4.2.5 Afforestation and Reforestation

This section elaborates on the general discussion of methods applicable to all activities (Section 4.2 Methods for estimation, measurement, monitoring and reporting of LULUCF activities under Article 3.3 and 3.4) and should be read in conjunction with the general discussion presented earlier in this chapter.

4.2.5.1 DEFINITIONAL ISSUES AND REPORTING REQUIREMENTS

Under the definitions of the Marrakesh Accords, both afforestation and reforestation refer to direct, human-induced conversion of land to forest from another land use. The definitions do not include replanting or regeneration following harvest or natural disturbance, because these temporary losses of forest cover are not considered deforestation. Harvest followed by regeneration is considered a forest management activity. The distinction between the two activities is that afforestation occurs on land that has not been forest for at least 50 years, while reforestation occurs on land that has been forest more recently, though not since 31 December 1989. For the identification of units of land, afforestation and reforestation will be discussed together because the two definitions differ only by the time since the area was last forested, and because the same carbon reporting and accounting rules apply to both activities. When calculating changes in carbon stocks following afforestation and reforestation, the assumptions about the initial size and composition of the litter, dead wood, and soil organic carbon pools should reflect the preceding land-use type and history, rather than the distinction between afforested and reforested sites.

The annual inventory should, at a minimum, identify (for Reporting Method 1 in Section 4.2.2.2):

- The geographical location of the boundaries of the areas that encompass units of land subject to afforestation/reforestation activities (including those units of land subject to activities under Article 3.3, which would otherwise be included in land subject to elected activities under Article 3.4). The geographical boundaries which are reported should correspond to strata in the estimation of land areas as described in Section 5.3;
- For each of these areas, or strata, estimates of the area of the units of land affected by afforestation/reforestation activities in the two subcategories, namely those subject to Article 3.3, and those subject to Article 3.3 that would otherwise be subject to Article 3.4;
- The year of the start of afforestation/reforestation activities, which will be between 1 January 1990 and the end of the inventory year. Within the boundary of the areas afforestation/reforestation activities may have started in different years. It is *good practice* to group afforestation and reforestation units of land by age and to report the area in each age class separately; and
- The area of units of land subject to afforestation/reforestation in each productivity class and species combination to assign growth rate estimates and to support the calculation of carbon stock changes and non-CO_2 greenhouse emissions.

A more comprehensive system (Reporting Method 2 in Section 4.2.2.2) identifies each unit of land subject to afforestation/reforestation activities since 1990 (again in the two subcategories – Article 3.3 and Article 3.3 that would otherwise be subject to Article 3.4), using the polygon boundaries, a coordinate system (e.g., the Universal Transverse Mercator (UTM) Grid or Latitude/Longitude), or a legal description (e.g., those used by land-titles offices) of the location of the land subject to afforestation or reforestation activities. Chapter 2 (Basis for consistent representation of land areas) discusses in detail the possible approaches for consistent representation of land areas.

4.2.5.2 CHOICE OF METHODS FOR IDENTIFYING UNITS OF LAND SUBJECT TO DIRECT HUMAN-INDUCED AFFORESTATION/ REFORESTATION

Parties need to report on the carbon stock changes and non-CO_2 greenhouse gas emissions during the commitment period on areas that have been subject to afforestation and reforestation (AR) activities since 1990. The first step in this process is to make national parameter choices for the forest definition within the ranges allowed by the Marrakesh Accords, namely 0.05 – 1 ha for minimum area, minimum tree crown cover of 10-30% (or equivalent stocking level), minimum height at maturity of 2 to 5 meters and to report on these parameters, in the annual greenhouse gas inventory as set out in Table 4.2.4a. As explained in Section 4.2.2.5.1 it

is also *good practice* to choose a parameter for the minimum width of forest areas. Once the parameters have been chosen, they will allow identification of units of land subject to afforestation and reforestation.

The identification of units of land subject to afforestation / reforestation activities requires the delineation of areas that:

- Meet or exceed the size of the country's minimum area in the applied forest definition (i.e., 0.05 to 1 ha), and
- Did not meet the definition of forest on 31 December 1989, and
- Do meet the definition of forest at the time of the assessment and after 1 January 1990 as the result of direct human-induced activities.

Note that the definition of forest can be met by young trees that do not yet meet the minimum height or crown cover criteria, provided that they are expected to reach these parameter thresholds at maturity.

It is *good practice* to distinguish those areas that did not meet the crown cover threshold in the definition of forest on 31 December 1989, for example because of recent harvest or natural disturbances, from those areas that were non-forest on that date, because only the latter areas are eligible for afforestation and reforestation activities under the Marrakesh Accords. The Marrakesh Accords require that Parties provide information on the criteria used to distinguish harvesting or forest disturbance that is followed by the re-establishment of a forest from deforestation.[43] It is *good practice* to apply the same criteria when evaluating whether a unit of land meets the definition of forest. For example, if a country uses the criterion "time since harvest" to distinguish temporary forest cover loss from deforestation, and specifies that a harvested area will regenerate within X years, then only those areas that have been harvested more than X years prior to 31 December 1989 and that have not regenerated would be eligible for reforestation, as only they would be considered non-forest on 31 December 1989. Similarly, areas that have been disturbed by wildfire or other natural disturbances more than X years prior to 31 December 1989 and that have not regenerated to forest are classified as non-forest on 31 December 1989 and would therefore be eligible for reforestation.

As discussed in Section 4.2.2.2 (Reporting methods for land subject to Article 3.3 and 3.4 activities), Parties have the option to either report a complete inventory of all *units of land* subject to Article 3.3 activities, or to stratify the land into areas, i.e., defining the boundaries of these areas, and to then develop for each area estimates or inventories of the units of land subject to afforestation, reforestation and deforestation activities. Combined approaches are also possible: complete spatial inventories of all units of land can be developed for some strata, while estimates based on sampling approaches are developed for other strata in the country.

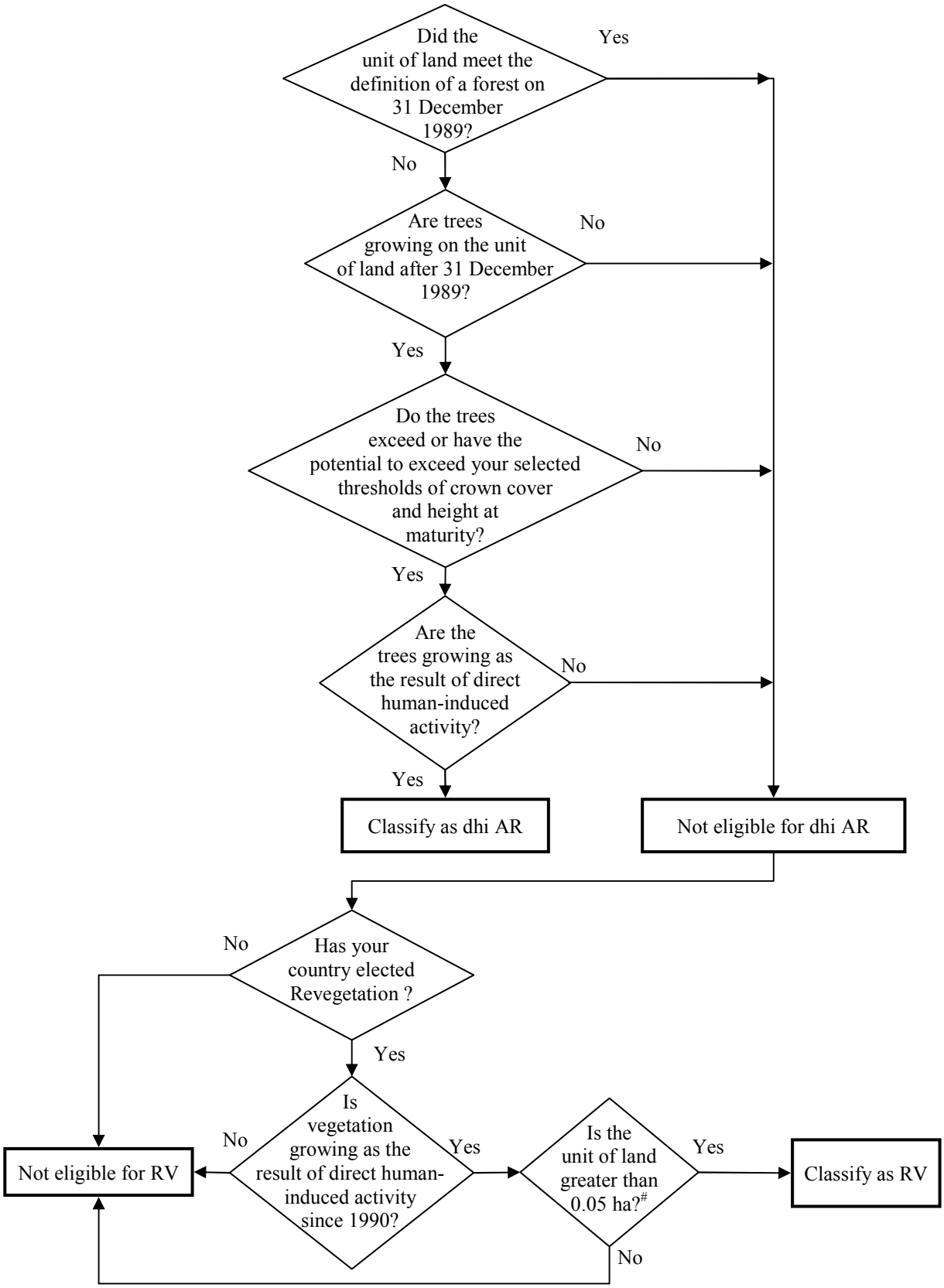
A Party's choice of methods for the development of an inventory of afforestation and reforestation activities will depend on the national circumstances. It is *good practice* to use Approach 3 in Chapter 2 (Basis for consistent representation of land area, Section 2.3.2.3) for the identification of units of land subject to afforestation and reforestation since 1990. As discussed above, this requires that the spatial resolution of the systems in Approach 3 meets the requirements for the identification of the minimum forest area of 0.05 to 1 ha. The methods available to identify lands subject to afforestation and reforestation activities are discussed in Section 4.2.8.2. It is *good practice* to provide information on uncertainties in the estimates of the total area of the units of land subject to afforestation and reforestation as discussed in Section 4.2.4.2 above.

It is *good practice* to provide documentation that all afforestation and reforestation activities included in the identified units of land are direct human-induced. Relevant documentation includes forest management records or other documentation that demonstrates that a decision had been taken to replant or to allow forest regeneration by other means.

In some cases it may not be clear whether newly established trees will pass the forest threshold. The difference between afforestation/reforestation activities and revegetation is that revegetation does not (and will not) meet the Party's definition of a forest (i.e., the height at maturity or the minimum crown closure). Where it is uncertain whether the trees on a unit of land will pass the thresholds of the definition of forest, it is *good practice* not to report these areas as afforested or reforested land, and to await confirmation (at a later time) that these parameter thresholds have been or will be passed. Prior to meeting the definition of afforestation or reforestation, the carbon stock changes on these units of land could be reported in the land-use category in which the land was reported prior to the land-use change, provided that this category is included in the national accounts, e.g., as cropland or revegetation. (Note that this approach is consistent with the treatment of deforestation, i.e., units of land that have not been confirmed as deforested remain in the forest category – see Section 4.2.6.2.1). A decision tree for determining of whether an area will qualify for afforestation/reforestation or for revegetation is given in Figure 4.2.5.

[43] See paragraph 8(b) of the Annex to draft decision -/CMP.1 (Article 7), contained in document FCCC/CP/2001/13/Add.3, p.23.

Figure 4.2.5 **Decision tree for determining whether a unit of land qualifies for direct human-induced (dhi) Afforestation/Reforestation (AR) or Revegetation (RV).**



See paragraph 1(e) in the Annex to draft decision -/CMP.1 (Land use, land-use change and forestry), contained in document FCCC/CP/2001/13/Add.1, p.58.

Links with methodologies in this report and the *IPCC Guidelines* on reporting of land areas and carbon stock changes and non-CO_2 greenhouse gas emissions in inventories under the UNFCCC are given in the box below.

BOX 4.2.2

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Section 2.3 (Representing land areas): Cropland, grassland, wetland, settlements and other land converted to forest land since 1990. Should include all transitions between 1990 and 2008, and in later inventory years, transitions on an annual basis. Note that some areas that have turned into forest since 1990 in the UNFCCC inventory may not have been converted through direct human-induced activity.

LINKS WITH THE *IPCC GUIDELINES*

Not available in a format that meets requirements in the Marrakesh Accords for geographical location of the boundaries.

4.2.5.3 CHOICE OF METHODS FOR ESTIMATING CARBON STOCK CHANGES AND NON-CO_2 EMISSIONS

Estimation of carbon stock changes from afforestation and reforestation activities should be consistent with the methods set out in Chapter 3 and the equations it contains, and applied at the same or higher tier as used for UNFCCC reporting. Growth characteristics of young trees differ from those of the managed forest as a whole, and special provisions may be needed where the UNFCCC inventory (prepared according to Section 3.2.2, Land converted to forest land) is not sufficiently detailed to provide information that applies to young stands.

On areas subject to Article 3.3 activities, gross-net accounting rules are applied and information on carbon stock changes in the base year (i.e., 1990) is therefore not required. Only the net changes in ecosystem carbon stocks and the non-CO_2 greenhouse gas emissions during each year of the commitment period are estimated and reported.

At Tier 1, biomass growth is determined using the data in Chapter 3, Section 3.2.2 (Land Converted to Forest Land).

At Tier 2, regional or national growth rates will be available as a function of stand age, species or site quality, but data may be missing for stands between 0 and 23 years (the stand age reached in 2012 by trees planted in 1990). Where biomass estimates exist for stands older than 23 years, biomass at younger ages can be estimated by interpolating between the known value and biomass zero at age zero using a sigmoidal growth function fitted to the data that are available for older stands.

At Tier 3, biomass growth rates should be established directly using measured data, validated growth models, or empirical yield tables for the appropriate combinations of species and site conditions. It is *good practice* to include ground-based field measurements as part of any Tier 3 method, either as a component of a national (or project) forest inventory or of a growth and yield forest monitoring system.

Determination of the size and dynamics of litter, dead wood and soil organic carbon pools prior to the afforestation activity may require the use of methods developed for cropland management or other land uses (see Chapter 3).

Links with methodologies in this report and the *IPCC Guidelines* on reporting of carbon stock changes and non-CO_2 greenhouse gas emissions in inventories under the UNFCCC are given in the box below.

BOX 4.2.3

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Chapter 3 Section 3.2.2 (Land converted to forest land)

LINKS WITH THE *IPCC GUIDELINES*

5 A Changes in forest and other woody biomass stocks (afforestation). *To be determined through separate monitoring for afforestation/reforestation activities*

5 C Abandonment of managed lands *(only portion that goes to forest)*

5 D CO_2 emissions and removals from soils *(only afforestation/reforestation proportion)*

5 E Other (CH_4, N_2O in managed forests) *(only afforestation/reforestation proportion)*

The default methods in the *IPCC Guidelines* do not cover belowground biomass, dead wood, litter or emissions of non-CO_2 greenhouse gas.

4.2.5.3.1 POOLS AFFECTED BY AFFORESTATION/REFORESTATION ACTIVITIES

Afforestation/reforestation activities often involve site preparation (slashing and possibly burning coarse biomass residue, and tilling or ploughing on parts of or the whole area), followed by planting or seeding. These activities may affect not only biomass pools, but also soil, as well as dead wood and litter, if (in the latter instances) land with woody shrub or sparse tree cover was afforested.

The Marrakesh Accords require Parties to estimate carbon stock changes in all five pools (see Table 3.1.1) during the commitment period unless the Party can demonstrate by transparent and verifiable information that the pool is not a source,[44] for which *good practice* advice is set out in Section 4.2.3.1. It is *good practice* to include carbon stock changes and non-CO_2 greenhouse gas emissions that result from pre-planting activities, such as site preparation or shrub removals. Soil carbon may show some decline with afforestation of grasslands (e.g., Tate *et al.*, 2003; Guo and Gifford. 2002). Net ecosystem losses of carbon after planting and seeding can persist over many years. Therefore, estimates of pre-activity carbon stocks in the area may be required to initialise the models used to estimate stock changes. Since there is no forest on the area prior to the afforestation/reforestation activity, the assessment should be done by methods described in the appropriate sections of Chapter 3, e.g., Section 3.3 for cropland.

For afforestation or reforestation activities that begin during the commitment period, reporting for that unit of land should begin at the beginning of the year in which the activity commences.[45] Site preparation and seeding/planting activities should be considered part of the activity, and associated emissions during the commitment period should therefore be included.

4.2.5.3.2 HARVESTING OF AFFORESTATION/REFORESTATION LAND DURING THE COMMITMENT PERIOD

Some short rotation forests established through afforestation and reforestation activities may be affected by harvesting during the first commitment period. The Marrakesh Accords allow Parties to limit debits from such harvests during the first commitment period.[46]

Although this is an accounting issue, it has implications for the design of carbon monitoring and reporting systems for units of land subject to afforestation or reforestation since 1990. In particular, it is *good practice* to identify the afforestation and reforestation lands on which harvesting occurs in the inventory year during the commitment period, to track carbon stock changes and non-CO_2 greenhouse gas emissions on these lands on a

[44] Paragraph 21 in the Annex to draft decision -/CMP.1 (Land use, land-use change and forestry), contained in document FCCC/CP/2001/13/Add.1, p.62.

[45] Paragraph 6(d) in the Annex to draft decision -/CMP.1 (Article 7), contained in document FCCC/CP/2001/13/Add.3, p.23.

[46] "*For the first commitment period, debits resulting from harvesting during the first commitment period following afforestation and reforestation since 1990 shall not be greater than credits accounted for on that unit of land.*" (cf. paragraph 4 in the Annex to draft decision -/CMP.1 (Land use, land-use change and forestry), contained in document FCCC/CP/2001/13/Add.1, p.59.

year by year basis during the first commitment period, so that they can be compared with the amount of credits received previously for these units of land.

The methods given in Chapter 3 for estimating non-CO_2 greenhouse gas emissions on lands converted to forest land are applicable for the afforestation and reforestation activities (see Section 3.2.2.4 Non-CO_2 greenhouse gases). If the units of land subject to afforestation and reforestation are subject to disturbances, then the Chapter 3 methods in other sections may also be applicable (see e.g., Section 3.2.1.4.3 Fires).

4.2.6 Deforestation

This section addresses specific methods applicable to deforestation activities and should be read in conjunction with the general discussion in Sections 4.2.2 to 4.2.4.

4.2.6.1 DEFINITIONAL ISSUES AND REPORTING REQUIREMENTS

Under the definitions of the Marrakesh Accords, deforestation refers to direct, human-induced conversion of forest to non-forest land. The definitions do not include harvest that is followed by regeneration since this is considered a forest management activity. Forest cover loss resulting from natural disturbances, such as wildfires, insect epidemics or wind storms, are also not considered direct human-induced deforestation, since in most cases these areas will regenerate naturally or with human assistance. Human activities (since 1990) such as cropland management or the construction of roads or settlements, that prevent forest regeneration by changing land use on areas where forest cover was removed by a natural disturbance, are also considered direct human-induced deforestation.

The annual inventory should, at a minimum, identify: (for Reporting Method 1 in Section 4.2.2.2):

- The geographical location of the boundaries of the areas that encompass units of land subject to direct human-induced deforestation activities. The geographical boundaries which are reported should correspond to strata in the estimation of land areas as described in Section 5.3;
- For each of these areas, or strata, an estimate of the area of the units of land affected by direct human-induced deforestation activities, and the area of these units of land that are also subject to elected activities under Article 3.4 (cropland management, grazing land management, revegetation);
- The year of the deforestation activities (1990 or later), which could be estimated through interpolation from a multi-year inventory; and
- The area of units of land subject to direct human-induced deforestation in each of the new land-use categories (cropland, grazing land, settlements) to support the calculation of carbon stock changes and non-CO_2 greenhouse emissions.

A more comprehensive system (Reporting Method 2 in Section 4.2.2.2) identifies each unit of land subject to deforestation since 1990 using the polygon boundaries, a coordinate system (e.g., the Universal Transverse Mercator (UTM) Grid or Latitude/Longitude), or a legal description (e.g., those used by land-titles offices) of the location of the land subject to deforestation activities. Chapter 2 (Basis for consistent representation of land areas) discusses in detail the possible approaches for consistent representation of land areas.

Parties will need to use the methods outlined in Chapter 2 (Basis for consistent representation of land areas), taking into account Section 5.3 and the guidance in Section 4.2.2 to ensure that units of land subject to deforestation are adequately identified in land-use change and other inventory databases. The Marrakesh Accords require that areas subject to direct human-induced deforestation since 1990 be reported separately from areas subject to direct human-induced deforestation since 1990 that are also subject to elected activities under Article 3.4. This will ensure that carbon stock changes in areas that have been deforested since 1990 (Article 3.3) and that are subject to other elected land uses such as cropland management (Article 3.4) are not counted twice.

A Party's choice of methods for the development of an inventory of units of land subject to deforestation activities will depend on the national circumstances. For detecting deforestation areas it is *good practice* to use Approach 3 in Section 2.3.2. Section 4.2.2.2 provides a general discussion of methods for the reporting on units of land subject to Article 3.3 activities.

4.2.6.2 CHOICE OF METHODS FOR IDENTIFYING UNITS OF LAND SUBJECT TO DIRECT HUMAN-INDUCED DEFORESTATION

Annex B Parties to the Kyoto Protocol must report carbon stock changes and non-CO_2 greenhouse gas emissions during the commitment period on land areas that have been subject to direct human-induced deforestation activities since 1990 (after 31 December 1989). The definition of deforestation is given by the Marrakesh Accords.[47] Deforestation for the purposes of the Kyoto Protocol involves the conversion of forest land to non-forest land. To quantify deforestation, forest must first be defined in terms of potential height, crown cover and minimum area as already described for afforestation and reforestation activities. The same parameter values for the definition of forest must be used for determining the area of land subject to deforestation.

Once a Party has chosen its parameter values for the definition of forests, the boundaries of the forest area can be identified for any point in time. Only areas within these boundaries are potentially subject to deforestation activities. "Treed areas" that do not meet the minimum requirements of the country-specific forest definition can therefore not be deforested.

The identification of units of land subject to deforestation activities requires the delineation of units of land that

1. Meet or exceed the size of the country's minimum forest area (i.e., 0.05 to 1 ha), and
2. Have met the definition of forest on 31 December 1989, and
3. Have ceased to meet the definition of forest at some time after 1 January 1990 as the result of direct human-induced deforestation.

Units of land can only be classified as deforested if they have been subject to direct human-induced conversion from forest to non-forest land. Areas in which forest cover was lost as a result of natural disturbances are therefore not considered deforested, even if changed physical conditions delay or prevent regeneration, provided that these changes in physical conditions are not the result of direct human-induced actions. If, however, the natural disturbance is followed by a non-forest land use, then this will prevent the regeneration of forest, and the deforestation must be considered direct human induced. Forest areas that have been flooded as a result of changed drainage patterns (e.g., road construction or hydroelectric dams) and where the flooding has resulted in a loss of forest cover, are considered to be subject to direct human-induced deforestation.

Linkages with methodologies in this report and the *IPCC Guidelines* on reporting of land areas related to deforestation (conversion of forest to other land uses) in inventories under the UNFCCC are given in the box below.

BOX 4.2.4

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Forest land converted to cropland, grassland, settlements, wetland, other land since 1990 as determined through Approach 3 in Chapter 2.

LINKS WITH THE *IPCC GUIDELINES*

Not available in a format that meets requirements in the Marrakesh Accords for geographical location of the boundaries.

[47] Paragraphs 1(d), 3 and 5, respectively, in the Annex to draft decision -/CMP.1 (Land use, land-use change and forestry), contained in document FCCC/CP/2001/13/Add.1, pp.58-59:

"Deforestation" is the direct human-induced conversion of forested land to non-forested land.

For the purposes of determining the area of deforestation to come into the accounting system under Article 3, paragraph 3, each Party shall determine the forest area using the same spatial assessment unit as is used for the determination of afforestation and reforestation, but not larger than 1 hectare.

Each Party included in Annex I shall report, in accordance with Article 7, on how harvesting or forest disturbance that is followed by the re-establishment of a forest is distinguished from deforestation. This information will be subject to review in accordance with Article 8.

4.2.6.2.1 DISCRIMINATING BETWEEN DEFORESTATION AND TEMPORARY LOSS OF FOREST COVER

Parties must report on how they distinguish between deforestation and areas that remain forests but where tree cover has been removed temporarily[48], notably areas that have been harvested or have been subject to other human disturbance but for which it is expected that a forest will be replanted or regenerate naturally. It is *good practice* to develop and report criteria by which temporary removal or loss of tree cover can be distinguished from deforestation. For example, a Party could define the expected time periods (years) between removal of tree cover and successful natural regeneration or planting. The length of these time periods could vary by region, biome, species and site conditions. In the absence of land-use change, such as conversion to cropland management or construction of settlements, areas without tree cover are considered "forest" provided that the time since forest cover loss is shorter than the number of years within which tree establishment is expected. After that time period, lands that were forest on 31 December 1989, that since then have lost forest cover due to direct human-induced actions and that failed to regenerate, are identified as deforested and the carbon stock changes and non-CO_2 greenhouse gas emissions for this land are to be recalculated and added to those of other deforested areas.

Although the loss of forest cover is often readily identified, e.g., through change detection using remote sensing images, the classification of this area as deforested is more challenging. It involves assessing the unit of land on which the forest cover loss has occurred, as well as the surrounding area, and typically requires data from multiple sources to supplement the information that can be obtained from remote sensing. In some cases a new land use can be determined from remote sensing images, for example where it is possible to identify agricultural crops or infrastructure such as houses or industrial buildings. Information about actual or planned land-use changes and actual or planned forest regeneration activities can be used to distinguish deforestation from temporary loss in forest cover. Where such information is missing or unavailable, only the passage of time will tell whether or not the cover loss is temporary. In the absence of land-use change or infrastructure development, and until the time for regeneration has elapsed, these units of land remain classified as forest. Note that this is consistent with the approach suggested for afforestation and reforestation, i.e., units of land that have not been confirmed as afforested/reforested remain classified as non-forest land. A Party may also choose a more conservative approach. It could calculate, based on regional averages or other data, the proportion of the lands without forest cover that is expected not to regenerate to forest and assign this proportion of the area to lands subject to deforestation.

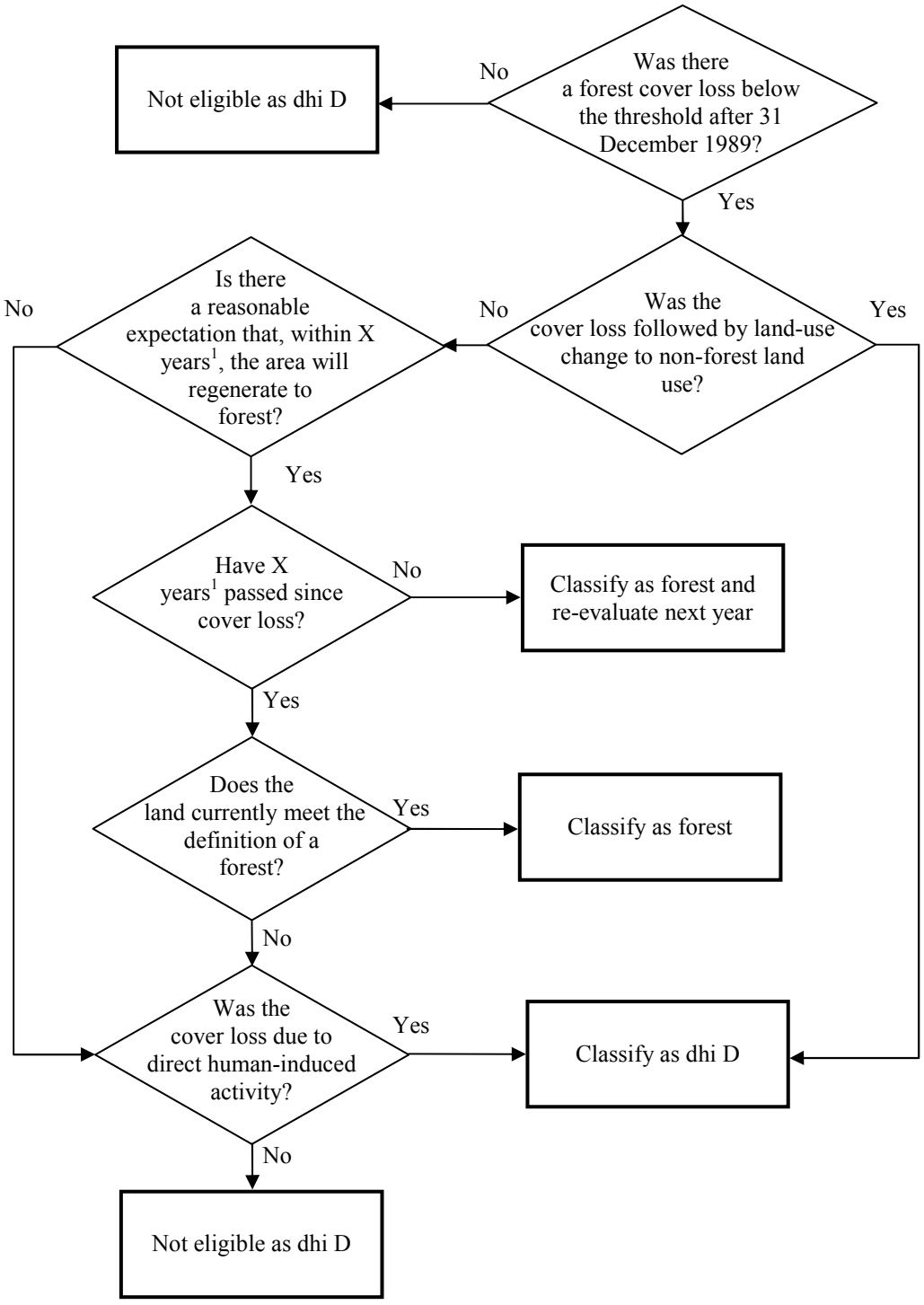
Regardless of the approach selected, it is *good practice* for Parties to identify and track the units of land with loss of forest cover that are not yet classified as deforested, and to report on their area and status in the annual supplementary information (see Table 4.2.4b in Section 4.2.4.3) It is also *good practice* to confirm that, on these units of land, regeneration did occur within the expected time period. Units of land for which, at the end of a commitment period, no direct information was available to distinguish deforestation from other causes of cover loss, could be reassessed annually or at a minimum prior to the end of the next commitment period. If regeneration did not occur or if other land-use activities are observed, then these units of land should be reclassified as deforested and the carbon stock changes recalculated accordingly (see also Chapter 5, Section 5.6 Recalculation and time series consistency).

The task of distinguishing temporary forest cover loss and deforestation can be supported by information on harvested areas and areas subject to natural disturbances. In many countries, information on harvest cut blocks and on natural disturbance events is more readily available than information on deforestation events. Such information can be used to distinguish direct human-induced deforestation from temporary cover loss (e.g., harvest) or non-human induced disturbances (e.g., wildfire or insect outbreak). Attribution of the cause of forest cover loss to the remaining areas would be made easier and would support the identification and verification of units of land subject to deforestation.

A decision tree for determining of whether a unit of land is subject to direct human-induced deforestation is given in Figure 4.2.6.

[48] Paragraph 8(b) in the Annex to draft decision -/CMP.1 (Article 7), contained in document FCCC/CP/2001/13/Add.3, p.23.

Figure 4.2.6 Decision tree for determining whether a unit of land is subject to direct human-induced (dhi) Deforestation (D)



[1] Refer to country-specific criteria for distinguishing harvesting from deforestation.

4.2.6.3 CHOICE OF METHODS FOR ESTIMATING CARBON STOCK-CHANGES AND NON-CO_2 GREENHOUSE GAS EMISSIONS

The Marrakesh Accords specify that all carbon stock changes and non-CO_2 greenhouse gas emissions during the commitment period on units of land subject to direct human-induced deforestation since 1990 must be reported. Where deforestation occurred between 1990 and the beginning of the commitment period, changes in the carbon pools after the deforestation event need to be estimated for each inventory year of the commitment period. Post-

disturbance losses during the commitment period will result primarily from the continuing decay of dead wood, litter and soil carbon remaining on the site after the deforestation event. These losses can be offset by increases in biomass pools.

If the deforestation occurs during the commitment period, biomass carbon stocks will decrease but, depending on deforestation practices, some of this biomass may be added to litter and dead wood pools. Their increase can initially partly offset biomass carbon losses and delay emissions. In subsequent years, carbon is likely to be released from litter and dead wood pools through decay or burning.

On areas subject to Article 3.3 activities, gross-net accounting rules are applied[49] and information on carbon stock changes in the base year (i.e., 1990) is therefore not required. Only the net changes in ecosystem carbon stocks and the non-CO_2 greenhouse gas emissions during each year of the commitment period are estimated and reported.

For the estimation of carbon stock changes, it is *good practice* to use the same or a higher tier than is used for estimating emissions from forest conversion in Sections 3.3.2/3.4.2/3.5.2/3.6/3.7.2 (Conversion from forest to any other broad land-use category).

Carbon stock changes on lands subject to deforestation activities during the commitment period can be estimated by determining the carbon stocks in all pools prior to and after the deforestation event. Alternatively, the stock changes could be estimated from the carbon transfers out of the forest, e.g., the amount harvested or the fuel consumed in the case of burning. For deforestation events that occur prior to the commitment period, knowledge of pre-deforestation carbon stocks will also be useful for the estimation of post-disturbance carbon dynamics. For example, estimates of emissions from decay of litter, dead wood, and soil organic carbon pools can be derived from data on pool sizes and decay rates. Information about pre-deforestation carbon stocks can be obtained from forest inventories, aerial photographs, satellite data, by comparison with adjacent remaining forests, or can be reconstructed from stumps where these are remaining on the site. Information on the time since deforestation, on the current vegetation and on management practices on that site is required for the estimation of carbon stock changes and non-CO_2 greenhouse gas emissions.

Where units of land subject to deforestation become land under cropland management or grazing land management, the established methodologies described in relevant sections of this report (Sections 3.3 Cropland, 3.4 Grassland, 4.2.8 Cropland management, 4.2.9 Grazing land management and 4.2.10 Revegetation) should be used to estimate carbon stocks changes. The estimation of carbon stock changes on lands going to other categories is covered in sections 3.5 to 3.7. Several of these categories may contain little or no carbon, or the change in carbon may be very small. Box 4.2.5 summarises links with methodologies on estimation of carbon stock changes and non-CO_2 emissions in this report and with the *IPCC Guidelines.*

BOX 4.2.5

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Chapter 3 sections on "lands converted to …" (only portion that comes from forest). (Sections 3.3.2, 3.4.2, 3.5.2, 3.6, 3.7.2 and related Appendices).

LINKS WITH THE *IPCC GUIDELINES*

5 B CO_2 emissions and non-CO_2 emissions from burning and decay of biomass from Forest and grassland conversion (only portion that comes from forest)

5 D CO_2 emissions and removals from soils (only D portion)

The default methodologies in *IPCC Guidelines* do not cover belowground biomass and dead organic matter.

[49] Except for Parties that fall under the provisions of the last sentence of Article 3.7.

4.2.7 Forest Management

This section addresses specific methods for the identification of areas subject to forest management and the calculation of carbon stock changes and non-CO_2 greenhouse gas emissions for these areas. This section should be read in conjunction in the general discussion in Sections 4.2.2 to 4.2.4.

4.2.7.1 DEFINITIONAL ISSUES AND REPORTING REQUIREMENTS

Under the Marrakesh Accords, "Forest Management" is defined as "*a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner*"[50]. It includes both natural forests and plantations meeting the forest definition in the Marrakesh Accords with the parameter values for forests that have been selected and reported by the Party. Parties must decide by 31 December 2006 whether to include forest management in their national accounts and document their choices in the submission to the UNFCCC Secretariat.

There are two approaches conceivable that countries could choose to interpret the definition of forest management. In the narrow approach, a country would define a system of specific practices that could include stand-level forest management activities, such as site preparation, planting, thinning, fertilization, and harvesting, as well as landscape-level activities such as fire suppression and protection against insects, undertaken since 1990. In this approach the area subject to forest management might increase over time as the specific practices are implemented on new areas. In the broad approach, a country would define a system of forest management practices (without the requirement that a specified forest management practice has occurred on each land), and identify the area that is subject to this system of practices during the inventory year of the commitment period. [51]

Section 4.2.2 (Generic methodologies for area identification, stratification and reporting) explains that the geographical location of the boundaries of the areas containing land subject to forest management activities need to be defined and reported. Two reporting methods are outlined in Section 4.2.2.2.

In Reporting Method 1 a boundary may encompass multiple forest management lands and other kinds of land use such as agriculture or unmanaged forests. Any estimates of carbon stock changes resulting from forest management are for the forest management areas only. In Reporting Method 2, a boundary defines 100% forest management land without other kinds of land-use. In Reporting Method 2, a Party identifies the geographic boundary of all lands subject to forest management throughout the country.

The Marrakesh Accords also specify that lands subject to forest management (Article 3.4) that are also subject to Article 3.3 activities (in this case only afforestation and reforestation) be reported separately from those lands that are subject to forest management only.

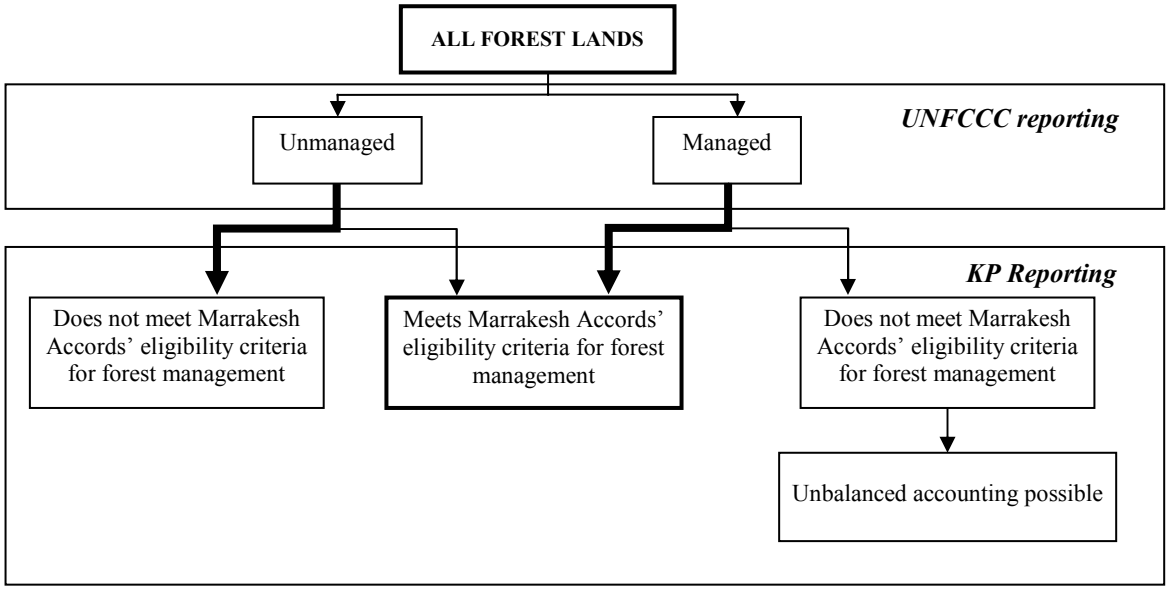
4.2.7.2 CHOICE OF METHODS FOR IDENTIFYING LANDS SUBJECT TO FOREST MANAGEMENT

Land subject to "Forest Management" as defined by the Marrakesh Accords is not necessarily the same area as "managed forests" in the context of the *IPCC Guidelines* used for UNFCCC reporting. The latter includes all forests under direct human influence, including forests that may not meet the requirements of the Marrakesh Accords. Most of the forest area that is subject to forest management under Article 3.4 of the Kyoto Protocol would also be included in the area of "managed forests" of a Party. The relationships are summarized in Figure 4.2.7.

[50] See paragraph 1 (f) in the Annex to draft decision -/CMP.1 (Land use, land-use change and forestry), contained in document FCCC/CP/2001/13/Add.1, p.58.

[51] In practice, the two approaches could lead to very similar results. For example, if the narrow approach includes landscape-level activities such as fire suppression, then the area subject to these and other forest management activities could be the same as the one resulting from the application of the broad approach.

Figure 4.2.7 **Relationship between different forest categories. Some of these lands may also be subject to activities under Article 3.3 (afforestation or reforestation) as outlined in Figure 4.1.1. Thick arrows indicate where the majority of the area included in a particular category for UNFCCC reporting is likely to be included for Kyoto Protocol reporting. See Sections 4.2.7 and 4.2.7.1 for further explanations.**



It is *good practice* for each Party that elects forest management to provide documentation of how it applies the Marrakesh Accords' definition of forest management in a consistent way, and how it distinguishes areas subject to forest management from areas that are not. Examples of country-specific decisions include the treatment of tree orchards or grazing lands with tree cover. It is *good practice* to base the assignment of land to activities using criteria of predominant land use.

Figure 4.2.7 outlines the relationship between different forest categories. For UNFCCC reporting, countries have subdivided their forest area into managed forests (those that are included in the reporting) and unmanaged forest (not included). The managed forests could further be subdivided into those areas that meet the Marrakesh Accords' eligibility criteria for forest management activities and those (if any) that do not.

Since most countries have in place policies to manage forests sustainably, and/or use *practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner*[52], the total area of managed forest in a country will often be the same as the area subject to forest management. It is *good practice* to define the national criteria for the identification of land subject to forest management such that there is good agreement between the area of managed forest (as reported under the UNFCCC) and the area of forest subject to forest management. Where differences occur between the two, these should be explained and the extent of the differences should be documented. In particular, where areas that are considered managed forest are excluded from the area subject to forest management, the reason for the exclusion should be provided, to avoid the perception of unbalanced accounting (Figure 4.2.7). Unbalanced accounting can occur if areas that are considered a source are preferentially excluded and areas considered a sink are included in the national reporting. The IPCC Report on *Definitions and Methodological Options to Inventory Emissions from Direct Human-Induced Degradation of Forests and Devegetation of Other Vegetation Types* further addresses the issue of unbalanced accounting.

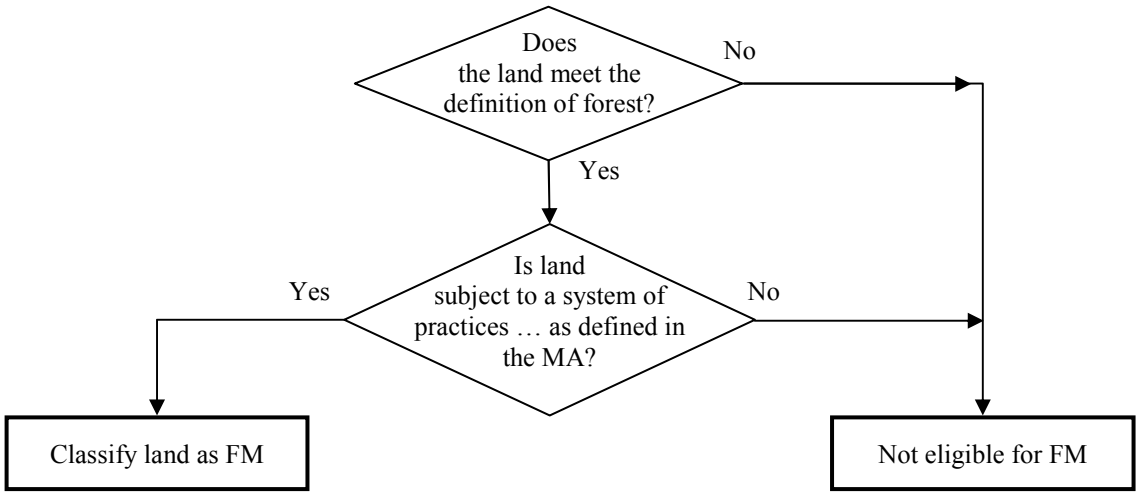
There may be national circumstances that justify the designation of areas that have been considered "unmanaged forest" for UNFCCC reporting as land subject to forest management under the Kyoto Protocol. For example, a Party may have chosen to exclude forested national parks from the area of managed forest because they are not contributing to the timber supply. But where these parks are managed to fulfil relevant ecological (including biodiversity) and social functions, and are subject to forest management activities such as fire suppression, a

[52] See paragraph 1(f) in the Annex to draft decision -/CMP.1 (Land use, land-use change and forestry), contained in document FCCC/CP/2001/13/Add.1, p.58.

country may choose to include these forested national parks as lands subject to forest management (Figure 4.2.7). In such cases, the country should consider including all areas subject to forest management activities in its managed forest area for future UNFCCC reporting years.

Figure 4.2.8 gives the decision tree for determining whether land qualifies as subject to forest management. Land that is classified as subject to forest management must meet the country's criteria for forest. It is possible that more than one direct human activity impacts the land. In such cases, national criteria need to be developed by which such lands are consistently assigned to the appropriate categories.

Figure 4.2.8 Decision tree for determining whether land qualifies as being subject to Forest Management



It is *good practice* to develop clear criteria for the distinction between land subject to forest management, and land subject to other Article 3.4 activities, and to apply these criteria consistently across space and time. For example, forest areas that are predominantly managed for grazing could be included under forest management or grazing land management, but not both. Similarly, fruit orchards can meet the definition of forest, but be under cropland management. It is *good practice* to consider the predominant human influence on land when deciding its classification. Whether land is classified under forest management, or grazing land management/cropland management has implications for the accounting rules that apply, as outlined in Table 4.1.1.

It is *good practice* for each Party to describe its application of the definition of forest management and to delineate boundaries of the areas that encompass land subject to forest management in the inventory year of the commitment period. In most cases, this will be based on information contained in forest inventories including criteria such as administrative, zoning (e.g., protected areas or parks) or ownership boundaries, since the difference between managed and unmanaged forests or, possibly, between managed forest meeting the Marrakesh Accords definition of forest management and managed forest not doing so, may be difficult or impossible to detect by remote sensing or other forms of observation. Lands subject to afforestation and reforestation activities that also qualify as forest management lands must be identified separately from those areas meeting only the criteria of Article 3.3 or those only subject to forest management under Article 3.4. Identification of these areas reduces the possibility of double counting.

The area of land subject to forest management can increase (or decrease) over time. For example, if a country expands its road infrastructure into previously unmanaged forests and initiates harvesting activities, the area of land subject to forest management is increasing and the associated carbon stock changes need to be estimated accordingly. Where changes in area occur over time, it is essential that the methods for carbon stock change calculation are applied in the sequence outlined in Section 4.2.3.2. Failure to use the correct computational methods may result in an apparent but incorrect increase in carbon stocks that is the result of the area change.

Once an area has been included in the carbon stock change reporting under the Kyoto Protocol it cannot be removed, but it can change the reporting category (as outlined in Section 4.1.2). The area subject to forest management can only decrease over time when area is lost through deforestation activities. Units of land that are deforested are, however, subject to the rules of Article 3.3 and future carbon stock changes must be reported. Thus, while the area reported under Article 3.4 would be decreasing, the area reported under Article 3.3 would be increasing by the same amount.

Box 4.2.6 summarises links with methodologies in this report and with the *IPCC Guidelines* for the identification of land areas.

BOX 4.2.6

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Forest land remaining forest land in Chapter 3.

LINKS WITH THE *IPCC GUIDELINES*

Not available in a format that meets requirements in the Marrakesh Accords for geographical location of the boundaries.

4.2.7.3 CHOICE OF METHODS FOR ESTIMATING CARBON STOCK CHANGES AND NON-CO_2 GREENHOUSE GAS EMISSIONS

The methods to estimate carbon stock changes in the various pools follow those in the *IPCC Guidelines* as elaborated in Chapter 3 for above- and belowground biomass and soil organic carbon, with litter being the same as the forest floor pool and dead wood the same as coarse woody debris, both definitions as described in Chapter 3 in Table 3.1.2.

On areas subject to forest management activities, gross-net accounting rules are applied and information on carbon stock changes in the base year (i.e., 1990 in most cases) is therefore not required. Only the net changes in ecosystem carbon stocks and the non-CO_2 greenhouse gas emissions during each year of the commitment period are estimated and reported.

In general, the LULUCF sector methods of the *IPCC Guidelines* as elaborated by Chapter 3 of this report are applicable to forest management lands. They include "*any forest which experiences periodic or on-going human interventions that affect carbon stocks*" (p. 5.14, Reference Manual, IPCC, 1997). The tier structure should be applied as follows:

- Tier 1 as elaborated in Chapter 3 assumes that the net change in the carbon stock for litter (forest floor), dead wood and soil organic carbon (SOC) pools is zero, but the Marrakesh Accords specify that above- and belowground biomass, litter, dead wood and SOC should all be counted unless the country chooses not to count a pool that can be shown not to be a source. Therefore Tier 1 can only be applied if the litter, dead wood and SOC pools can be shown not to be a source using the methods outlined in the Section 4.2.3.1. Tier 1 can also only be applied if forest management is not considered a key category, which can only be the case if "forest land remaining forest land" in Chapter 3 are not a key category.
- Tier 2 and 3 methods should be applied with all pools quantified unless the Party decides to exclude those that can be shown not to be a source, using the methods described in Section 4.3.2.1.

The information requirements for Kyoto Protocol reporting can only be satisfied with the information contained in the national UNFCCC inventory if:

1. The areas subject to forest management are the same as the areas of the managed forest (Figure 4.2.8), (or where these are not the same the area and carbon stock changes of the areas subject to forest management are known), and
2. The area and carbon stock changes of the managed forest within the geographic boundaries of each of the strata used in a country are known, and
3. The area of the managed forest that was the result of direct human-induced afforestation or reforestation since 1990 is known, along with the carbon stock changes on this area.

Where it is possible to extract this information from the UNFCCC inventory, the following steps will be necessary to prepare Kyoto Protocol reporting from the Party's UNFCCC inventory:

1. Calculate and then sum the carbon stock changes for remaining forests and transitions to forest including all pools for each of the strata used in the country.
2. Subtract carbon stock changes on areas (if any) that meet the criteria for managed forests but not for forest management as defined by the Marrakesh Accords. If national circumstances lead to the situation that the area subject to forest management under Article 3.4 contains areas that are not part of the managed forest, then the carbon stock changes on this additional area have to be added.

3. Subtract the carbon stock changes on units of land subject to afforestation and reforestation from the total remaining after Step 2, and report the results using reporting Table 4.2.5 and the means for displaying mapped information.

A possibly more practicable alternative is to calculate and sum the carbon stock changes for each stratum (the areas defined by the location of the geographical boundaries) during each year of the commitment period on all land areas that are subject to forest management. To meet the Kyoto Protocol reporting requirements, national forest carbon accounting systems should be able to track for all forest areas, whether these are classified as managed forest (UNFCCC) or subject to Articles 3.3 and/or 3.4 of the Kyoto Protocol. Such systems can then be used to calculate and report the net carbon stock changes in all relevant categories for both UNFCCC and Kyoto Protocol reporting. Such a comprehensive approach would also ensure consistency among the methods used for calculating and reporting carbon stock changes, because the same forest and land-use change inventories would be the basis for the computations used in both UNFCCC and Kyoto Protocol reporting.

Box 4.2.7 summarises links with methodologies in this report and with the *IPCC Guidelines* to estimate carbon stock changes and non-CO_2 emissions.

BOX 4.2.7

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Chapter 3 Section 3.2.1 (Forest land remaining forest land)

The area subject to forest management may not be the same as the area of "forest land remaining forest land" and estimates may have to be adjusted accordingly.

LINKS WITH THE *IPCC GUIDELINES*

5 A Changes in forest and other woody biomass stocks (subtract all afforestation and reforestation since 1990 - as determined above - from the 5A category estimate).

5 D CO_2 emissions and removals from soils

5 E Other (CH_4, N_2O in managed forests)

The default methodologies in the *IPCC Guidelines* do neither cover belowground biomass, nor dead organic matter.

Methods for estimating non-CO_2 emissions from forests remaining forests are addressed in Chapter 3 (Section 3.2.1). The *good practice guidance* for choosing activity data and emission factors for the estimation of non-CO_2 emissions as discussed in Chapter 3 also applies to forest management lands.

4.2.8 Cropland Management

4.2.8.1 DEFINITIONAL ISSUES AND REPORTING REQUIREMENTS

"Cropland management" is the system of practices on land on which agricultural crops are grown and on land that is set-aside or temporarily not being used for crop production.[53] It is *good practice* to include, in land subject to cropland management, all the lands in category (ii) of the land-use (LU) system of Chapter 2 (Section 2.2 Land-use categories), namely Cropland/arable/tillage.

To be included under cropland management are all lands under temporary (annuals) and permanent (perennials) crops, and all fallow lands set at rest for one or several years before being cultivated again. Perennial crops include trees and shrubs producing fruits, such as orchards (see exceptions below), vineyards and plantations such as cocoa, coffee, tea and bananas. If these lands meet the threshold criteria for forests (see Footnote 6 in Section 4.1 for the definition of "forest" given in the Marrakesh Accords), it is *good practice* to include them under cropland management or forest management, but not under both. Rice paddies are also included under croplands, but associated methane emissions will be reported under the Agriculture Sector and not in the LUCF sector in countries' greenhouse gas inventories, as described in the *IPCC Guidelines* and *GPG2000.* Treed areas such as orchards or shelterbelts that were established after 1990 and meet the definition of a forest can qualify as afforestation/reforestation, and if they do, can be included under those categories (see Section 4.1.2 General rules for categorization of land areas under Articles 3.3. and 3.4). Arable land, which is normally used for cultivation of temporary crops but is temporarily used for grazing, can also be included under croplands.[54]

Given the potential diversity in national land use classification systems, it is *good practice* for countries to specify what types of lands are included under cropland management in their national land use system and how they are distinguished from grasslands/rangelands/pastures (as in land-use category (iii) described in Section 2.2) and from the lands subject to afforestation/reforestation, forest management, grazing land management and revegetation they are (or might be) reporting. For example, it is *good practice* to specify whether and to what extent orchards or shelterbelts are included under cropland management. This will enhance the transparency of the reporting and the comparability across Parties.

To use the proposed methodology for determining carbon stock changes on those lands, the total cropland area needs to be subdivided into areas under various sets of management practices (which may overlap both in time and space) for the base year and each of the years in the commitment period. The carbon emission and removal factors depend on both the current and previous management on the land. Some areas may be emitting CO_2, some may be sequestering carbon, others may be in equilibrium, and this may change if management changes.

To obtain more disaggregated data on land uses and practices, a more comprehensive set of definitions of land-use and management systems within croplands for different climatic zones, such as those given in the *IPCC Guidelines,* is needed. Broad families of practices under cropland management that affect carbon stocks include tillage practices, rotations and cover crops, fertility management, plant residue management, erosion control and irrigation management (IPCC, 2000b, p.184). Further details can be found in Chapter 3 of this report.

4.2.8.1.1 1990 BASE YEAR

Cropland management, grazing land management and revegetation activities under Article 3.4 require net-net accounting.[55] For this purpose, greenhouse gas emissions and removals in the base year must be reported for any of these Article 3.4 elected activities (cropland management, grazing land management and revegetation). This entails determining the total areas on which each of the activities occurred in the base year and calculating the carbon stock changes for those areas. The non-CO_2 greenhouse gas emissions are covered in the Agriculture sector of the *IPCC Guidelines* in 1990 for those areas (see the text on non-CO_2 gases in this section and Box 4.1.1, Examples 1 and 2 in Section 4.1.2).

[53] Paragraph 1(g) in the Annex to draft decision -/CMP.1 (Land use, land-use change and forestry), contained in document FCCC/CP/2001/13/Add.1, p.58.

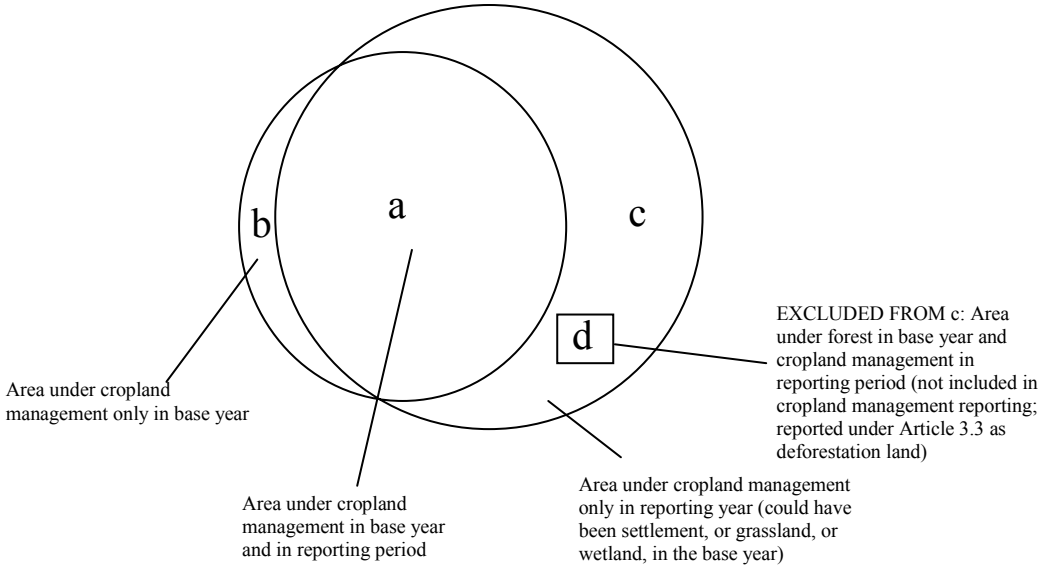
[54] http://www.unescap.org/stat/envstat/stwes-class-landuse.pdf

[55] Net-net accounting refers to the provisions of paragraph 9 of the Annex to draft decision -/CMP.1 (Land use, land-use change and forestry) contained in document FCCC/CP/2001/13/Add.1, p.59-60.

If the area under an Article 3.4 activity changes significantly between the base year and the commitment period, this may lead to unbalanced estimates (that is, subtraction of stock changes on a land base that changes in size over time (see Box 4.2.8)).

BOX 4.2.8
AN EXAMPLE OF CROPLAND MANAGEMENT AREAS IN 1990 AND THE COMMITMENT PERIOD (NET-NET ACCOUNTING)

In this example the area under cropland management in the base year expands to a larger area in the reporting year during the commitment period. Some of the area was under cropland management in both the base year and during the reporting period (a). Some of the area under cropland management in the base year is no longer under cropland management in the reporting year (b). There are also areas under cropland management in the reporting year that were not under cropland management in the base year (c). Area (d) is under cropland management, but was subject to deforestation which takes precedence. Under the Kyoto Protocol, the emissions and removals in areas (a) + (b) in the base year are compared to emissions and removals in areas (a) + (c) – (d) in the reporting year.



This approach avoids having to track the carbon stock changes arising from activities not covered by the Marrakesh Accords. Like other alternatives, it may have some policy implications. For example, a simple change in area without a change in stock change per unit area could yield a credit or debit without there being an actual loss or gain by the atmosphere.

For most Parties with commitments under Annex B of the Kyoto Protocol, the base year is 1990. But under the provisions of Article 4.6 of the UNFCCC, Parties with economies in transition (EITs) are granted some flexibility on the level of historical emissions chosen as a reference. As a consequence five EITs have a base year or period between 1985 and 1990 and hence they will need to assess the CO_2 and other greenhouse gas emissions and removals for those years. Historical data on land-use and management practices in 1990 (or appropriate year) and in years prior to 1990 are needed to establish the 1990 base year net emissions/removals of soil carbon from cropland management. Using the method described in Chapter 3 (Section 3.3.1.2.1.1. Change in Carbon stocks in soils – Mineral soils), land-use/land management change is assumed to have an impact for 20 years; hence, in this approach, the net carbon stock change in 1990 is calculated from management during 1970 to 1990. If area and activity data are available for 1970 to 1990, the net carbon stock change during the 1990 base year can be established using the default carbon emission and removal factors as described above. The duration of impact may be shorter or longer than 20 years. It is *good practice* to use a more appropriate time period, based on country-specific data and measurements (see Tier 2 and Tier 3 approaches in Section 4.2.8.3.1). If area and activity data are not available for 1970 to 1990 (or other appropriate time period) there is no historical data upon which to establish carbon stock change during the base year (1990), which will therefore have to be reconstructed from other data if cropland management is selected for the first commitment period.

The estimate of soil carbon stock change in the base year has a pronounced effect in net-net accounting. Where reliable data are not available for 1970 to 1990 (or other applicable time period), countries can choose the most appropriate of the following options:

- Choose not to elect cropland management as an activity under the Kyoto Protocol for the first commitment period.
- Report an emission (loss of carbon) for 1990 (or appropriate base year) *only* if it can be verified that the land was, in the 20 years prior to the base year, subject to a management change (e.g., cultivation of previously-forested lands) that leads to loss of soil carbon.
- Use a default emission/removal factor of '0' for 1990 if it can be shown that there have been few changes in management practices on the applicable land in the 20 years prior to 1990.
- Use data from another year shown to be a reliable proxy for the base year (e.g., 1989 in place of 1990). The proxy year should be as close to 1990 as possible and, all else being equal, preference should be given to a more recent year.
- Use a country-specific methodology, shown to be reliable, to estimate base year soil carbon stock change in 1990. It is *good practice* to verify that this methodology does not over- or underestimate emissions/removals in the base year (see discussion of Tier 2 and 3 methods in Section 4.2.8.3). In most cases, these methods also require historical data on management practices prior to 1990.

This approach may sometimes result in a conservative estimate of net soil carbon stock change but, in the absence of reliable and verifiable data for calculating 1990 carbon stock change, will help avoid overestimating the net removal of carbon from the atmosphere.

4.2.8.2 CHOICE OF METHODS FOR IDENTIFYING LANDS

General guidance on identification of lands subject to cropland management is provided in Sections 4.1.1, 4.1.2, 4.2.1, and 4.2.2. Under the Marrakesh Accords, the geographical location of the boundaries of the area that encompass land subject to cropland management needs to be reported annually, along with the total land areas subject to this activity.

The geographical location of boundaries may include a spatially explicit specification of each land subject to cropland management, but does not have to. Instead, the boundaries of larger areas encompassing smaller lands subject to cropland management may be provided, along with estimates of the area subject to cropland management in each of the larger areas. In either case, the land subject to cropland management and the management thereon need to be tracked through time because the continuity of management affects carbon emissions and removals. For example, a Party wishing to claim carbon removals due to conversion to no-till of 10% of an area under cropland management must demonstrate that no-till has been practiced on the same land for that period, since carbon accumulation in mineral soil depends on continuity of no-till (and the carbon emission/removal factors have been derived for continuous no-till). The rate of carbon removal for the total area therefore depends upon whether the same 10% of land has remained under no-till or if the 10% of no-till occurs on a different portion of the area in different years; it is not sufficient merely to state that 10% of the cropland management area has been under no-till for the whole period. It is *good practice* to follow continuously the management of land subject to cropland management; this could be achieved either by continuously tracking each land subject to cropland management from 1990 until the end of the commitment period (e.g. see Section 4.2.8.1 Definitional issues and reporting requirements), or by developing statistical sampling techniques, consistent with the advice in Section 5.3, that allow the management transitions on cropland management land to be determined (see also Section 4.2.4.1 Developing a consistent time series).

At the national level criteria that could be relevant to subdivision for the purpose of stratification when setting up a sampling strategy include:

- Climate
- Soil type
- Degree of disturbance (e.g. tillage frequency and intensity)
- Level of organic input (e.g. plant litter, roots, manure, other amendments)
- Temporarily re-grassed lands (e.g. set-aside)
- Fallow lands
- Lands with woody biomass stocks (e.g. shelterbelts, orchards, other perennial plantations)

- Lands converted to croplands since 1990 (land-use change) that are not in any other land-use category.

For all resulting subcategories under cropland management, the areas derived from the conversion of forests (i.e., deforestation) since 1990, need to be tracked separately as these will be reported as units of lands subject to deforestation.

At higher tiers further subdivision of the cropland management area may be necessary.

Methods to identify croplands with adequate disaggregation may include:

- National land-use and management statistics: in most countries, the agricultural land base including croplands is usually surveyed regularly, providing data on distribution of different land uses, crops, tillage practice and other aspects of management, often at sub-national regional level. These statistics may originate, in part, from remote sensing methods.
- Inventory data from a statistically based, plot-sampling system: land-use and management activities are monitored at specific permanent sample plots that are revisited on a regular basis.

Further *good practice guidance* on identifying land areas is given in Chapter 2 (Basis for consistent representation of land areas).

Links to related methods for cropland area identification in other chapters of this report and in the *IPCC Guidelines* are given in Box 4.2.9 below:

BOX 4.2.9

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Section 2.3.2 (Three Approaches): Croplands that remain croplands or any conversion that leads to croplands in Chapter 2 (except forests to croplands). *Should include all transitions between 1990 (or 1970, where required for base year estimate) and 2008, and in later inventory years transitions on an annual basis.*[56]

LINKS WITH THE *IPCC GUIDELINES*

Not available in a format that meets requirements in the Marrakesh Accords for geographical location of the boundaries.

4.2.8.3 CHOICE OF METHODS FOR ESTIMATING CARBON STOCK CHANGES AND NON-CO_2 GREENHOUSE GAS EMISSIONS

For croplands, the *IPCC Guidelines* identify three potential sources or sinks of CO_2 from agricultural soils:

- Net changes in organic carbon stocks of mineral soil associated with changes in land use and management
- Emissions of CO_2 from cultivated organic soils
- Emissions of CO_2 from liming of agricultural soils

Total annual emissions/removals of CO_2 are calculated by summing emissions/removals from these sources (see Section 3.3.1.2).

Carbon stock changes in other pools (aboveground, belowground biomass, litter and dead wood) should be estimated if applicable (i.e., unless the Party to the Kyoto Protocol chooses not to report on a certain pool and provides verifiable information that carbon stocks are not decreasing). For most crops, annual crop biomass can be neglected, but trees, shelterbelts and woody crops on croplands need to be accounted for either under cropland management, afforestation/reforestation or forest management. Relevant methods for estimating carbon stock changes and non-CO_2 greenhouse gas emissions from aboveground and belowground biomass, litter and dead wood can be found in the afforestation/reforestation or forest management sections (see Table 4.2.8) and Chapter 3 (see Box 4.2.10) of this report. The appropriate references are summarized in Table 4.2.8. The following sections focus largely on the soil carbon pool. For generic decision trees, guiding the choice of methods also for other subcategories, see Figures 3.1.1 and 3.1.2 in Chapter 3.

[56] If more than one land conversion occurs on the same land in the transition period of the matrix, then the transition period may have to be shortened to reflect these transitions.

TABLE 4.2.8
SECTIONS WHERE METHODOLOGIES CAN BE FOUND FOR ESTIMATING DIFFERENT CARBON POOLS ON CROPLAND

Pools to be estimated	Section where methodologies can be found
Aboveground biomass	Section 4.2.5 (Afforestation and Reforestation) and Section 4.2.7 (Forest Management)
Belowground biomass	Section 4.2.5 (Afforestation and Reforestation) and Section 4.2.7 (Forest Management)
Litter and dead wood	Section 4.2.5 (Afforestation and Reforestation) and Section 4.2.7 (Forest Management)
Soil C	Section 4.2.8.3
Non-CO_2	*GPG2000* and Section 4.2.8.3.4 (only for emissions not covered by the *IPCC Guidelines* and *GPG2000* Agriculture chapters)

If the Party chooses not to account for a particular pool, then it needs to verifiably demonstrate that this pool is not a source. Reporting requirements for such a choice can be found in Section 4.2.3.1.

For each of the carbon pools, different methodologies are used at different tiers to estimate net carbon emissions and removals for the 1990 base year and the years during the commitment period. Since different methods may yield different estimates (with different levels of uncertainty), it is *good practice* to use the same tier and methodology to estimate carbon emissions/removals in 1990 and during the commitment period.

Methods used to estimate net soil carbon emissions and removals, both for the 1990 base year and the commitment period, are described in detail in Chapter 3. Links to pertinent methods in Chapter 3 of this report and the *IPCC Guidelines* are given in Box 4.2.10. The following sections provide a brief review of these methods already described earlier, identifying aspects specific to the Kyoto Protocol.

BOX 4.2.10

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Section 3.3.1.1 Change in biomass

Section 3.3.1.2 Change in carbon stocks in soils

LINKS WITH THE *IPCC GUIDELINES*

4 Non-CO_2 greenhouse gases

5 B Forest and grassland conversion (conversion of grasslands to croplands)

5 D CO_2 emissions and removals from soils

4.2.8.3.1 MINERAL SOILS

For carbon stock change from mineral soils, the decision tree in Figure 4.2.9 should be used to decide which tier to use for reporting of cropland management under the Kyoto Protocol. For Article 3.4 activities it is *good practice* to use Tier 2 or Tier 3 for reporting carbon stock changes from mineral soils, if CO_2 emissions from cropland management is a key category.

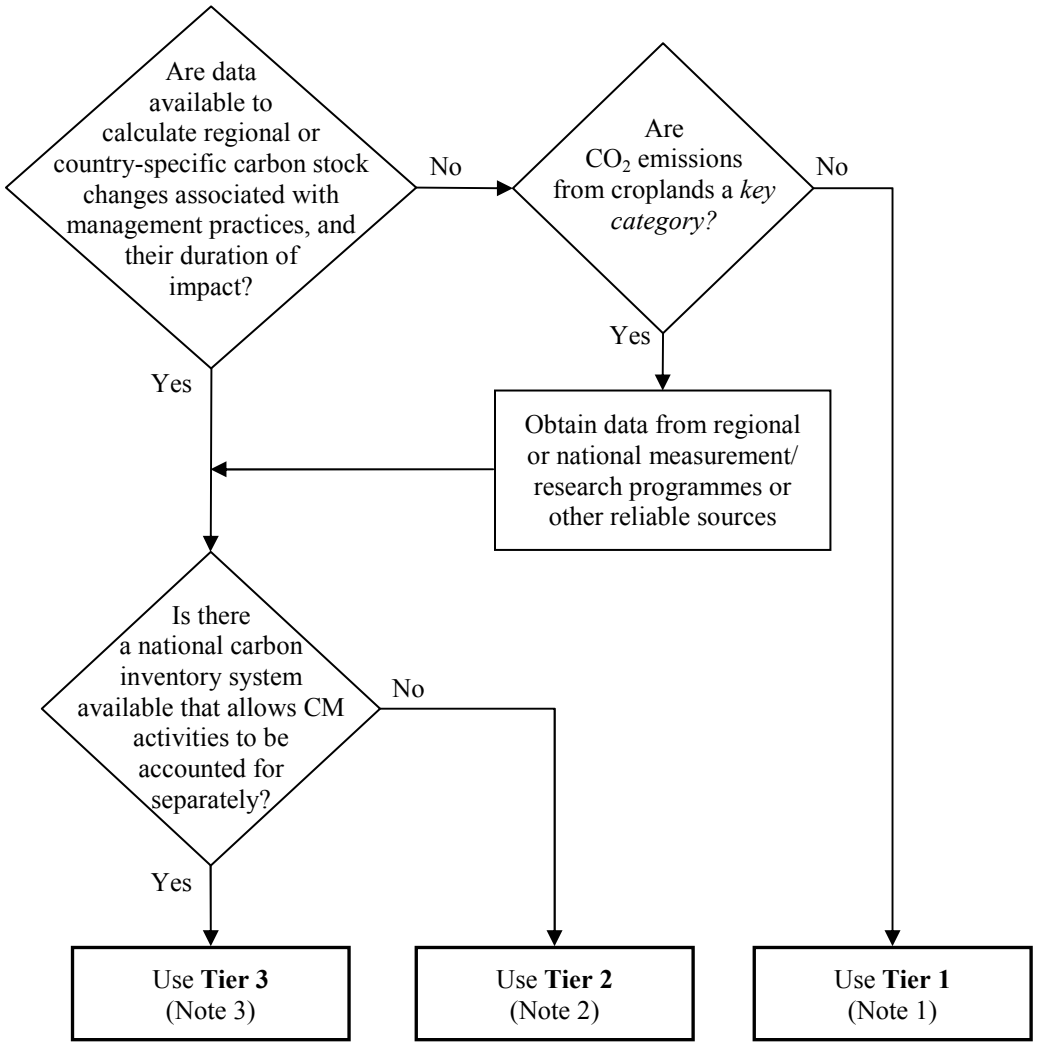
Methods for estimating carbon stock changes in mineral soils

Methods for estimating carbon stock changes fall into one of three tiers. These tiers are to be distinguished from the methods of estimating activity data (land areas). For estimating land areas, it is *good practice* to use the methods following Approach 2 or 3 (Chapter 2), taking into consideration the guidance in Section 4.2.2, for the higher tiers in Chapter 3; for estimating carbon stock changes lower tiers may be used. The decision tree in Figure 4.2.9 guides the choice of a *good practice* methodology.

Tier 1

The Tier 1 method for estimating carbon stock changes in mineral soils is described in Chapter 3 (Section 3.3.1.2: Change in carbon stocks in soils) and is based on the method outlined in the *IPCC Guidelines,* pages 5.35–5.48 of the reference manual (IPCC, 1997). The default values given in the *IPCC Guidelines*, based on a 20-year period, have been updated and used to derive annual carbon stock change factors. These are directly comparable with the Tier 1 methods used for national greenhouse gas inventories given in Chapter 3 (LUCF sector good practice guidance).

Figure 4.2.9 Decision tree for selecting the appropriate tier for estimating carbon stock changes in mineral soils under cropland for Kyoto Protocol reporting (see also Figure 3.1.1)



Note 1: Use the matrix/database of default values.

Note 2: Use regionally specific parameters, soil data and duration of impact.

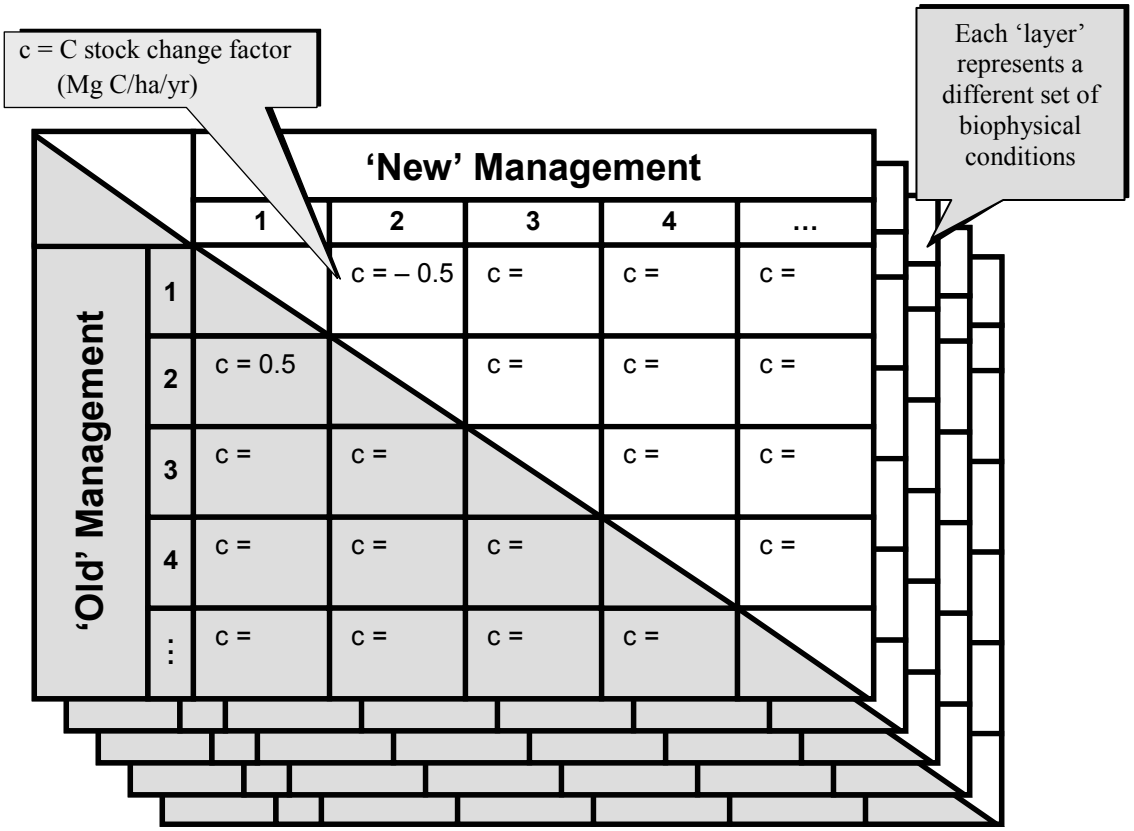
Note 3: Use more sophisticated modelling techniques, often linked to geographical databases.

It is *good practice* to follow continuously the management of land subject to cropland management. This could be achieved either by continuously tracking each land subject to cropland management from 1990 until the end of the commitment period (e.g., see Section 4.2.7.1 Definitional issues and reporting requirements), or by developing statistical sampling techniques, consistent with the advice in Section 5.3, that allow the management transitions on cropland management land to be determined (see Section 4.2.4.1 Developing a consistent time series).

Using the default values given in the *IPCC Guidelines*, average yearly rates of carbon stock change can be calculated for each soil type, climatic region and land-use or management change combination. These can be used as default annual "carbon stock change factors"[57], and can be represented in a series of tables, a matrix or a relational database. Such a system is shown schematically in Figure 4.2.10 where the numbers 1,2,3,… represent different management practices.

[57] See also footnote 32 above.

Figure 4.2.10 **Conceptual illustration of the matrix of carbon stock change factors derived for different land-use, land-management transitions for each set of biophysical combinations. These could be accessed via tables or a relational database. For Tier 1, default values (see text above) are used for the carbon stock change factor. Default values for management shifts in opposite direction are the same, but of opposite sign. For example, if a shift from management practice 1 to management practice 2 has a carbon stock change factor of -0.5, then a shift from management practice 2 to management practice 2 has a factor of + 0.5.**



The yearly carbon stock change factor will often be more accurate than the default values for absolute carbon stocks.[58]

These default carbon stock change factors have been compiled into a database so that default factors can be accessed for each soil type, input level and land-use and land-management transition considered in the *IPCC Guidelines* without referring to multiple tables. The database can be found in Annex 4A.1 (Tool for Estimation of Changes in Soil Carbon Stocks associated with Management Changes in Croplands and Grazing Lands based on IPCC Default Data) on the attached CD-ROM (including instructions on how to use the database).

Calculating annual carbon stock change factors

The *IPCC Guidelines* assume a linear change in soil carbon stocks over a 20-year period after a change in management, moving the soil carbon stock from an equilibrium position at t_0 (year of management change) to another equilibrium position at t_{20} (20 years after the change in management). The rate of carbon stock change therefore is assumed to remain constant for the first 20 years after a management change and then becomes zero as a new equilibrium has been reached.

[58] The carbon stock change factor reflects a change in carbon stocks, which is much smaller than the absolute carbon stock; the change in carbon stocks can be reasonably correct even if the absolute values are not.

The method for calculating annual carbon stock change factors is described in Chapter 3 (Section 3.3.1.2; Equation 3.3.3). For a summary of the steps and a sample calculation, see Section 3.3.1.2.1.1: Choice of method (mineral soils).

Calculation of carbon stock change resulting from cropland management

Carbon stock change can be used to calculate a yearly emission/removal of carbon for up to 20 years after a land-use or land-management change by multiplying the carbon stock change factor by the area to which the change has been applied as follows:

EQUATION 4.2.1
ANNUAL SOIL CARBON EMISSIONS/REMOVALS FROM CROPLAND MANAGEMENT

$$\Delta C_{CM\ SOC} = CSF \bullet A$$

Where:

$\Delta C_{CM\ SOC}$ = annual change in carbon stock in soil organic carbon, Mg C yr^{-1}

CSF = carbon stock change factor, Mg C ha^{-1} yr^{-1}

A = area, ha

(See also Equation 3.3.4 in Chapter 3)

For net-net accounting, the calculation shown in Equation 4.2.1 has to be performed for both the base year and reporting year. For discussion of the applicable area, see Section 4.1.2 (General rules for categorization of lands areas under Articles 3.3 and 3.4).

Tier 2

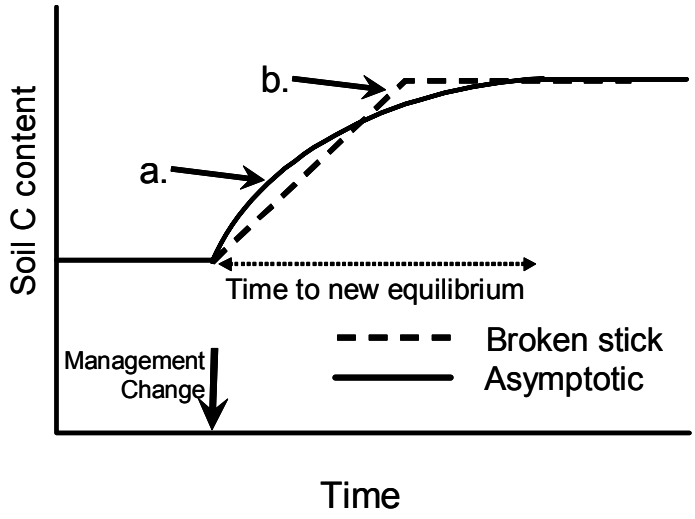
The Tier 2 method also uses the methodology described in the *IPCC Guidelines* (Reference Manual and Workbook), but now the default factors are replaced with country- or region-specific values shown to be more reliable (e.g., from literature values, long-term experiments or the local application of well-calibrated, well-documented soil carbon models). Different regional data for soil carbon content (such as that available from national soil inventories) can also be used. Similarly, it is *good practice* to replace the default value for the duration of change (20 years) with a more appropriate value, if adequate information is available to justify it.

Regionally specific or local carbon stock change factors should be better than default factors at representing actual carbon stock change in a given region. When replacing default carbon factors, rigorous criteria must be applied to demonstrate that any change in factors does not lead to under- or overestimation of the soil carbon change. Regional or country-specific factors should be based on measurements that are conducted frequently enough and over a long enough time period and with sufficient spatial density to reflect variability of the underlying biochemical processes, and documented in accessible publications.

The 20-year period over which soil carbon stock changes are assumed to change from one equilibrium position to another is an approximation: in cooler climates, changes may take more than 20 years to reach a new equilibrium (roughly 50 years); in tropical climates, a new equilibrium may be reached in shorter periods (roughly 10 years; Paustian *et al.*, 1997). At Tier 2, different regional or country-specific values for the duration of impact of land-use or land-management change can be used where these exist or can be reliably estimated.

Alternatively an asymptotic model can also be fitted to data of soil carbon stock changes (see Figure 4.2.11; compare to the "broken-stick" model used in the *IPCC Guidelines* in which a linear change occurs over 20 years after which no further change occurs). Using this method, different carbon stock change factors could be applied in different years after a land-use or management change so that stock changes are not underestimated soon after a change ("a" on Figure 4.2.11), or overestimated as the soil approaches the new equilibrium ("b" on Figure 4.2.11).

Figure 4.2.11 **Schematic representation of a change in soil carbon stocks after a carbon-sequestering management change is imposed represented by a broken-stick model of stock change (as used in the *IPCC Guidelines* where the time to a new equilibrium is 20 Years) and by an asymptotic curve (for definitions of 'a' and 'b' see text)**

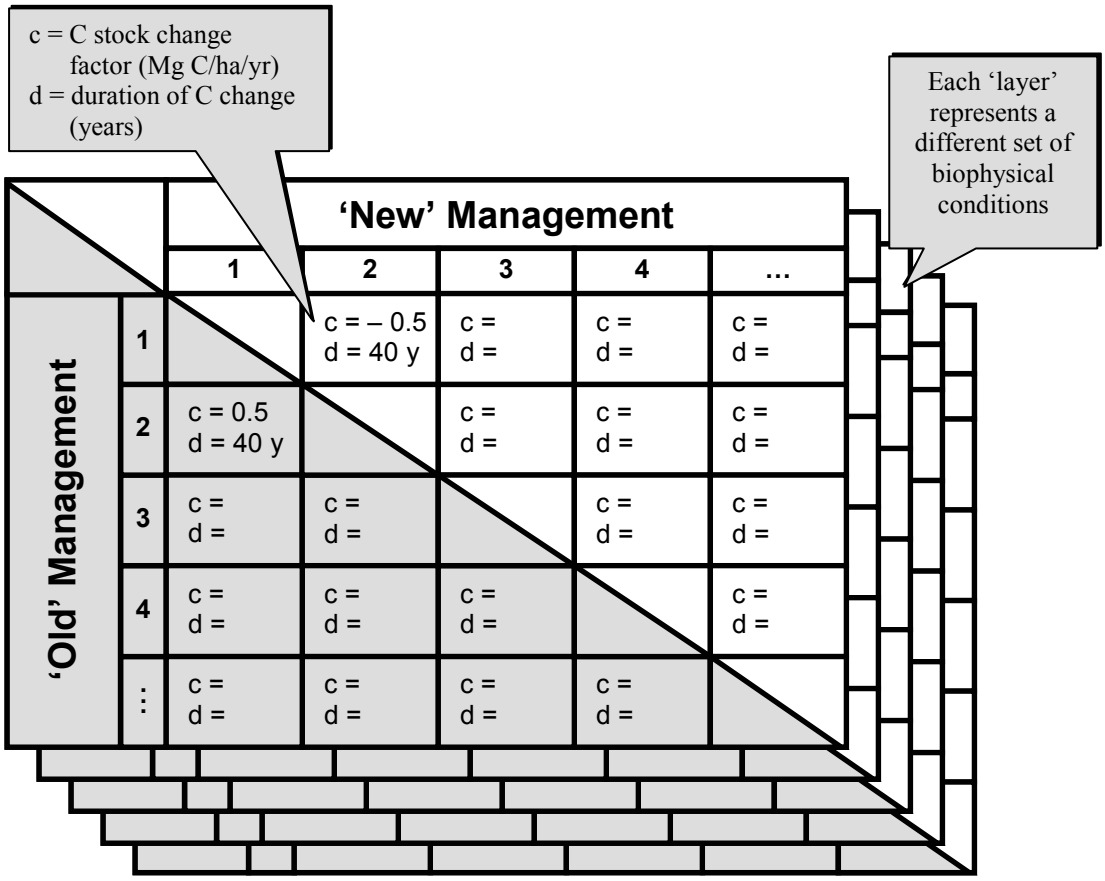


If for the duration of impact a value other than 20 years is used, this needs to be included in the matrix, as represented schematically in Figure 4.2.12.

At Tier 2, default factors (e.g., input factors) associated with a different land-use or land-management change can be replaced by more detailed relationships between the intensity of a practice (e.g., the amount of an organic amendment applied to the soil) and a change in the yearly soil carbon emissions/removals. For example, in Europe Smith *et al.* (2000) have developed such relationships (e.g., average yearly soil carbon stock change (tonnes C ha^{-1}) = 0.0145 x amount of animal manure (tonnes dry matter ha^{-1} yr^{-1}) added; recalculated from data in Smith *et al.*, 1997; $R^2 = 0.3658$, n = 17, $p < 0.01$). Similar relationships could be derived from long-term data for different soil types in different climatic regions. Alternatively, well-calibrated and well-evaluated models of soil carbon change (e.g., CENTURY (Parton *et al.*, 1987), RothC (Coleman and Jenkinson, 1996)) could be used to generate either stock change factors, or the intensity relationships described above, for different soils in different climatic regions.

Rigorous criteria must be applied so that any carbon stock change is not under- or overestimated. It is *good practice* that stock change factors be based on experiments sampled according to the principles set out in Section 5.3, and to use the experimental values if they are more appropriate than the default values to the region and management practice. Factors based on models should only be used after the model has been tested against experiments such as those described above and any model should be widely evaluated, well-documented and archived. It is *good practice* to provide confidence limits and/or uncertainty estimates associated with regional, country-specific or local stock change factors.

Figure 4.2.12 **Conceptual illustration of the matrix of carbon stock change factors derived for different land-use, land-management transitions for each set of biophysical combinations. The Tier 2 method is extended by using regionally specific estimates of carbon factors or estimates of the duration of impact of land-use/management change. Depending on how they are calculated, carbon stock change factor (c) and duration (d) values for management shifts in opposite direction will often be the same, but the 'c' value will have opposite sign.**



Tier 3

Tier 3 methods that can be used for the national UNFCCC inventory (as described in Chapter 3, Section 3.3.1.2.1.1 Choice of method) are also likely to be used for reporting under the Kyoto Protocol. Compared with the static matrix used at Tiers 1 and 2, Tier 3 can often better represent the management history of a land, allowing better calculation of soil carbon changes resulting from multiple changes in management practices over time. Furthermore soils can take much longer than 20 years to reach equilibrium, and Tier 3 (like Tier 2) methods can take this into account. Large scale computing power makes possible a spatially disaggregated system linked to management practice data which could keep track of carbon stock changes over time if linked to rate equations with carbon contents, initialised at some point and cross-checked periodically. Tier 3 can also be based on repeated statistical sampling consistent with the principles set out in Section 5.3 of sufficient density to capture the soil types, climatic regions and management practices that occur. Tier 3 methods, therefore, encompass a range of methodologies, more elaborate than Tier 2, usually based on sophisticated modeling techniques, often linked to geographical databases.

Choice of carbon stock change factors for mineral soils

The carbon emission/removal factors used at each tier are described briefly in the following sections.

Tier 1: At Tier 1, average yearly carbon stock changes in mineral soils are calculated from default values by dividing the 20-year stock change by 20, as set out in Chapter 3, Equation 3.3.3. Full details of these factors and the resulting stock change estimates can be found in the *IPCC Guidelines*, pages 5.35–5.48, and are provided in the database described in Annex 4A.1. (Default values in Annex 4A.1 are slightly modified from those in the

IPCC Guidelines). For a summary of the steps and a sample calculation, see Section 3.3.1.2.1.1, Choice of method (mineral soils).

Tier 2: At Tier 2, some or all of the default values for carbon stock change (Tier 1) are replaced by values shown to be more reliable. These new values may be based on literature values, measured changes in carbon stocks, on simple carbon models, or a combination of these. (See 'Choice of management data for mineral soils' below for some examples). It is good practice to show that the new values, compared to those they replace, are more accurate for the conditions and practices to which they are applied.

Tier 3: For mineral soils, Tier 3 carbon stock change factors are country-derived, and may be calculated using complex models. The carbon models used for Tier 3 are generally more complex than those in Tier 2, taking into account soil (e.g., clay content, chemical composition, parent material), climate (e.g., precipitation, temperature, evapotranspiration), and management factors (e.g., tillage, carbon inputs, fertility amendments, cropping system). *Good practice* requires that the models be calibrated using measurements at benchmark sites, and that models and assumptions used are described transparently.

In all cases, rigorous criteria must be applied so that any change in carbon stocks is neither under- or overestimated; models used to estimate carbon stock changes should be well-documented and should be evaluated using reliable experimental data for conditions and practices to which the models are applied. It is *good practice* to provide estimates of confidence limits or uncertainty. Default carbon stock change factors may also be replaced by values generated as part of national/regional carbon accounting systems (see Section 4.2.7.2 Choice of methods for identification of lands subject to Forest Management).

Choice of management data for mineral soils

Area data on land uses and practices need to be available in accordance with Approach 2 or Approach 3 (Section 2.3.2), and guidance given in Section 4.2.2.3. The data on management required for each of three tiers are outlined briefly here.

Tier 1: Using the IPCC Guidelines (see also Chapter 3, Section 3.3.1.2.1.1), impacts of land-use or land management change are assumed, by default, to have an impact for 20 years. If area and activity data are available for 20 years prior to the base year, a net carbon removal/emission for the base-year can be established using the default carbon stock change factors described above. The land-use changes and management practices at Tier 1 are the same as those given in the IPCC Guidelines: clearing of native vegetation with conversion to cultivated crops or pasture, land abandonment, shifting cultivation, differing residue addition levels, differing tillage systems and agricultural use of organic soils. Within these specific land-use or land-management changes, activities are defined semi-quantitatively, e.g., "high input" vs. "low input" systems. Land-use or management systems are not subdivided into finer levels of detail than this. Areas may be obtained from international data sets (e.g., FAO), though some of these sources lack the spatial explicitness needed for reporting and may only be helpful for cross-checking data. If area and activity data are available for 1970 through 1990, a 1990 baseline net carbon stock change can be established using the default carbon stock change factors described above. If area and activity data are not available for 1970 through 1990, see Section 4.2.7.2 for alternative options for estimating the land areas.

Tier 2: The management practices at Tier 2 are the same as those given in the *IPCC Guidelines* and at Tier 1. But for Tier 2, to make them country-specific, some management practices may be subdivided, or new ones may be added. Within the agricultural management systems described in the *IPCC Guidelines*, management data include descriptors such as "high input" and "low input". These descriptors can be replaced at Tier 2 by more explicit descriptors, for example, high organic amendment rates (e.g., >20 tonnes dry matter ha^{-1} yr^{-1}), medium organic amendment rates (e.g., 10-20 tonnes dry matter ha^{-1} yr^{-1}), low organic amendment rates (e.g., <10 tonnes dry matter ha^{-1} yr^{-1}), and zero organic amendment. Further subdivisions could, for example, reflect different forms of organic amendment, such as animal manure, cereal residues and sewage sludge, where corresponding removal factors are available. An alternative to the use of more detailed descriptor categories is the use of relationships similar to those derived for Europe by Smith *et al.* (1997, 1998, and 2000) and for the USA by Lal *et al.* (1998). These could be based on a new, more comprehensive analysis of global data sets. Figures could include the change in carbon stock associated with a given practice (e.g., zero till), or a relationship between intensity of a practice and soil carbon change, e.g., average yearly soil carbon emission/removal (tonnes C ha^{-1}) = 0.0145 x amount of animal manure (tonnes dry matter ha^{-1} yr^{-1}) added; recalculated from data in Smith *et al.*, (1997; $R^2 = 0.3658$, $n = 17$, $p < 0.01$). Alternatively, well-calibrated and well-evaluated models of soil carbon change (e.g., CENTURY (Parton *et al.*, 1986) RothC (Coleman and Jenkinson, 1996), or others) could be used to generate either default carbon stock change factors, or to generate the intensity relationships described above for each activity, for different soils in different climatic regions. These examples illustrate how practices can be made more country-specific, but other refinements are also possible. Tier 2 methods may require area descriptions of higher resolution than those in Tier 1. In any case, rigorous criteria must be applied so that any

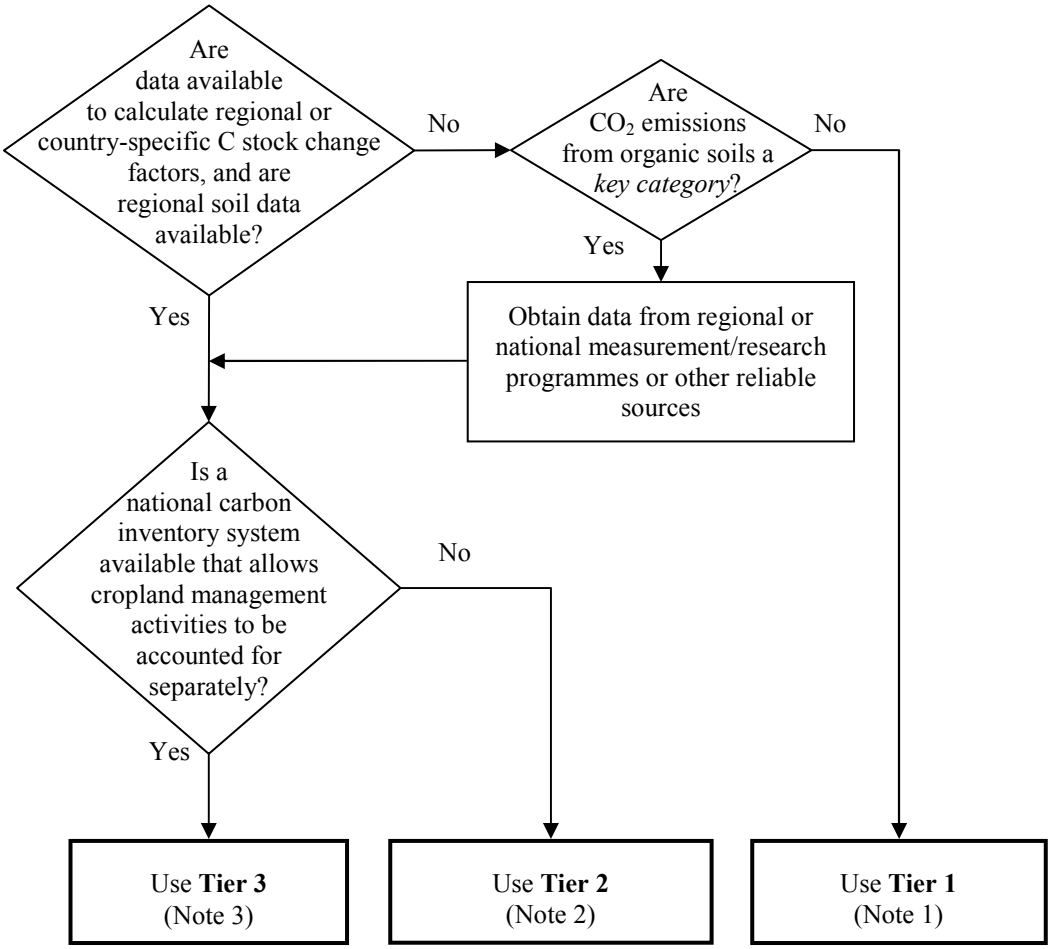
change in emissions or removals is neither under- nor overestimated (see 'Choice of carbon stock change factors for mineral soils' for discussion of criteria)

Tier 3: Management data used in the more complex Tier 3 methodologies need to be consistent with the level of detail required by the model. It is *good practice* to use management data at a spatial resolution appropriate for the model, and to have, or be able to estimate reliably, quantitative measures of the management factors required by the model.

4.2.8.3.2 CARBON STOCK CHANGES IN ORGANIC SOILS

For carbon stock changes in organic soils, the following decision tree (Figure 4.2.13) should be used to decide which tier to use for reporting under the Kyoto Protocol.

Figure 4.2.13 Decision tree for selecting the tier at which to report carbon stock changes in organic soils under the Kyoto Protocol (see also Figure 3.1.1)



Note 1: Use the matrix/database of default values.

Note 2: Use region-specific parameters, soil data and duration of impact.

Note 3: Use more sophisticated modelling techniques, often linked to geographical databases.

Methods for estimating CO_2 emissions/removals from organic soils

Tier 1: When organic soils are converted to agriculture, they are typically drained, cultivated, and limed, resulting in the oxidation of organic matter. The rate of carbon release will depend on climate, the composition (decomposability) of the organic matter, the degree of drainage and other practices such as fertilisation and liming. The Tier 1 method is set out in Section 3.3.1.2 which is based on the method given in the *IPCC Guidelines.*

Tier 2: If more reliable country- or region-specific data is available on CO_2 emissions from organic soils it is *good practice* to use these values instead of Tier 1 defaults. Any data used should be shown to be more reliable than defaults.

Tier 3: The complex systems described in Chapter 3 (LUCF sector good practice guidance) for national greenhouse gas inventories may use methods or models for estimating CO2. These emissions may also be used to estimate non-CO2 greenhouse gas emissions in an integrated way. However, the non-CO2 emissions should be reported in the Agriculture sector, and double counting and omission should be avoided. It is good practice to use models which are calibrated using measurements at benchmark sites, and to describe models and assumptions used transparently.

Choice of carbon emission/removal factors for organic soils

Tier 1: The default carbon emission/removal factors for Tier 1 are provided in Chapter 3 (Table 3.3.5; Section 3.3.1.2.1.2).

Tier 2: For organic soils, it is *good practice* to replace the default values identified in Chapter 3 (Table 3.3.5; Section 3.3.1.2.1.2) with country- or region-specific factors if these are shown to be more reliable than the defaults. It is *good practice* to use replacement emission/removal factors based on experimental results derived from experiments that are well-designed, with adequate sampling to give adequate statistical power. Any emission or removal factors based on models should only be used after the model has been tested against experiments, such as those described above, and any model should be widely evaluated, well-documented and archived. It is *good practice* to provide confidence limits and/or uncertainty estimates associated with any replacement emission/removal factors. Replacement emission/removal factors must be shown to better represent local conditions or practice than default factors by comparing both default and replacement factors against measurements or experiments within the region.

Tier 3: For organic soils, CO_2 and non-CO_2 greenhouse gas emissions or emissions/removals may be estimated as part of processed-based modelling using national emission/removal factors. It is *good practice* to use such methods if they have been well-documented and evaluated. Before methods are applied they should be thoroughly tested and evaluated, as described for Tier 2.

Choice of management data for organic soils

The same considerations apply as for management data for cropland management activities on mineral soils, as described earlier in Section 4.2.8.3.1.

4.2.8.3.3 CO_2 EMISSIONS FROM LIMING

Supplementary data provided for the Kyoto Protocol includes CO_2 emissions from liming of croplands only if cropland management is elected.

Methods for estimating CO_2 emissions from liming

Liming is commonly used to ameliorate soil acidification. Carbonate minerals such as limestone $CaCO_3$ and dolomite $CaMg(CO_3)_2$ are usually used. When added to acid soil these compounds release CO_2 at a rate which will vary according to soil conditions and the compound applied. Repeat applications are made every few years but can be averaged out over time and the average annual rate is the basis for inventory calculations.

Tier 1: The Tier 1 method for estimating CO_2 emissions from liming is identical to that described in Chapter 3 (Section 3.3.1.2.1.1).

Tier 2: A Tier 2 method for liming uses national or regional figures in place of the default coefficients described in Chapter 3 (Section 3.3.1.2.1.1) for soil CO_2 emissions due to liming, where these are shown to be more reliable.

Tier 3: The complex methods used at Tier 3 as described in Chapter 3 may account explicitly for liming. These may integrate effects also on non-CO_2 emissions. It is *good practice* to use such methods if they have been well-documented and evaluated.

Choice of carbon emission factors for liming

It is *good practice* to use the default values given in the Chapter 3 (Section 3.3.1.2.1.1). If a Party chooses to use alternative national emission factors (Tier 2), these should be justified by more detailed data on the composition of the lime used. Tier 3 methods may in addition include the integrated effect of liming and management practices on the non-CO_2 emissions. It is *good practice* to use such factors if they have been well-documented and evaluated.

4.2.8.3.4 NON-CO_2 GREENHOUSE GASES

Methodologies for estimating N_2O and CH_4 emissions are given in the Agriculture Chapters of the *IPCC Guidelines* and the *GPG2000*, which give methodologies for the following sources of agricultural emissions that are related to cropland management (the list also applies to grazing land management and revegetation):

1) Direct N_2O emissions from agricultural soils due to
   - Use of synthetic fertilisers,
   - Use of animal excreta as fertiliser,
   - Biological nitrogen fixation due to cultivation of legumes and other nitrogen fixing crops,
   - Crop residue and sewage sludge application,
   - Cultivation of soils with high organic content;
2) Indirect N_2O emissions from nitrogen used in agriculture, including emissions from
   - Volatilisation and subsequent atmospheric deposition of NH_3 and NO_x (originating from the application of fertilisers and manures),
   - Nitrogen leaching and runoff;
3) CH_4 emissions from rice cultivation;
4) Non-CO_2 emissions from burning of vegetation;
5) CH_4 from enteric fermentation;
6) CH_4 and N_2O emissions from manure management.

These emissions should not be reported under cropland management but as agricultural emissions[59] and are covered in Chapter 4 (Agriculture) of the *GPG2000*. Even for Parties that do not elect cropland management under Article 3.4, these emissions should be reported as emissions from sources listed in the Annex A to the Kyoto Protocol. Parties that elect cropland management should also report these emissions in the agriculture sector and not include them under Article 3.4.

Non-CO_2 emissions/removals on deforested lands converted to cropland (Article 3.3) need to be reported separately from those under cropland management (Article 3.4). If non-CO_2 emissions/removals on deforested land cannot be determined directly, they may be estimated as a fraction of total non-CO_2 emissions/removals from cropland, corresponding to the area of total cropland on deforested land. For example, if 10% of the cropland area is on deforested land, then 10% of total cropland non-CO_2 emissions/removals would be ascribed to lands that have been subject to deforestation since 1990.

Some management practices adopted to increase soil carbon may also influence the emissions of non-CO_2 gases. Many of these effects are included in the Agriculture Chapters of the *IPCC Guidelines* and *GPG2000*, but there may be other effects on non-CO_2 gases not considered in the *IPCC Guidelines* and *GPG2000* (see examples presented in Box 4.2.11).

[59] According to the Marrakesh Accords estimates of emissions from sources and removals by sinks from for Article 3.3 and 3.4 activities are to be clearly distinguished from anthropogenic emissions from the sources listed in Annex A to the Kyoto Protocol (cf. paragraph 5 in the Annex to draft decision -/CMP.1 (Article 7), contained in document FCCC/CP/2001/13/Add.3, p.22).

BOX 4.2.11
EXAMPLES OF POSSIBLE INFLUENCES OF CARBON STOCK CHANGES ON EMISSIONS OF NON-CO_2 GASES

Example 1: Influence of reduced tillage on N_2O emission.
Adoption of reduced or no-tillage often increases soil carbon in croplands. However, at the same time it may also alter N_2O emissions, through effects on porosity (and the fraction of the porosity occupied by water), N cycling, temperature, and other factors (e.g., Weier *et al.*, 1996; MacKenzie *et al.*, 1998; Robertson *et al.*, 2000; Smith *et al*., 2001). The observations are inconclusive, with some studies showing higher N_2O emission under no-till than under tilled systems, and others showing little effect or lower N_2O emissions. The available data suggest that this variable response depends on interactive effects of soil and climate, and that wetter environments with poorer aeration, in which N_2O emissions generally tend to be highest, are also associated with higher emissions under no-till than under conventional tillage (e.g., Linn and Doran, 1984; Weier *et al.*, 1996; Vinten *et al.*, 2002).

Example 2: Links between organic matter turnover and N_2O emission.
Organic matter in soil is continually decomposing, resulting in the release of ammonia, and of nitrate. A portion of this 'available' N may be converted to N_2O. Consequently, practices that increase the rate of organic matter decomposition (e.g., ploughing of grasslands, increased use of 'fallow' periods) may stimulate N_2O emissions. In contrast, re-planting grasslands and reducing 'fallow' frequency may reduce N_2O emissions. The significance and magnitude of these effects, however, are not well-understood and it may not be possible to quantify them reliably at this stage.

Example 3: Effect of cropland management on CH_4 oxidation.
Some practices that enhance soil carbon in croplands may also influence the rate of CH_4 oxidation in soils, negatively or positively (e.g., Smith *et al*., 2001). Often these effects are smaller than those on N_2O, when expressed in units of CO_2-equivalence.

Example 4: Effect of draining organic soils.
Emissions of CH_4 may decrease as CO_2 losses increase with soil drainage, and N_2O emissions may also be affected. (Note that the *IPCC Guidelines* assume that all carbon is lost as CO_2; if this is departed from, it must be justified by scientifically sound and well-documented data. Methods for estimating N_2O emissions from cultivated organic soils are given in the Agriculture Chapters of the *IPCC Guidelines* and *GPG2000*, and these emissions should be reported as described there to avoid double-counting.).

The effects on non-CO_2 emissions of these and other management practices may be included in higher tier methods for agriculture, as noted in *GPG2000* (Section 4.7, page 4.53 to 4.66). Where estimated, they should still be reported with Agriculture, to avoid double counting. Examples of how these effects could be estimated include:

- Direct measurement of the non-CO_2 greenhouse gases at representative sites;
- Estimation of emission rates based on literature values taking into account management, soil and climate.

4.2.9 Grazing land management

4.2.9.1 DEFINITIONAL ISSUES AND REPORTING REQUIREMENTS

Grazing land management is the system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced. Grazing lands are, by definition, 'managed' to some extent, so the lands under grazing land management are in fact potentially all the lands within a country subject to grazing; that is, all lands predominantly used for livestock production, based on criteria decided upon and explicitly described by the country. Note that not all grasslands are necessarily grazing lands.

In order to ensure a comprehensive coverage, it is *good practice* to include all of the following lands in the grazing lands category:

- Improved pastures/grasslands/rangelands: These are lands subject to intensive, controlled grazing. Management practices such as fertilizing/manuring, irrigation, reseeding, liming, or spraying are used to control productivity. Lands used permanently for herbaceous forage crops are also included.

- Unimproved/natural pastures/grasslands/rangelands: These lands are usually composed of native vegetation including hay and bushes, and grazing is mainly extensive. There is no or little grass management except burning in some instances. However, the intensity, frequency, and seasonality of grazing and animal distribution are managed (even by default) or can be specifically managed to prevent loss of stored carbon, for example by avoiding overgrazing.

Pastures, rangelands or savannahs on which trees and shrubs are grown should be included under grazing land management if the growing of forage crops or grazing is the most important activity on the area, based on criteria established and explicitly stated by the country. Where treed lands meet the definition of a forest and the trees have been established since 1990, the land should be included under the afforestation/reforestation category. However, lands that meet the definition of 'forest' can be included in grazing land management, if grazing is the dominant activity, based on the criteria established by the country.

Set-aside lands, such as cultivated lands reverted to perennial grasslands, should be included under cropland management if they are only temporarily set-aside (typically this is for 5 years or less, but any set-aside likely to return to cropland under the national conditions for set-aside should be counted as cropland). They should be included under grazing land management if they are permanently set-aside. Protected lands, such as those subject to permanent cover programmes should be included under grazing land management if they are also used for livestock production. Lands that are only temporarily used for grazing, as part of a cropping rotation, would normally be included under cropland management. For consistency, the criteria used to distinguish between cropland and grazing land and revegetation should be explicitly stated and applied consistently.

Given the potential overlap with other land-use categories, it is *good practice* for countries to specify what types of lands are included under the category grazing land/rangeland/pastures in their national land-use system. Moreover, countries should also specify how these lands differ from (a) lands in land-use category (ii) of Chapter 2 (cropland/arable/tillage), and (b) lands subject to other activities under Article 3.3 (AR) and Article 3.4 (FM, RV, CM – if elected). This will enhance the comparability of reporting across countries.

In addition, all lands that were forest on 31 December 1989 and that are subject to grazing land management in the reporting year need to be identified, tracked and reported as a separate category ('Deforestation' lands that would otherwise be subject to grazing land management).

In order to allow the application of the proposed methodology for determining CO_2 emissions/removals on those lands, (i.e., area times a carbon stock change factor, the factor being positive, negative or null depending on management and land use or land-use change), the total grazing land area needs to be subdivided into areas under various sets of management practices (which may overlap both in time and space) for the base year and the years in the commitment period. The carbon stock change factors depend on both the current and previous management. Some areas may be emitting carbon, others may be sequestering CO_2, others may be in equilibrium and this may change if management changes.

To obtain more disaggregated data on land uses and practices, a more comprehensive definition of land use and management systems within grazing lands/rangelands/pasture for different climatic zones can be developed. Broad families of practices under grazing land management that affect carbon stocks include: herd management, presence of woody plants, fertilization, irrigation, species composition, legume management, and fire management (IPCC, 2000b, p.184 and p. 205). See also Chapter 3 (LUCF sector good practice guidance) and Section 4.2.9.2 below.

4.2.9.1.1 1990 BASE YEAR

See Section 4.2.8.1 Definitional issues and reporting requirements.

4.2.9.2 CHOICE OF METHODS FOR IDENTIFYING LANDS

General guidance on identification of lands relevant to grazing land management is provided in Sections 4.1.1, 4.1.2, 4.2.1, and 4.2.2. Under the Marrakesh Accords, the geographical location of the boundaries of the area that encompass land subject to grazing land management need to be reported annually, along with the total land areas subject to this activity. The geographical location of the boundaries may include a spatially explicit specification of each land subject to grazing land management, but does not have to. This is analogous to the case for cropland management as discussed in Section 4.2.8.1 (Definitional issues and reporting requirements). It is *good practice* to follow continuously the management of land subject to grazing land management. This could be achieved either by continuously tracking each land subject to grazing land management from 1990 until the end of the commitment period (see Section 4.2.8.1), or by using statistical sampling techniques that allow the transitions of management on grazing land to be determined and that, at the same time, are consistent with the requirements of

Section 5.3 (see also Section 4.2.4.1 Developing a consistent time series). At the national level, different layers of breakdown of the total grazing land area are needed, for instance using criteria that concern primary national circumstances, management practices and other subdivisions. These could include:

- Climate
- Soil type
- Degree of disturbance (e.g., compaction, disturbance by livestock foot action, frequency of burning, erosion)
- Level of organic input (e.g., plant litter, roots, manure, other amendments)
- Lands that are intermittently grazed (e.g., set-aside, grass as part of a rotation)
- Grazing intensity (utilization percentage of the pasture)
- Treed lands (shelterbelts, orchards, other perennial plantations)
- Lands converted to grazing-lands since 1990 (land-use change) that are not in any other land-use category.

For all of the resulting subcategories the areas under grazing land management that were derived from conversion of forests (i.e., deforestation) since 1990 need to be tracked separately as these will be reported as units of lands subject to deforestation.

At Tier 3 further subdivision of the area subject to grazing land management may be necessary.

Methods to identify lands subject to grazing land management with necessary disaggregation available in some Annex I countries include the following:

- National land use and management statistics: the agricultural land base including land subject to grazing land management is surveyed in most countries on a regular basis. These may be derived, in part, from remote sensing of pasture and soil surface condition and changes in stocking rate.
- Inventory data from a plot, statistically based, sampling system: land use and management activities are monitored at specific permanent sample plots that are revisited on a regular basis.

Information on these areas would have to be compiled either for all lands affected by grazing land management or summarised as estimates for all the strata (defined by the boundaries of the areas of land) that a Party chooses to apply for the reporting of its land use statistics. Further *good practice guidance* on identifying land areas is given in Chapter 2 (Basis for consistent representation of land areas).

Links to methods for area identification in other chapters of this report and *IPCC Guidelines* are given in Box 4.2.12.

BOX 4.2.12

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Section 2.3.2 (Three approaches): Grasslands (unmanaged or managed) that become managed grasslands or any conversion that leads to managed grasslands in Chapter 2 (except forests to grasslands), provided that these managed grasslands are subject to grazing land management. *Should include all transitions between 1990 (or 1970, where required for base year estimate) and 2008, and in later inventory years transitions on an annual basis.*[60]

LINKS WITH THE *IPCC GUIDELINES*

Not available in a format that meets requirements in the Marrakesh Accords for geographical location of the boundaries.

[60] If more than one land conversion happens on the same unit of land in the transition period of the matrix, then the transition periods may have to be shortened to account for these transitions.

4.2.9.3 CHOICE OF METHODS FOR ESTIMATING CARBON STOCK CHANGES AND NON-CO_2 GREENHOUSE GAS EMISSIONS

Like for cropland management, methodologies at one of three tiers are used for estimating CO_2 emissions/removals from mineral soils, organic soils and liming. The procedure is identical with different factors being derived and different activity data being used (as described in more detail in the sections below).

Total annual soil emissions/removals of CO_2 are calculated by summing:

- Net changes in organic carbon stocks of mineral soils
- Emissions of CO_2 from organic soils
- Emissions of CO_2 from liming

Carbon stock changes also need to be estimated for other carbon pools, as appropriate. For grazing lands with no woody vegetation, annual crop biomass can be neglected where there is no long-term change in the cover. However, carbon in biomass of trees, shelterbelts and woody crops on grazing lands need to be accounted for under either (but not both) grazing-land management, afforestation/reforestation or forest management (unless an Annex I Party to the Kyoto Protocol chooses not to and provides verifiable information that carbon stocks are not decreasing). Methods for above- and belowground biomass, litter and dead wood can be found in the afforestation/reforestation or forest management sections and Chapter 3 (LUCF sector good practice guidance) of this report. For guidance in estimating carbon emissions/removals in pools other than in the soil, see Box 4.2.13 and Table 4.2.8. Figure 3.1.1 in Chapter 3 provides further guidance on selecting appropriate methods.

BOX 4.2.13

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Section 3.4.1.1 Change in biomass

Section 3.4.1.2 Change in carbon stocks in soils

LINKS WITH THE *IPCC GUIDELINES*

4	Non-CO_2 greenhouse gases
5 B	Forest and grassland conversion (conversion of grazing lands to croplands)
5 D	CO_2 emissions and removals from soils

4.2.9.3.1 MINERAL SOILS

The decision tree used for selecting the tier for estimating carbon stock changes in mineral soils under grazing land management is analogous to the one used for croplands – see Figure 4.2.9 above.

Methods for estimating carbon stock changes in mineral soils

The methods used for estimating carbon stock changes in mineral soils under grazing land management are identical to those used for croplands. See the methods under Tiers 1, 2 and 3 described in Section 4.2.8.3.1 (Mineral soils) and also in Chapter 3 (Sections 3.3.1.2, 3.4.1.2, 3.4.2.2). As for cropland management all methods require that the lands subject to grazing land management be tracked continuously through time. At Tier 1, the database of default annual stock change factors in Annex 4A.1, is applicable also for grazing lands (see Section 4.2.8.3.1). However, for Article 3.4 activities it is *good practice* to use Tier 2 or Tier 3 for estimating carbon stock changes from mineral soils if CO_2 emissions from grazing land management is a key category.

Choice of carbon emission/removal factors for mineral soils

The choice of carbon stock change factors at each tier follows the same lines as described under cropland management. The carbon stock change factors are held within the same database. At higher tiers, as for cropland

management, carbon stock change factors can be calculated from literature values (e.g., Follett *et al.*, 2000), long-term experiments and model runs. It is *good practice* for replacement stock change factors, if based on experimental results, to be derived from experiments that are well designed, with adequate sampling to give adequate statistical power. Any factors based on models should only be used after the model has been tested against experiments such as those described above, and any model should be widely evaluated, well-documented and archived. It is *good practice* to provide confidence limits and/or uncertainty estimates associated with any emission/removal factors. Emission/removal factors must be shown to represent local conditions or practice, based on measurements or experiments within the region.

Choice of land use and management data for mineral soils

Like for cropland management, if area and management data are available for 1970 through 1990, a base year (1990 or other) net carbon emission/removal can be established using the default carbon emission/removal factors described above. If area and management data are not available for 1970 through 1990 the options available are those already described for cropland (see Section 4.2.8.1.1: 1990 base year). Here only the activity data required for each of three tiers are outlined briefly.

Tier 1: The management practices at Tier 1 are the same as those given in the IPCC Guidelines. The different management impacts defined there are: clearing of native vegetation with conversion to cultivated crops or pasture; land abandonment; shifting cultivation; differing residue addition levels; differing tillage systems; agricultural use of organic soils for grazing. Within these specific land-use or land-management changes, practices are defined semi-quantitatively, e.g., "high input" vs. "low input" systems. Land-use and management systems are not subdivided to finer levels of detail than this. Areas may be obtained from international data sets (e.g., FAO). If area and management data are available for 1970 through 1990, the 1990 base year net carbon stock change can be established using the default carbon emission/removal factors described above. If area and management data are not available for 1970 through 1990 the options available are those described above for cropland (see Section 4.2.8.1.1). If grazing land management is deemed a key category, then it is good practice to use a Tier 2 or 3 method.

Tier 2: The management practices at Tier 2 are the same as those given in the *IPCC Guidelines* and at Tier 1. To make them country-specific, however, some practices may be subdivided, or new ones may be added. For example, within the agricultural management systems described in the *IPCC Guidelines*, management data includes descriptors such as "high input" and "low input"; these descriptors could be replaced at Tier 2 by more explicit descriptors; for example, high grazing level, medium grazing level, low grazing level, and zero grazing. Further subdivision of activities may also be necessary; for example, different forms of grazing. An alternative to the use of more detailed descriptor categories is the use of relationships relating the intensity of a practice (e.g., grazing level) with a change in the carbon emission/removal factor. Alternatively, well-calibrated and well-evaluated models of soil carbon change (e.g., CENTURY (Parton *et al.*, 1986), RothC (Coleman and Jenkinson, 1996), or others) could be used to generate either default carbon emission/removal factors, or to generate the intensity relationships for each activity, for different soils in different climatic regions. These examples show how, at Tier 2, activities can be made more country-specific, but other refinements are also possible. Rigorous criteria must be applied so that any increase in the sink size is not under- or overestimated.

Tier 3: Management data used in the more complex Tier 3 approaches are likely to be subdivided as described for Tier 2 above.

4.2.9.3.2 CO_2 EMISSIONS FROM ORGANIC SOILS

The decision tree for use with organic soils under grazing land management is identical to that from cropland management, cf. Figure 4.2.13. The methods described under Tiers 1, 2 and 3 for cropland also apply to grazing land, cf. Section 4.2.8.3.2 (Carbon stock changes in organic soils) and also Chapter 3 (Sections 3.3.1.2 and 3.4.1.2). As for croplands, non-CO_2 greenhouse gas emissions/removals from organic soils are also important, with some emissions (i.e., methane, CH_4) decreasing as CO_2 losses increase with soil drainage. It is important when calculating changes in carbon emissions/removals from organic soils to also consider non-CO_2 greenhouse gas emissions, bearing in mind that, as a rule, these are covered in the Agriculture sector. However, note that the *IPCC Guidelines* assume that all carbon is emitted as CO_2; if this assumption is departed from, it must be justified by scientifically sound and well-documented data.

Choice of carbon emission/removal factors for organic soils

Factors for organic soils are described in the equivalent subsection for cropland management (Section 4.2.8.3.2 Carbon stock changes in organic soils) and Chapter 3 (Sections 3.3.1.2 and 3.4.1.2).

Choice of management data for organic soils

Management data for organic soils are as for *IPCC Guidelines* as described and amended above for mineral soils.

4.2.9.3.3 CO_2 EMISSIONS FROM LIMING

For carbon emissions from liming, the same methods can be used for land subject to grazing land management as for those under cropland management (see Section 4.2.8.3.3 CO_2 emissions from liming).

4.2.9.3.4 NON-CO_2 GREENHOUSE GASES

Methodologies for N_2O and CH_4 emissions from soils are given in the Agriculture chapter of *GPG2000*, which gives methodologies for sources of agricultural soil emissions that are related to grazing land management (see also Chapter 3, Section 3.4.1.3). Management practices adopted to increase soil carbon may also influence the emission of non-CO_2 greenhouse gases. Often these effects will be covered by the methods described for agriculture. For example, N_2O emissions from adding more fertilizer to build soil organic matter will be directly included. There may be other effects that are not covered by the default methods; for example, increasing the carbon pools could also increase levels of organic nitrogen which, when mineralised, could become available as a substrate for denitrification and thus increase N_2O production. Similarly, the cessation of tillage on conversion of croplands to grazing lands could, at some stage in the development of the grazing land make the soils more anaerobic, thus potentially enhancing denitrification and N_2O production (see Example 1 in Box 4.2.11). These effects can be calculated in higher-tier methods, but still should be reported in the Agriculture sector, to avoid double counting or omission.

Non-CO_2 greenhouse gas emissions/removals on deforested lands converted to grazing land (Article 3.3) need to be reported separately from those under grazing land management (Article 3.4). For further guidance, see corresponding section on cropland management (Section 4.2.8.3.4).

4.2.10 Revegetation

4.2.10.1 DEFINITIONAL ISSUES AND REPORTING REQUIREMENTS

"Revegetation" is a direct human-induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum area of 0.05 hectares and does not meet the definitions of afforestation and reforestation. Land should be classified under revegetation if it meets the revegetation definition and takes place after 1 January 1990 (see the decision tree in Figure 4.2.5 for further guidance). The methods for estimating carbon stock changes from revegetation differ somewhat from those applied to cropland management or grazing land management, and have similarities to those for afforestation and reforestation activities; even though revegetation is distinct from afforestation/deforestation, it also typically affects the aboveground carbon pool significantly.

Revegetation implies that vegetation is established to replace the previous (sometimes minimal) ground cover that had followed a land disturbance. For example, activities such as reclaiming/restoring herbaceous ecosystems on carbon-depleted soils, environmental plantings, planting of trees, shrubs, grass or other non-woody vegetation on various types of lands including urban areas, might all qualify as revegetation. Moreover, a tree planting may not qualify for afforestation/reforestation because it does not meet (and is not expected to meet during the commitment period) the minimum tree crown cover and/or minimum tree height chosen in the definition of forest, or because the consistent application of spatial configuration criteria (see Section 4.2.2.5) exclude it. In such a case the planting may qualify as revegetation. Note that revegetation does not necessarily entail a change in land use, in contrast to afforestation.

Set-aside lands such as cultivated lands subjected to revegetation should be included under cropland management if they are only temporarily set-aside (typically this is for 5 years or less, but any set-aside likely to return to cropland under the national conditions for set-aside should be counted as cropland).

It is *good practice* for Parties electing revegetation to provide documentation describing how the included areas meet the definition of revegetation and how they can be distinguished from other lands in land-use categories.

4.2.10.2 CHOICE OF METHODS FOR IDENTIFYING LANDS

General guidance on identification of lands subject to revegetation is provided in Sections 4.1.1, 4.1.2, 4.2.1, and 4.2.2. Generally, all lands subject to revegetation since 1 January 1990 should be tracked consistent with the national criteria that establish a hierarchy among Article 3.4 activities (if applicable) as explained in Section 4.1. Under the Marrakesh Accords, the geographical locations of the boundaries of the areas that encompass lands subject to revegetation need to be reported annually, along with the total land area subject to this activity.

The geographical location of the boundaries may include a spatially explicit specification of each land subject to revegetation, but does not have to. Instead, the larger area within which areas of land subject to revegetation are encompassed may be given. In either case, the lands subject to revegetation and the management thereon need to be tracked continuously through time. Continuity in monitoring/reporting of management on land could be achieved either by continuously tracking each land subject to revegetation from 1990 until the end of the commitment period (e.g., see Section 4.2.8.1 and 4.2.8.2), or by developing statistical sampling techniques, consistent with the requirements of Section 5.3, that allow the transition of different types of management on revegetation land to be determined (see Section 4.2.4.1 Developing a consistent time series).

Links to pertinent methods in this report and in the *IPCC Guidelines* are provided in Box 4.2.14.

BOX 4.2.14

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Section 2.3.2 (Three Approaches): No information on revegetation area in Chapter 2 approaches.

Requires country-specific criteria on what constitutes revegetation. Should include all transitions *between 1990 (or 1970, where required for base year estimate)* and 2008, and in later inventory years transitions on an annual basis.[61]

LINKS WITH THE *IPCC GUIDELINES*

Revegetation is not addressed in the *IPCC Guidelines*.

Guidance on methods to identify/monitor areas for revegetation lands

Methods for monitoring revegetation lands are the same as those used for afforestation/reforestation and deforestation lands (see Sections 4.2.5 and 4.2.6).

4.2.10.3 CHOICE OF METHODS FOR ESTIMATING CARBON STOCK CHANGES AND NON-CO_2 GREENHOUSE GAS EMISSIONS

For mineral soils, organic soils and for limed revegetation lands, the same methods and tier structures can be used as described for cropland management and grazing land management. Methods for aboveground biomass, belowground biomass, litter and dead wood on revegetation land, are described in Chapter 3, based on the *IPCC Guidelines* (see also Box 4.2.15, Table 4.2.8, Figure 3.1.1). For urban soils, methods are described in Annex 3.B, Chapter 3.

[61] If more than one land conversion happens on the same unit of land in the transition period of the matrix, then the transition periods may have to be shortened to account for these transitions.

BOX 4.2.15

LINKS WITH CHAPTER 2 OR 3 OF THIS REPORT

Section 3.4.2.1 Change in biomass

Section 3.4.2.2 Change in carbon stocks in soils

LINKS WITH THE *IPCC GUIDELINES*

4 Non-CO_2 greenhouse gases

5 A Changes in forest and other woody biomass stocks (grasslands / tundra)

5 C Abandonment of managed lands (grasslands / tundra)

5 D CO_2 emissions and removals from soils

5 E Other (e.g., dispersed trees that are managed but do not constitute a forest such as agroforestry, also referred to as "managed trees outside forests")

(not all five pools are included: belowground biomass and litter are missing)

4.2.10.3.1 CHOICE OF CARBON STOCK CHANGE FACTORS

There are no generic default values for revegetation activities in the *IPCC Guidelines*. A Party electing revegetation may use Tier 1 methods to estimate changes in soil carbon since default values may exist (see Section 4.2.8.3 (for cropland management), Section 4.2.9.3 (for grassland management) and also pertinent sections in Chapter 3: Sections 3.3.1.2, 3.4.1.2, 3.4.2.2). However, for all other pools default values do not exist, so it is *good practice* for a Party electing revegetation to provide country-specific values for stock change in each carbon pool and for pools not reported, to provide verifiable data that demonstrate that these are not declining in carbon (see Section 4.2.3.1 Pools to be reported). If revegetation is deemed a key category, then it is *good practice* to use a Tier 2 or 3 method.

At Tier 2, it is *good practice* to provide verifiable methods and documentation to show how the carbon stock change has been estimated for each pool elected under revegetation. For any carbon pool not elected, it is *good practice* to provide verifiable data that demonstrate that these are not declining (see Section 4.2.3.1 Pools to be reported).

At Tier 3 ecosystem carbon models, parameterised for the relevant plant functional types and soils included in the selected revegetation area, could be used to estimate annual carbon emissions and removals. As with models used for cropland management and grazing land management, they should be evaluated by testing against experiments, well-documented and archived.

4.2.10.3.2 CHOICE OF MANAGEMENT DATA

It is *good practice* to provide detailed documentation specifying the practices included under revegetation and the carbon emission/removal factors associated with each practice for each pool elected.

4.2.10.3.3 NON-CO_2 GREENHOUSE GASES

Methodologies for estimating N_2O and CH_4 emissions are given in the Agriculture chapters of the *IPCC Guidelines* and the *GPG2000*, which give methodologies for sources of agricultural soil emissions on revegetation land (the list of sources is similar to that described for cropland management – see Section 4.2.8.3).

These emissions should not be reported under revegetation but as emissions in the Agriculture sector from sources listed in Annex A to the Kyoto Protocol, and they should clearly be distinguished from emissions from revegetation reported under Article 3.4 of the Protocol.

It is *good practice* to report the non-CO_2 greenhouse gas emissions from sources on revegetation lands that might be affected by land-use practices under the Annex A sources inventory for the Kyoto Protocol. These sources belong to the inventory for the Agriculture sector (the list of sources is similar to that described for cropland management – see Section 4.2.8.3.4). Tier 3 methodologies may account for the detailed relationship between carbon storage and non-CO_2 greenhouse gas emissions if data are available to do so. Some examples of relevant activities are given in Box 4.2.11. These emissions should still be reported in the Agriculture sector.

Chapter 3 (Sections 3.3.2.2, 3.4.1.3, 3.4.2.3) provides further information on procedures for estimating non-CO_2 greenhouse gas emissions.

Non-CO_2 greenhouse gas emissions/removals on deforested lands subject to revegetation (Article 3.3) need to be reported separately from those under revegetation (Article 3.4). For further guidance, see corresponding section under cropland management (Section 4.2.8.3.4).