TABLE 4-10
SCALING FACTORS FOR METHANE EMISSIONS FOR RICE ECOSYSTEMS RELATIVE TO CONTINUOUSLY FLOODED FIELDS (WITHOUT ORGANIC AMENDMENTS)

Category	Sub-Category[a]			Scaling Factors (relative to emission factors for continuously flooded fields)
Upland	None			0
Lowland	Irrigated	Continuously flooded		1.0
		Intermittently flooded[b]	Single aeration	0.5 (0.2-0.7)
			Multiple aeration	0.2 (0.1-0.3)
	Rainfed	Flood prone		0.8 (0.5-1.0)
		Drought prone		0.4 (0-0.5)
	Deep water	Water depth 50-100 cm		0.8 (0.6-1.0)
		Water depth > 100 cm		0.6 (0.5-0.8)

[a] other rice ecosystem categories, like swamps, inland saline or tidal wetlands may be discriminated within each sub-category according to local emission measurements.

[b] defined as > 3 days aeration during the vegetative period.

Note: For irrigated and continuously flooded, lowland rice ecosystems, the default seasonally integrated methane emission is 20 g/m^2 (see Table 4-11) for soils 'without organic amendments'. For conversion to methane emissions from soils 'with organic amendments', apply a default correction factor of 2 (Range 2-5) to the corresponding rice ecosystem for the 'without organic amendment' category.

TABLE 4-11
SEASONALLY INTEGRATED METHANE EMISSION FACTORS FOR CONTINUOUSLY FLOODED RICE WITHOUT ORGANIC FERTILISER IN VARIOUS LOCATIONS OF THE WORLD

Country	Seasonally Integrated Emission Factor, EF[a] (g/m^2)	Literature/Remarks
Australia	22.5	NGGIC, 1996
China	13 (10-22)	Wassman et al., 1993a
India	10 (5 - 15)	Mitra et al., 1996 Parashar et al., 1996
Indonesia	18 (5 - 44)	Nugroho et al., 1994a,b
Italy	36 (17-54)	Schütz et al., 1989a
Japan	15	Minami, 1995
Republic of Korea	15	Shin et al., 1995
Philippines	(25 - 30)	Neue et al., 1994; Wassman et al., 1994
Thailand	16 (4 - 40)	Towpryaoon et al., 1993
USA (Texas)	25 (15 - 35)	Sass and Fisher, 1995
Arithmetic Mean[b]	20 (12-28)	-

[a] It is recognised that the emission factors presented in Table 4-11 will need to be periodically updated as better data become available. However, this dataset represents the best available information at the time of compilation.

[b] The arithmetic mean of the seasonally integrated emission factor, EF, is derived from the values shown in Table 4-11. The range of emission factors is defined as the standard deviation about the mean.

4.4 Prescribed Burning of Savannas

4.4.1 Introduction

Savannas are tropical and subtropical formations with continuous grass coverage. The growth of savannas is controlled by alternating wet and dry seasons: most of the growth occurs during the wet season. Man-made and/or natural fires frequently occur during the dry season, resulting in nutrient recycling and regrowth. Large scale burning takes place primarily in the humid savannas because the arid savannas lack sufficient grass cover to sustain fire. Savannas are burned every one to four years on average, with the highest frequency in the humid savannas of Africa.

The burning of savannas results in instantaneous emissions of carbon dioxide. However, because the vegetation regrows between the burning cycles, the carbon dioxide released to the atmosphere is reabsorbed during the next vegetation growth period. Therefore, this *Workbook* assumes that CO_2 net emissions are zero.

The burning of savannas also releases gases other than CO_2, including methane, carbon monoxide, nitrous oxide and oxides of nitrogen. Unlike CO_2 emissions these are net anthropogenic emissions and should be accounted for.

DEGRADED SAVANNAS

Although the default assumption is that biomass burned on savannas regrows in a short period, this may not always be the case. Sometimes savannas are burned too often, or for other reasons fail to recover completely. Over time savannas can degrade significantly as a result of human intervention. In this case there will be a long-term loss of carbon in aboveground biomass and soils. If this is occurring, the annual carbon loss should be accounted for, if possible, in addition to the information requested in the *Workbook*.

4.4.2 Data sources

There are no routinely published data on the amount of savanna burned, but several assessment papers have been published. The *FAO Forest Resource Assessment 1990: Tropical Countries* (FAO 1993) provides country estimates of savanna (grassland) area and the *Greenhouse Gas Inventory Reference Manual* provides additional references.

4.4.3 Methodology

The non-CO_2 trace gas emissions from savanna burning may be estimated through a series of simple calculations using either locally available data or defaults provided in the tables in this *Workbook*.

First the quantity of biomass that actually burns is calculated by multiplying area of savanna burned by average biomass density and by the fraction of exposed biomass which actually burns.

Second, carbon released is calculated multiplying quantity of biomass burned by fraction oxidised and then by carbon fraction.

The second calculation can be greatly improved by first dividing the quantity of biomass burned into living and dead fractions. The calculation is then carried out for each of these fractions using different fractions oxidised and carbon contents for the living and dead fractions.

NON-METHANE VOLATILE ORGANIC COMPOUNDS

NMVOCs are emitted in significant quantities from biomass burning. These emissions should be estimated using the same approach provided for other non-CO_2 gases. However, the default information has not yet been developed to include this class of gases in the *Workbook*. This is an area to be considered in future improvements to the *Guidelines*.

FRACTIONS

In order to determine the amount of savanna biomass that actually oxidises to release carbon to the atmosphere, several *fractions* must be applied sequentially. To start with, the quantity of biomass exposed to fire is calculated by multiplying the area of savanna burned in the inventory year by the average biomass density (in tonnes of dry matter per hectare). The fractions are then applied as follows.

Fraction which Actually Burns

Under normal open burning conditions all biomass in each hectare does not actually burn. The *Fraction which Actually Burns* (generally 0.80 - 0.85 but may be higher in very dry regions) is applied to derive the kilotonnes of dry matter which actually burn.

Fraction Oxidised

This next fraction to be applied expresses the biomass that oxidises. Not all of the burning biomass oxidises - a small fraction may remain as charcoal. The fraction oxidised is usually 0.8 to 1.0.

Carbon Fraction

The last fraction to be applied determines the amount of carbon that is released from the fraction of biomass which has oxidised.

Third, several ratios are applied to total carbon released to derive estimates of non-CO_2 trace gas emissions, as follows:

- a nitrogen-carbon ratio is applied to estimate total nitrogen content
- ratios for CH_4 and CO as fractions of total carbon
- ratios of N_2O and NO_x as fractions of total nitrogen

The resulting estimates of emissions are converted to total weight (i.e., from CH_4 as C to CH_4 total) using standard factors.

One country may possess more than one type of savanna with different characteristics; burns may vary in efficiency; and burns may take place at different times during the dry season, causing the burning to vary with the state of the vegetation (such as the moisture content and whether the biomass is alive or dead).

If data are locally available savanna burned should be subdivided into relevant subcategories reflecting these variations and entered into the worksheet. If you are relying on the default values in this *Workbook* you will only be able to carry out calculations at a national level.

Completing the Worksheet

STEP 1 ESTIMATING TOTAL BIOMASS THAT ACTUALLY BURNS

Use WORKSHEET 4-3 PRESCRIBED BURNING OF SAVANNAS at the end of this module to record inventory data. You should do this for a single national average category or subdivide if data are locally available for each relevant subcategory of savanna.

1 For each category of savanna, enter the Area Burned (in kilohectares) in column A.

If possible use locally available data for hectares of savanna burned annually. If this is not possible, a crude default approach is to determine the total savanna area and multiply by typical regional defaults for percentage burned annually from Table 4-12 (below).

TABLE 4-12
REGIONAL SAVANNA STATISTICS

Region	Fraction of Total Savanna Burned Annually	Aboveground Biomass Density (t dm/ha)	Fraction of Biomass Actually Burned	Fraction of Aboveground Biomass that is Living
Tropical America	0.50	6.6 ±1.8		
Tropical Asia	0.50	4.9		
Tropical Africa	0.75	6.6 ±1.6		
Sahel zone	0.05-0.15	0.5-2.5*	0.95	0.20
North Sudan zone	0.25-0.50	2-4*	0.85	0.45
South Sudan zone	0.25-0.50	3-6*	0.85	0.45
Guinea zone	0.60-0.80	4-8*	0.90-1.0	0.55
Australia	0.05-0.70	2.1-6		

Regional defaults are for seasonal average densities which should be used for emissions calculations. Values marked with * are maximum, season end densities which are appropriate defaults for these very dry sub-regions.

Note: These are ecological zones that do not correspond directly to areas with political boundaries of the same name. For example, the North and South Sudan Zones include countries other than Sudan and run East-West across the African continent.

See the *Greenhouse Gas Inventory Reference Manual* for sources of these figures.

2 For each category of savanna, enter the Biomass Density of the Savanna (in tonnes of dry matter per hectare) in column B. Table 4-12 provides available summary information by region which can be used as default data.

3 Multiply the Area Burned by the Biomass Density of the Savanna to give the Total Biomass Exposed to Burning (in gigagrams of dry matter, which is the same as kilotonnes dm). Enter the result in column C.

4 Enter the Fraction of Biomass Actually Burned in column D.

Use locally available data if available. You can use a general default figure in the range 0.80 - 0.85. Some specific values for African sub-regions are given in Table 4-12.

5 Multiply Total Biomass Exposed to Burning (column C) by the Fraction Actually Burned (column D) to give the Quantity Actually Burned. Enter the results in column E.

CATEGORIES OF SAVANNAS

A number of users of the draft *Guidelines,* particularly in Africa, have suggested that savannas should be divided into woody savannas and grasslands if possible. For woody savannas, the aboveground biomass densities prior to burning would be higher and the fraction oxidised should be lower, as much of the standing woody biomass would not be burned. Other subcategories by region, time of burning, etc. may also be useful.

STEP 2 ESTIMATING THE PROPORTIONS OF LIVING AND DEAD BIOMASS

1 Enter the Fraction of Living Biomass burned in column F.

Some default figures are in Table 4-12 for specific sub-regions in Africa. In other regions users must provide these values. If no information is available, users can do the calculation using "combined values" (see margin box: categories of savannas).

2 Multiply the Quantity Actually Burned by the Fraction of Biomass Living to give the quantity of Living Biomass Burned (in gigagrams of dry matter). Enter the result in column G.

3 Subtract the Living Biomass Burned from the Quantity of Biomass Actually Burned to give the quantity of Dead Biomass Burned (in gigagrams of dry matter). Enter the result in column H.

STEP 3 ESTIMATING THE TOTAL CARBON RELEASED

COMBINED VALUES

From this point on in the worksheet, each original category is split into two parts - living and dead - for which calculations are made separately. Each row in the worksheet splits into living and dead rows for columns I through J. If users are not able to report living and dead fractions, the default calculation can be done using "combined" values from Table 4-13.

1 For each category of savanna, enter the Fraction Oxidised for *living* and *dead* biomass. Enter the results in the appropriate boxes in column I. Default figures are in Table 4-13.

TABLE 4-13
GENERAL DEFAULT VALUES

	Fraction Oxidised	Carbon Fraction
Living Fraction	0.80	0.45
Dead Fraction	1.0	0.40
Combined	0.90	0.45

2 For each category of savanna multiply the Living Biomass Burned by the Fraction Oxidised for living biomass. **Also,** multiply Dead Biomass Burned by the Fraction Oxidised for dead biomass. Enter the results, in gigagrams of dry matter, in the appropriate boxes in column J.

3 For each category of savanna, living and dead, enter the Carbon Fraction (of dry matter) of living and dead biomass in column K. Default figures are in Table 4-13.

4 Multiply the Total Biomass Burned by the Carbon Fraction for each category of savanna, living and dead, to give the Total Carbon Released. Enter the results in column L in gigagrams of carbon.

5 Add the totals in column L and enter the result in the Total box at the bottom of the column. Carry the result forward to column L at the start of sheet 3 on the next page.

STEP 4 ESTIMATING NON-CO_2 TRACE GAS EMISSIONS FROM SAVANNA BURNING

1 Enter the Nitrogen-Carbon Ratio in column M.

If no data specific to biomass type are locally available, use the general default value for savannas, which is 0.006.

2 Multiply Total Carbon Released (column L) by the Nitrogen-Carbon Ratio to give the Total Nitrogen Content (in gigagrams of Nitrogen). Enter the result in the appropriate box in column N.

3 For each gas - methane (CH_4), carbon monoxide (CO), nitrous oxide (N_2O) and nitrogen oxides (NO_x) - enter an Emission Ratio in column O.

Table 4-14 shows the default ratios.

TABLE 4-14
EMISSION RATIOS AND RANGES FOR SAVANNA BURNING CALCULATIONS

Compound	Default value	Range
CH_4	0.004	0.002 - 0.006
CO	0.06	0.04 - 0.08
N_2O	0.007	0.005 - 0.009
NO_x	0.121	0.094 - 0.148

Note: Ratios for carbon compounds are mass of carbon released as CH_4 or CO (in units of C) relative to mass of total carbon released from burning (in units of C); those for the nitrogen compounds are expressed as the ratios of mass of nitrogen compounds released relative to the total mass of nitrogen released from the fuel.

See the *Greenhouse Gas Inventory Reference Manual* for sources.

4 Multiply Total Carbon Released (column L) (for CH_4 and CO), or Total Nitrogen Content (column N) (for N_2O and NO_x) by the emissions ratios in column O to give the total emissions for each gas. Enter the results in column P.

STEP 5 CONVERT EMISSIONS OF CARBON AND NITROGEN INTO METHANE, CARBON MONOXIDE, NITROUS OXIDE AND NITROGEN OXIDE EMISSIONS.

1 Multiply the emissions of each gas expressed as C or N by the appropriate Conversion Ratio[2] in column Q to give the Emissions from Savanna Burning for each gas emitted. Enter the results in column R.

[2] The molecular weight ratios given above for the emitted gases are with respect to the weight of nitrogen or carbon in the molecule. Thus for N_2O the ratio is 44/28 and for NO_x it is 46/14. NO_2 has been used as the reference molecule for NO_x.

4.5 Field Burning of Agricultural Residues

4.5.1 Introduction

Large quantities of agricultural residues are produced from farming systems world-wide. Burning of crop residues in the fields is a common agricultural practice, particularly in developing countries. It has been estimated that as much as 40 per cent of the residues produced in developing countries may be burned in fields, while the percentage is lower in developed countries. It is important to note that some crop residues are removed from the fields and burned as a source of energy, especially in developing countries. Emissions from this type of burning are calculated in the Energy module of this *Workbook*. Users should ensure that residue burning is properly allocated to these two components and not double counted.

This submodule deals exclusively with emissions of methane, carbon monoxide, nitrous oxide and nitrogen oxides from crop residues. In this *Workbook*, field burning of crop residues is not treated as a net source of carbon dioxide because it is assumed that the carbon released to the atmosphere is reabsorbed during the next growing season. However crop residue burning is a significant net source of emissions of methane, carbon monoxide, nitrous oxide and nitrogen oxides.

4.5.2 Data sources

Annual crop production statistics by country for most of the crops from which residues are burned may be found in FAO Production Year Books (e.g., FAO, 1991). Crop specific data for each country on ratios of residue to crop production, fraction of residue burned, dry matter content of residue and carbon and nitrogen contents of residue should be provided by individual countries if available. Table 4-15 *Selected Crop Residue Statistics* shows default data for crop residues.

TABLE 4-15 SELECTED CROP RESIDUE STATISTICS				
Product	Residue / Crop Ratio	Dry Matter Fraction	Carbon Fraction	Nitrogen-Carbon Ratio
Wheat	1.3	0.78-0.88	0.4853	0.012
Barley	1.2	0.78-0.88	0.4567	
Maize	1	0.30-0.50	0.4709	0.02
Oats	1.3			
Rye	1.6			
Rice	1.4	0.78-0.88	0.4144	0.014
Millet	1.4			0.016
Sorghum	1.4			0.02
Pea	1.5			
Bean	2.1			
Soya	2.1			0.05
Potatoes	0.4	0.30-0.60	0.4226	
Feedbeet	0.3	0.10-0.20[a]	0.4072[a]	
Sugarbeet	0.2	0.10-0.20[a]	0.4072[a]	
Jerusalem artichoke	0.8			
Peanut	1			

Note: Crop statistics in this table are not complete. For values not specified you should use values for the most similar crop type as defaults.

See the *Greenhouse Gas Inventory Reference Manual* for sources.

[a] These statistics are for beet leaves.

Completing the Worksheet

STEP 1 CALCULATING THE AMOUNT OF RESIDUE

Use WORKSHEET 4-4 FIELD BURNING OF AGRICULTURAL RESIDUES to enter data for this module.

1 Specify the important crops which produce residues burned in fields and enter these as categories on the Worksheet.

2 For each type of crop, enter Annual Production in gigagrams, which is the same as kilotonnes, of crop product in column A.

3 Enter the Residue to Crop Ratio for each crop type in column B. Use Table 4-15 above if there are no local statistics.

4 Multiply the Annual Production of each crop by the Residue to Crop Ratio to give the Quantity of Residue. Enter the result in column C.

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary

STEP 2 ESTIMATING THE AMOUNT OF DRY RESIDUE

1 Enter Dry Matter Fraction for each crop type in column D.

Default values for some crop types are shown in Table 4-15.

2 Multiply the Quantity of Residue by the Dry Matter Fraction to give the Quantity of Dry Residue in gigagrams of dry matter. Enter the result in column E.

STEP 3 ESTIMATING TOTAL BIOMASS BURNED

1 Enter the Fraction Burned in Fields for each crop type in column F.

Values should reflect an average of practices for the individual country. No default data are available.

2 Enter the Fraction Oxidised for each crop type in column G (default value 0.90).

3 Multiply the Quantity of Dry Residue by the Fraction Burned in Fields and the Fraction of Biomass Oxidised to give the Total Biomass Burned (in gigagrams of dry matter). Enter the result in column H.

STEP 4 CALCULATING THE TOTAL CARBON RELEASED

1 Enter the Carbon Fraction of each residue in column I.

Default values for some crop types are shown in Table 4-15. If no other information is available, use the general default for live biomass, which is 0.5.

2 Multiply the Total Biomass Burned by the Carbon Fraction of each residue to give the Total Carbon Released in gigagrams of carbon. Enter the results in column J.

3 Add the totals for each crop type in column J and enter the result in the Total box at the bottom of the column.

STEP 5 ESTIMATING TOTAL NITROGEN RELEASED

1 Enter the Nitrogen-Carbon Ratio for each crop type in column K.

The general default Nitrogen-Carbon ratio for crops is 0.01- 0.02. Some specific values for individual crops are given in Table 4-15.

2 Multiply the Total Carbon Released (column J) by the Nitrogen-Carbon Ratio (column K) to give the Total Nitrogen Released. Enter the result in column L.

3 Add the Total Nitrogen Released for each crop type and enter the result in the Total box at the bottom of column L.

STEP 6 ESTIMATING NON-CO_2 TRACE GAS EMISSIONS

1 Enter Emission Ratios in the relevant boxes in column M. Table 4-16 shows default emission ratios and ranges.

TABLE 4-16
DEFAULT EMISSION RATES FOR AGRICULTURAL RESIDUE BURNING CALCULATIONS

	Ratios	
Gas	Default	Range
CH_4	0.005	0.003-0.007
CO	0.06	0.04-0.08
N_2O	0.007	0.005-0.009
NO_x	0.121	0.094-0.148

Note**:** Ratios for carbon compounds are mass of carbon released as CH_4 or CO (in units of C) relative to mass of total carbon released from burning (in units of C); those for the nitrogen compounds are expressed as the ratios of mass of nitrogen compounds released relative to the total mass of nitrogen released from the fuel.

See the *Greenhouse Gas Inventory Reference Manual* for sources.

2 Multiply Carbon Released (Total from column J) by the Emission Ratios for CH_4 or CO (column M) to give the Emissions of Carbon as methane and carbon monoxide. Enter the results in the appropriate boxes in column N.

3 Multiply Nitrogen Released (Total from column L) by the Emission Ratios for N_2O or NO_x (column M) to give the Emissions of Nitrogen as nitrous oxide and nitrogen oxides. Enter the results in the appropriate boxes in column N.

4 For each gas, multiply by the Conversion Ratio[3] in column O to give the amount of Emissions from Burning Agricultural Residues. Enter the results, in gigagrams of each gas, in the appropriate boxes in column P.

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[3] The molecular weight ratios given above for the emitted gases are with respect to the weight of nitrogen or carbon in the molecule. Thus for N_2O the ratio is 44/28 and for NO_x it is 46/14. NO_2 has been used as the reference molecule for NO_x.

4.6 Agricultural Soils

4.6.1 Introduction

Adequate information exists to calculate N_2O emissions from agricultural systems including (1) direct emissions of N_2O from agricultural soils (including glasshouse systems farming and excluding effects of grazing animals) (2) direct soil emissions of N_2O from animal production and (3) indirect emissions of N_2O from nitrogen used in agriculture. The calculations can be performed in 9 steps in Worksheet 4-5.

4.6.2 Data Sources

All input data can be obtained from FAO databases.

The following input data are needed:

- Total use of synthetic fertiliser in country (N_{FERT}, in kg N/yr).
- Number of livestock in country for the following categories: non-dairy cattle, dairy cattle, poultry, sheep, swine and other animals; $N_{(T)}$.
- Dry pulses and soybeans produced in country ($Crop_{BF}$, in kg/yr).
- Dry production of other crops in country ($Crop_0$, kg/yr).
- Area of cultivated organic soils (Histosols) in country (F_{OS}, ha).

4.6.3 Methodology

Total N_2O–N emissions from a country (kg N_2O–N/yr) are:

$$N_2O = N_2O_{DIRECT} + N_2O_{ANIMALS} + N_2O_{INDIRECT}$$

Completing the Worksheets

Use WORKSHEET 4-5, AGRICULTURAL SOILS at the end of this module to record the data.

ESTIMATING DIRECT NITROUS OXIDE EMISSIONS FROM AGRICULTURAL FIELDS

STEP 1 AMOUNT OF N INPUT

1 Calculation of synthetic fertiliser use (F_{SN})

The Worksheet calculations require the total synthetic fertiliser, F_{SN}, used in the country excluding emissions of NH_3 and NO_x (F_{SN}). This can be calculated from the following equation.

EQUATION 1

$$F_{SN} = N_{FERT} \times (1 - Frac_{GASF})$$

where:

N_{FERT} = total use of synthetic fertiliser in country (kg N/yr);

$Frac_{GASF}$ = fraction of total synthetic fertiliser nitrogen that is emitted as $NO_x + NH_3$ (kg N/kg N) (see Table 4-17).

Enter F_{SN} in Worksheet 4-5, sheet 1 in column A.

2 Calculation of nitrogen from animal waste (F_{AW})

The data needed are: livestock numbers in country for the following categories: non-dairy cattle, dairy cattle, poultry, sheep, swine and other animals, $N_{(T)}$.

Using nitrogen excretion factors as listed in Table 4-6, total nitrogen excretion by livestock can be calculated from livestock numbers. Table 4-7 shows the percentage of the manure-N used as fuel ($Frac_{FUEL}$), and from grazing animals (Pasture range and Paddock) ($Frac_{GRAZ}$).

EQUATION 2

$$F_{AW} = (Nex\ (1-(Frac_{FUEL} + Frac_{GRAZ} + Frac_{GASM}))$$

EQUATION 3

$$Nex = \sum [N_{(T)} \times Nex_{(T)}]$$

EQUATION 4

$$Nex_{(AWMS)} = \sum [N_{(T)} \times Nex_{(T)} \times AWMS_{(T)}]$$

where:

$AWMS_{(T)}$ = fraction of $Nex_{(T)}$ that is produced in the different distinguished animal waste management systems in country (from Tables 4-6 and 4-7);

F_{AW} = manure nitrogen used as fertiliser in country, corrected for NH_3 and NO_x emissions and excluding manure produced during grazing (kg N/yr);

$Frac_{FUEL}$ = fraction of livestock nitrogen excretion contained in excrements burned for fuel (kg N/kg N totally excreted);

$Frac_{GRAZ}$	=	fraction of livestock nitrogen excreted and deposited onto soil during grazing (kg N/kg N excreted); country estimate;
$Frac_{GASM}$	=	fraction of total nitrogen excretion that is emitted as NO_x or NH_3 (kg N/kg N) (see Table 4-17);
$N_{(T)}$	=	number of animals per Type of animal in country;
Nex	=	total nitrogen excretion by animals in country (kg N/yr);
$Nex_{(T)}$	=	nitrogen excretion per Type of animal in country (kg/yr) (see Table 4-6);
$Nex_{(AWMS)}$	=	nitrogen excretion per Animal Waste Management System (kg/yr).

Worksheet 4-5A (Supplemental) MANURE NITROGEN USED AS FERTILISER

Use Worksheet 4-5A (Supplemental) to calculate Manure Nitrogen Used as fertiliser, corrected for NH_3 and NO_x emissions and excluding manure produced during grazing.

1 Enter the Total Nitrogen Excretion, Nex for all AWMS from column A, sheet 3 Worksheet 4-1, into column A.

2 Enter the Fraction of Nitrogen burned for Fuel, $Frac_{FUEL}$, in column B. See Table 4-17 for default data.

3 Enter the Fraction of Nitrogen Excreted during Grazing, $Frac_{GRAZ}$, in column C. See Table 1 in Appendix A, Pasture Range and Paddock.

4 Enter the Fraction of Nitrogen Excreted Emitted as NO_x and NH_3, $Frac_{GASM}$, in column D. See Table 4-17 for default data. Note that the data in Appendix A are in per cent. Divide these values by 100 to obtain the Fraction of Nitrogen Excreted during Grazing.

5 Sum columns B, C and D and subtract the total from one. Enter this figure in column E.

6 Multiply columns A and E, and enter the result into column F to obtain the Manure Nitrogen Used (corrected for NH_3 and NO_x emission and excluding manure produced during grazing), F_{AW}, into column F.

7 Enter F_{AW} in Worksheet 4-5, sheet 1 in column A.

TABLE 4-17 SUMMARY OF DEFAULT VALUES FOR PARAMETERS		
$Frac_{BURN}$	=	0.25 in developing countries 0.10 or less in developed countries (kg N/kg crop-N)
$Frac_{FUEL}$	=	0.0 kg N/kg nitrogen excreted [a]
$Frac_{GASF}$	=	0.1 kg NH_3–N + NO_x–N/kg of synthetic fertiliser nitrogen applied
$Frac_{GASM}$	=	0.2 kg NH_3–N + NO_x–N/kg of nitrogen excreted by livestock
$Frac_{GRAZ}$	=	See Table A-1, Appendix A (Column Pasture Range and Paddock).[a]
$Frac_{LEACH}$	=	0.3 kg N/kg nitrogen of fertiliser or manure
$Frac_{NCRBF}$	=	0.03 kg N/kg of dry biomass
$Frac_{NCR0}$	=	0.015 kg N/kg of dry biomass
$Frac_R$	=	0.45 kg N/kg crop-N
[a] Countries are recommended to obtain country specific data.		

3. Calculation of total nitrogen input in N-fixing crops (F_{BN})

Nitrogen input from N-fixing crops (F_{BN}, kg N/yr) can be calculated from dry biomass production of pulses and soybean in country, $Crop_{BF}$ (kg/yr;):

EQUATION 5

$$F_{BN} = 2 \times Crop_{BF} \times Frac_{NCRBF}$$

where:

$Crop_{BF}$ = production of pulses + soybeans in country (kg dry biomass/yr);

$Frac_{NCRBF}$ = fraction of nitrogen in N-fixing crop (kg N/kg of dry biomass) (see Table 4-17). The factor 2 converts the FAO crop production to total crop biomass.

Enter F_{BN} in Worksheet 4-5, sheet 1 in column A.

4. Calculation of nitrogen input from crop residues (F_{CR})

Data needed to calculate nitrogen input from crop residues (F_{CR}) are:

- Dry biomass production of pulses and soybean in country, $Crop_{BF}$ (kg/yr)
- Dry biomass production of other crops in country, $Crop_0$ (kg/yr)

These numbers can be obtained from FAO databases.

Crop residue returned to soils (F_{CR}, in kg N/yr) is calculated as:

EQUATION 6

$$F_{CR} = 2 \times [Crop_0 \times Frac_{NCR0} + Crop_{BF} \times Frac_{NCRBF}] \times (1-Frac_R) \times (1-Frac_{BURN})$$

where:

$Crop_{BF}$	=	production of pulses + soybeans in country (kg dry biomass/yr);
$Crop_0$	=	production of non-N-fixing crops in country (kg dry biomass/yr);
$Frac_{NCRBF}$	=	fraction of nitrogen in N-fixing crops (kg N/kg of dry biomass) (see Table 4-17);
$Frac_{NCR0}$	=	fraction of nitrogen in non-N-fixing crops (kg N/kg of dry biomass) (see Table 4-17);
$Frac_R$	=	fraction of crop residue that is removed from the field as crop (kg N/kg crop-N) (see Table 4-17);
$Frac_{BURN}$	=	fraction of crop residue that is burned rather than left on field (see Table 4-17).

The factor 2 converts edible crop production to total crop biomass production.

Worksheet 4-5B (Supplemental) NITROGEN INPUT FROM CROP RESIDUES

Use Worksheet 4-5B (Supplemental) to calculate Nitrogen input from Crop Residues.

1 Enter the Production of non-N-fixing crops, $Crop_0$, in a country into column A. If production data are not available as dry biomass, multiply $Crop_0$ by (1-0.15) to account for crop water content.

2 Enter the Fraction of Nitrogen of non-N-fixing crops, $Frac_{NCR0}$, into column B. See Table 4-17 for default values.

3 Enter the Production of Pulses and Soybeans, $Crop_{BFN}$, into column C. If production data are not available as dry biomass, multiply $Crop_0$ by (1-0.15) to account for crop water content.

4 Enter the Fraction of Nitrogen in N-fixing crops, $Frac_{NCRBF}$ into column D. See Table 4-17 for default data.

5 Subtract the Fraction of Crop Residue Removed from Field, $Frac_R$, from one, and enter the result in column F. See Table 4-17 for default data.

6 Subtract the Fraction of Crop Residue Burnt, $Frac_{BURN}$, from one, and enter the result in column G. See Table 4-17 for default data.

7 Multiply columns A and B, and columns C with D. Sum the products, and multiply the result with the values in columns F and G. Multiply the result by 2 and enter the result into column H to obtain the nitrogen input from crop residues, F_{CR}.

8 Enter F_{CR} in Worksheet 4-5, sheet 1 in column A.

STEP 2 ESTIMATING DIRECT NITROUS OXIDE EMISSIONS EXCLUDING CULTIVATION OF HISTOSOLS

1 Enter Emission Factors for Direct Emissions in column B. Use default values for emission factor EF_1 provided in Table 4-18 or more precise locally available data.

2 Multiply the Amount of N input (column A) by the Emission Factor for Direct Emissions (column B) to give the Direct Soil emissions of N_2O. Multiply the final result by 10^{-6} to express it as gigagrams. Enter the results in column C.

3 Sum the Direct Soil Emissions and enter the total in the bottom of the column C.

STEP 3 ESTIMATING DIRECT N_2O EMISSIONS FROM CULTIVATION OF HISTOSOLS

1 Enter Area of Cultivated Organic Soils, F_{os} , in column D.

2 Enter Emission Factor for Direct Soil Emissions in column E. Use default values for Emission Factor, EF_2 provided in Table 4-18 or more precise locally available data.

3 Multiply the Area of Cultivated Organic Soils (column D) by Emission Factor for Direct Soil Emissions (column E) to give the total Direct Emissions from Histosols. Multiply the final result by 10^{-6} to express it as gigagrams. Enter the result in column F.

TABLE 4-18
SUMMARY OF DEFAULT EMISSION FACTORS FOR AGRICULTURAL EMISSIONS OF N_2O

EF_1	=	0.0125 (0.0025-0.0225) kg N_2O–N/kg nitrogen input
EF_2	=	5 temperate and 10 tropical (2-15) (kg N/ha/yr)
EF_3	=	see Table 4-8
EF_4	=	0.01 (0.002-0.02) kg N_2O–N per kg NH_3–N and NO_x–N emitted
EF_5	=	0.025 (0.002-0.12) kg N_2O–N per kg nitrogen leaching/runoff
EF_6	=	0.01 (0.002-0.12) kg N_2O–N per kg sewage-N produced

STEP 4 ESTIMATING TOTAL DIRECT N_2O EMISSIONS

Direct N_2O emissions can be calculated from the following equation:

EQUATION 7

$$N_2O_{DIRECT} \text{ (kg N/yr)} = [F_{SN} + F_{AW} + F_{CR} + F_{BN}] \times EF_1 + F_{OS} \times EF_2$$

1 Add the two totals from columns C and F together and then multiply by the conversion ratio 44/28 to give the Total Direct N_2O Emissions. Enter the result in column G.

STEP 5 ESTIMATING SOIL EMISSIONS OF N_2O FROM GRAZING ANIMALS

Only emissions from pasture range and paddock are reported here. The N_2O emissions from other Waste Management Systems are reported under Manure Management (Worksheet 4-1, sheet 2). N_2O emissions from grazing animals ($N_2O_{ANIMALS}$ in kg N/yr) can be calculated as follows:

EQUATION 8

$$N_2O_{ANIMALS} = N_2O_{(AWMS)} = \Sigma_{(T)}[N_{(T)} \times Nex_{(T)} \times AWMS_{(T)} \times EF_{3(AWMS)}]$$

where:

$N_2O_{ANIMALS}$	=	N_2O emissions from animal production in a country (kg N/yr);
$N_2O_{(AWMS)}$	=	N_2O emissions from Animal Waste Management Systems in the country (kg N/yr);
	=	$[N_{(T=1)} \times Nex_{(T=1)} \times AWMS_{(T=1)} \times EF_{3(AWMS)}]+ \ldots + [N_{(T=TMAX)} \times Nex_{(T=TMAX)} \times AWMS_{(T=TMAX)} \times EF_{3(AWMS)}]$;
$N_{(T)}$	=	number of animals of type T in the country;
$Nex_{(T)}$	=	N excretion of animals of type T in the country (kg N/animal /yr); (see Table 4-6);
$AWMS_{(T)}$	=	fraction of $Nex_{(T)}$ that is managed in one of the different distinguished animal waste management systems for animals of type T in the country; (see Table 4-7);
$EF_{3(AWMS)}$	=	N_2O emission factor for an AWMS (kg N_2O-N/kg of Nex in AWMS); (see Table 4-8);
T	=	type of animal category;
T_{MAX}	=	maximum types of animals distinguished in the country.

1 Enter Nitrogen Excretion, $Nex_{(AWMS)}$, value for Pasture Range and Paddock (from Worksheet 4-1 Supplemental) into column A.

2 Enter Emission Factor for AWMS in column B. Use default values for Emission Factors, EF_3, provided in Table 4-18 or more precise locally available data.

3 Multiply $Nex_{(AWMS)}$ (column A) by the Emission Factor (column B) and then by the conversion ratio 44/28 to give Emissions of Nitrous Oxide from Grazing Animals. Multiply the final result by 10^{-6} to express it as gigagrams. Enter the result in column C.

STEP 6 ESTIMATING INDIRECT EMISSIONS FROM ATMOSPHERIC DEPOSITION OF NH_3 AND NO_X

1 Enter the total amount of Synthetic Fertiliser N Applied to Soil, $N_{(FERT)}$, in column A.

2 Enter the Fraction of Synthetic Fertiliser N Applied that Volatilizes ($Frac_{GASFS}$) in column B. Use default values provided in Table 4-17 or more precise locally available data.

3 Multiply the total Amount of Synthetic Fertiliser Applied in the country (column A) by the Fraction of Synthetic Fertiliser N Applied that Volatilizes (column B) to give the total Amount of Synthetic Fertiliser Applied to Soil that Volatilizes. Enter the result in column C.

4 Enter the Total N Excretion by Livestock (Nex) calculated using equation 3 in column D.

5 Enter the Fraction of Total Manure N Excreted that Volatilizes ($Frac_{GASM}$) in column E. Use default values provided in Table 4-17 or more precise locally available data.

6 Multiply the Total N Excretion by Livestock, (Nex), (column D) by Fraction of Total Manure N Excreted that Volatilizes, $Frac_{GASM}$, (column E). Enter the result in column F.

7 Enter Emission Factor, EF_4, in column G. Use default values provided in Table 4-18 or more precise locally available data.

8 Add columns C and F and then multiply by Emission Factor, EF_4, (column G) to give Nitrous Oxide Emissions. Multiply the final result by 10^{-6} to express it as gigagrams. Enter the result in column H.

STEP 7 ESTIMATING INDIRECT EMISSIONS FROM LEACHING

1 Enter the total amount of Synthetic Fertiliser Use in the country $N_{(FERT)}$ in column I.

2 Enter the total Livestock N Excretion (Nex), calculated using Equation 3, in column J.

3 Enter the Fraction of N that Leaches, $Frac_{LEACH}$, in column K. Use default values provided in Table 4-17 or more precise locally available data.

4 Enter the Emission Factor, $EF_{5,}$ in column L. Use default values provided in Table 4-18 or more precise locally available data.

5 Add total amount of Synthetic Fertiliser Use in the country $N_{(FERT)}$ (column I) to Nex (column J). Multiply by $Frac_{LEACH}$ (column K) and then by EF_5 (column L) to give the indirect Nitrous Oxide Emissions from Leaching. Multiply the final result by 10^{-6} to express it as gigagram. Enter the result in column M.

STEP 8 ESTIMATING INDIRECT EMISSIONS

Indirect N_2O emissions (kg/yr) can now be calculated in Worksheet 4-5, Sheets 1 (atmospheric deposition), and 2 (leaching and runoff) as:

EQUATION 9

$$N_2O_{INDIRECT} = N_2O_{(G)} + N_2O_{(L)}$$

where:

$N_2O_{(G)}$ = $(N_{FERT} \times Frac_{GASF} + Nex\ Frac_{GASM}) \times EF_4$;

$N_2O_{(L)}$ = $(N_{FERT} + Nex) \times Frac_{LEACH} \times EF_5$.

where:

$Frac_{LEACH}$ = fraction of nitrogen input to soils that is lost through leaching and runoff (kg N/kg of nitrogen applied); (see Table 4-19);

$N_2O_{INDIRECT}$ = indirect N_2O emissions from country (kg N/yr);

$N_2O_{(G)}$ = N_2O emissions from country due to atmospheric deposition of NH_3 and NO_x (kg N/yr);

$N_2O_{(L)}$ = N_2O emissions from country due to nitrogen leaching and runoff (kg N/yr).

1 Sum the two totals in columns H and M and then multiply by the conversion ratio 44/28 to give the Total Indirect Nitrous Oxide Emissions. Enter the result in column N.