agriculture provides a detailed guide of load estimation techniques through monitoring and modelling of pollutant load [14]. Loading models include techniques which are primarily designed to predict pollutant movement from the land surface to waterbodies and are categorized as (a) watershed loading models, (b) field-scale models, and (c) receiving-water models. Of these, field-scale models are most frequently used in agricultural systems [48]. More recently, USA EPA developed a document that describes and catalogues tools that are currently in use to estimate nitrogen, phosphorus, and sediment losses and identifies the uses for which these tools are most appropriate to achieve watershed protection [15].

23. In Europe, the European Pollutant Release and Transfer Register (E-PRTR) promulgated by the Regulation No 166/2006[32] stipulates that E-PRTR database must include releases of pollutants from diffuse sources where available [16]. When such data are not available, the European Commission is required to take actions to initiate reporting on these sources. In the last 15 years

[29] https://www.tfeip-secretariat.org/guidance-and-resources-1
[30] https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html
[31] https://www.canada.ca/en/environment-climate-change/services/air-pollution/publications/emissions-inventory-report-2020/annex-2-4.html
[32] https://eur-lex.europa.eu/eli/reg/2006/166/2009-08-07

several international activities were initiated by the Commission and the European Environmental Agency (EEA) to stimulate and facilitate reporting on diffuse sources. One of these projects was "Diffuse water emissions in E-PRTR Project" completed in 2013 is of particular relevance as the researchers 1) gathered available data on diffuse releases to surface water with data sets available up to 2009; 2) proposed alternative estimation methods where emission data are not available on the European scale; 3) developed a methodology to derive disaggregated spatial data to obtain geographical information system layers; 4) derived gridded emission map layers covering all EU27 Member States and the EFTA countries (Switzerland, Liechtenstein, Norway and Iceland) for the selected sectors and pollutants with the highest resolution possible [16].

D. Overview of approaches for inventories on non-point (diffuse) source discharges to land from agriculture

24. Compared to the available information for air and water, the information on the methodologies for estimates of the non-point (diffuse) source discharges on land is limited. Wierl et al [98] described several sources and methods used in the watershed in Wisconsin, USA which can be applied to other regions. These included: nonpoint-source control plans, field inventories, conservation plans for farm operations, county databases, and other agricultural management agencies. Watershed descriptions were developed for each of the evaluation monitoring watersheds and include information on location, climate, soil types, topography, nonpoint pollution sources, and surface-water resources. The land-use inventory team identified and quantified agricultural sources of pollutants, which included barnyard-animal waste, streambank erosion, upland soil loss, and manure spreading [98]. Lokupitiya and Paustian [99] provide a comprehensive description of methodologies and approaches for estimating GHG emissions and removals in agricultural soils.

25. For further guidance, the following documents are recommended:

- ***European Commission (2016). Soil Threats in Europe. JRC Technical Report*** [100]. This report provides comprehensive information on the major soil threats in Europe. It also includes definition of the soil threat and processes involved, state of the soil degradation, drivers/pressures (including climate, human activities, policies), key indicators and effects of the soil threat, and effects of the soil threat on soil functions.
- ***OECD (2020). Resource Compendium of PRTR release estimation techniques, Part II: Summary of Diffuse Source Techniques, Series on Pollutant Release and Transfer Registers No. 19. ENV/JM/MONO (2020)30*** [1]. This is the most recent Compendium of PRTR release estimation techniques which provides the most comprehensive, up-to-date information available on diffuse source techniques to estimate emissions and releases to air, water and land.
- ***Xiang, C., Wang, Y. and Liu, H. (2017). A scientometrics review on nonpoint source pollution research. Ecological Engineering 99: 400–408*** [17]. This paper provides insights and global trends in non-point source pollution research. 3246 journal articles on nonpoint source pollution were retrieved from the SCI-E and SSCI databases for the 14 years period (2001 to 2015).

E. Accuracy and uncertainty

26. The quality of inventories is influenced by a number of factors including accuracy (the measure of 'truth' of a measure or estimate); comparability (between different methods or datasets); completeness (the proportion of all emissions sources that are covered by the inventory); and representativeness (in relation to the study region and sources of emissions) [1].

27. The feasibility and level of accuracy of non-point (diffuse) source emissions sources is determined by the types and quality of available information [5]. The UNITAR Guidelines highlighted that the availability of information needed vary greatly between countries and for different regions

within a country. Therefore, the evaluation of availability and accuracy of information is a key when considering types of non-point (diffuse) to be included in the national PRTR system [5].

28. In discussing the accuracy and uncertainty, the OECD Compendium [1] points out definitions of accuracy and confidence described in the EEA Guidebook 2016 (updated in 2019) [101]. The Compendium highlights the fact that although the “truth” for any specific emission rate or magnitude is seldom known, the emissions can be estimated with both confidence and reliability. While confidence in inventory estimates does not make them accurate or precise, it assists in the development of a consensus that the data can be incorporated into the inventory [1]. The USEPA highlighted that prediction uncertainty is caused by natural process variability, and bias and error in sampling, measurement, and modeling [14]. A comprehensive description of uncertainties which may occur in the National Greenhouse Gas Inventories is provided in chapter 3 of the IPCC Refinement 2019 to the 2006 IPCC Guidelines [102].

29. According to the OECD Compendia [1][6], errors or uncertainty in the preparation of the inventories may include: 1) Emission factors (which do not reflect real life conditions); 2) Activity data that do not adequately reflect the study region (scaling down national or state activity data to smaller regions always results in decreased accuracy); 3) Spatial and temporal disaggregation may introduce errors that are difficult to quantify; 4) Sample surveys may be subject to sampling errors.

F. Quality control and quality assurance

30. The IPCC Refinement 2019 to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories provides a comprehensive description of the quality assurance/quality control (QA/QC) and verification in chapter 6 [103]. These are also relevant to inventories of non-point (diffuse) sources to water and land. The IPCC Guidelines document highlights the fact that a QA/QC and verification system contribute to the objectives of good practice in inventory development, and in particular to the improvements in transparency, consistency, comparability, completeness, and accuracy of inventories. It also provides definitions of QC, QA, and verification (Box A.1):

Box A.1.: Definitions of QA/QC and Verification

Quality Control (QC) is a system of routine technical activities and procedures to assess and maintain the quality of the inventory as it is being compiled and is compiled by the inventory team. The QC system is designed to: (i) Provide routine and consistent checks to ensure data integrity, correctness, and completeness; (ii) Identify and address errors and omissions; and (iii) Document and archive inventory material and record all activities. QC activities comprise general methods such as accuracy checks on data acquisition and calculations, and the use of approved standardised procedures for emission and removal calculations, measurements, estimating uncertainties, archiving information and reporting. QC activities also include technical reviews of categories, activity data, emission factors, other estimation parameters, and methods.

Quality Assurance (QA) is a system of review procedures conducted by independent third parties. The purpose of reviews is to verify that measurable objectives (data quality objectives) are met, and to ensure that the inventory represents the best possible estimates of emissions and removals given the current state of scientific knowledge and data availability and support the effectiveness of the QC programme.

Verification refers to the collection of activities and procedures conducted during the planning and development stage, or after the completion of an inventory that can help to establish its reliability for the intended applications of the inventory.

31. The OECD Compendiums [1][6] also provide summary of QA/QC. They highlight the importance of proper documentation, which ensures reproducibility, transparency and assists future inventory updates. Documentation should include all raw data used, assumptions, steps in calculations,

and communications with data providers and QA/QC processes. Important missing data (e.g., missing pollutants, missing source types) also need to be acknowledged and documented [1][6].

Annex III
Appendices A to E

Appendix A

Sources of Further Information on Techniques used to estimate methane releases from Enteric Fermentation to Air

International

- IPCC (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Gavrilova, O., Leip, A., Dong, H., MacDonald, J.D., Bravo, C.A.G., Amon, B., Rosales, R.B., del Prado, A., de Lima, M.A., Oyhantçabal, W, van der Weerden, T.J. and Widiawati, Y. (eds). Volume 4 General Guidance and Reporting. Chapter 10: Emissions from Livestock and Manure Management. Published: IPCC, Switzerland. url: https://www.ipcc-nggip.iges.or.jp/public/2019rf/vol4.html
  This document provides updated data on Tier 1 enteric fermentation factors for cattle and buffalo for each region of the World (Table 10.11) [ref 10].

US

- US EPA (1995-2018), Compilation of Air Pollutant Emission Factors, Volume I, Stationary Point and Area Sources, AP-42 (United States Environmental Protection Agency, North Carolina, US), Chapter 14, Section 4: Enteric Fermentation – Greenhouse Gases, http://www3.epa.gov/ttnchie1/ap42/ch14/final/c14s04.pdf

Canada

- Basarab, J.A., Okine, E.K., Baron, V.S., Marx, T.H., Ramsey, P., Ziegler, K., and Lyle, K.L. (2005). Methane emissions from enteric fermentation in Alberta's beef cattle population: A model methodology for Canada. Canadian Journal of Animal Science, 85(4), pp. 501-512 [ref 104].
- Karimi-Zindashty, Y., MacDonald, J.D., Desjardins, R.L., Worth, D.E., Hutchinson, J.J., and Vergé, X.P.C. (2012). "Sources of uncertainty in the IPCC Tier 2 Canadian livestock model.", Journal of Agricultural Science, 150(5), pp. 556-569. Doi : 10.1017/s002185961100092x [ref 105]

Australia

- Lines-Kelly, R. (2014). Enteric methane research: A summary of current knowledge and research. Published by the New South Wales Department of Primary Industries. url: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0011/532694/ag-resources-climate-enteric-methane.pdf [ref 106]

Mediterranean Region

- Cóndor, R.D, Valli, L., De Rosa, G., Di Francia, A. and De Lauretis, R. (2008). Estimation of the methane emission factor for the Italian Mediterranean buffalo. Animal 2(8):1247-1253.https://doi.org/10.1017/S1751731108002292 [ref 107]
- Ammar, H., Abidi, S., Ayed, M., Moujahed, N., deHaro Martí, M.E., Chahine, M., Bouraoui, R., López, S., Cheikh M'hamed, H. and Hechlef, H. (2020). Estimation of Tunisian Greenhouse Gas Emissions from Different Livestock Species1. Agriculture 10: 562-579. doi:10.3390/agriculture10110562. [ref 108]
- Ibidhi, R., & Calsamiglia, S. (2020). Carbon Footprint Assessment of Spanish Dairy Cattle Farms: Effectiveness of Dietary and Farm Management Practices as a Mitigation Strategy. Animals: an open access journal from MDPI, 10(11), 2083. https://doi.org/10.3390/ani10112083 [ref 109]
- Koch, J., Dayan, U. and Mey-Marom, A. (2000). Inventory of Greenhouse Gaseous Emissions Israel. Water Air and Soil Pollution 123(1):259-271. DOI: 10.1023/A:1005271424293 [ref 110]
- Ersoy E, Ugurlu A. The potential of Turkey's province-based livestock sector to mitigate GHG emissions through biogas production. Journal of Environmental Management. 2020 Feb;255:109858. DOI: 10.1016/j.jenvman.2019.109858. [ref 111]

- Grossi, G., Vitali, A., Lacetera, N., Danieli, P. P., Bernabucci, U., & Nardone, A. (2020). Carbon Footprint of Mediterranean Pasture-Based Native Beef: Effects of Agronomic Practices and Pasture Management under Different Climate Change Scenarios. Animals: an open access journal from MDPI, 10(3), 415. https://doi.org/10.3390/ani10030415 [ref 112]

APPENDIX B

Sources of Further Information on Techniques used to estimate emissions and releases from Manure management

International

- Boezeman, D., Wiering, M. and Crabbé, A. (2020). Agricultural Diffuse Pollution and the EU Water Framework Directive: Problems and Progress in Governance. Editorial to the MDPI Special Issue “Water Quality and Agricultural Diffuse Pollution in Light of the EU Water Framework Directive”. Water 12 2590: doi:10.3390/w12092590 [ref 113]
- Tao, Y., Liu, J., Guan, X., Chen, H., Ren, X., Wang, S., Ji, M. (2020). Estimation of potential agricultural non-point source pollution for Baiyangdian Basin, China, under different environment protection policies. PLoS One 15(9): e0239006. Published online 2020 Sep 22. doi: 10.1371/journal.pone.0239006 [ref 22].

Europe

- Preux, D. and Fribourg-Blanc, B. (2005). Overview of emissions to water - existing data collections. European Topic Centre on Water. url: https://unstats.un.org/unsd/environment/envpdf/pap_wasess4b1france.pdf [ref 18].
- Special Issue "Water Quality and Agricultural Diffuse Pollution in Light of the EU Water Framework Directive", https://www.mdpi.com/journal/water/special_issues/Water_Framework_Directive_Pollution

USA

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APPENDIX C

Sources of Further Information on Techniques used to estimate releases from Silage leachate

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Sources of Further Information on Field burning of agricultural waste (Biomass Burning)

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