CHAPTER 8

SETTLEMENTS

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No refinement.

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No refinement.

8.2.1.2 CHOICE OF EMISSION/REMOVAL FACTORS

This section provides updates on methods.

Few allometric biomass equations exist specifically for trees or shrubs in urban settings (Nowak, 1996; Jo, 2002;) so investigators have tended to apply equations derived for forest trees, adjusting the resulting biomass with a coefficient (such as 0.80 [Nowak, 1994; Nowak and Crane, 2002; Nowak et al., 2013]) intended to take account of the allometry of open-grown trees in cities where above-ground biomass for a given diameter is typically lower than that of forest-grown trees (Nowak, 1996). Allometric equations for some shrub species exist, but have not routinely been applied to urban settings (Smith and Brand, 1983; Nowak *et al*., 2002 for shrub leaf biomass estimates). Below-ground tree biomass can be derived from above-ground biomass by multiplying the latter by an estimated root: shoot ratio, as described by Cairns *et al*. (1997) and applied for urban settings by Nowak *et al*. (2002). See Chapter 4 (Forest Land) for examples of root: shoot ratios (R) (also called below-ground to above-ground biomass ratio) often used in forest settings. Ratios appropriate to the region of interest can be assumed to apply without modification to settlements.

Tree growth and mortality in settlements can be affected by urban conditions such as variations in local air quality, atmospheric deposition, enhanced atmospheric CO_2 concentrations, and reduced air exchange in the root zone due to impermeable paving surfaces (e.g., Pouyat et al., 1995; Idso et al., 1998; Idso et al., 2001; Gregg et al., 2003; Pouyat and Carreiro, 2003; Nowak et al., 2013). In addition, management practices for urban trees also affect its growth and mortality. Therefore, the values and equations used to predict tree growth in settlements at higher tiers should, to the extent feasible, allow for the surrounding environment and the condition of the trees, and take into account the urban environment, then conditions and management practices of urban trees.

Carbon stored in the woody components of trees makes up the largest compartment of standing biomass stocks and annual biomass increment in settlements. For example, Nowak and Crane (2002) estimated on a citywide basis that the net annual carbon storage by trees in cities in the conterminous USA ranged from 600 to 32,200 tonnes C yr^{-1}. Jo (2002) found that the amount of C sequestered annually in three Korean cities varied from 2,900 to 40,300 tonnes. Clearly, the estimates depend on the land use definition of Settlements in each country as well as kind of tree covered area considered and hence extent of the Settlement areas being considered.

The variation is less per unit land area; for ten cities in the United States, measurements of C stored in woody biomass ranged from 150 to 940 kg C ha^{-1} yr^{-1} (Nowak and Crane, 2002) and for three Korean cities annual C stored in woody biomass varied from 530 to 800 kg C ha^{-1} yr^{-1} (Jo, 2002). Trees in urban lawns in Colorado (USA) stored 1,590 kg C ha^{-1} yr^{-1} (Kaye *et al*., 2005). City level studies show that annual sequestration rates ranged from less than 1.5 to more than 5.0 t C (ha crown cover) $^{-1}$ yr^{-1}but most of the rates are in the range from 2.0 to 4.0 t C (ha crown cover) $^{-1}$ yr^{-1}(Nowak et al., 2013, Escobedo et al., 2010, McPherson et al., 2013, Chaparro and Terradas, 2009, Mills et. al., 2015, Yang et al., 2005, Liu and Li, 2012 and Vaccari et al., 2013). The studies indicate that the annual sequestration per unit of urban area or even per unit of crown cover in settlements depends on the specific situation on urban land such as type of vegetation, species composition, density of planted tree and shrub, management type of urban area, shade of buildings etc. In the case of parks and urban trees, estimation methods are provided below. For Settlements areas stocked by trees with forest-like conditions, refer to the estimation methods in Chapter 4, Volume 4 (Forest Land).

At a national level, data are still sparse, though availability is increasing. For example, Nowak et al., 2013 estimated the average removal factor of tree biomass (CRW) for US urban forest as 2.77 t C (ha crown cover)$^{-1}$ yr^{-1} based on studies in 28 US cities and 6 US states, Pasher et al., 2014 provided the Canadian removal factor of urban forest in settlement as 2.12 t C (ha crown cover)$^{-1}$ yr^{-1} which adjusted the US removal factor to the Canadian climate condition. McPherson et al., 2013 reviewed carbon sequestration rate per urban tree cover area in 32 cities to encompass a range of sizes, climates and cultures (US, Canada, Spain, Germany, Korea and China) and derived a mean value as 2.79 t C (ha crown cover)$^{-1}$ yr^{-1}.

Tier 1

This method assumes, probably conservatively, that changes in biomass carbon stocks due to growth in biomass are fully offset by decreases in carbon stocks due to removals (i.e., by harvest, pruning, clipping) from both living and from dead biomass (e.g., fuelwood, broken branches, etc.). Therefore, in a Tier 1 approach $\Delta C_G = \Delta C_L$ and for all plant components, and $\Delta C_B = 0$ in Equation 2.7 in Chapter 2, Volume 4 (Generic Methodologies Applicable to Multiple Land-Use Categories).

Tier 2

Trees

Tier 2 calls for parameter values for CRW_{ij} (Equation 8.2) and C_{ij} (Equation 8.3). In *the 2006 IPCC guidelines,* it was explained that the default removal factors for tree biomass (CRW), i.e. 2.9 tonnes C (ha crown cover)$^{-1}$ yr^{-1} is based on a sample of ten US cities, with values that ranged from 1.8 to 3.4 tonnes C (ha crown cover)$^{-1}$ yr^{-1} (Nowak and Crane, 2002). An updated study based on 28 US cities and six US states provides an average removal factor for tree biomass (CRW) of 2.8 tonnes C (ha crown cover)$^{-1}$ yr^{-1} (Nowak et al., 2013), the value is used as an updated of the global default. Additional removal factors for tree biomass (CRW) of 2.1 t C (ha crown cover)$^{-1}$ yr^{-1}is based on Canadian study which is adjusted the result of US study mentioned above to their climatic condition. Countries located in cold temperate and boreal region as well as dry regions may use this lower default parameter. These removal factors are usually suitable for Tier 2a. The updated Table 8.1 shows updated data and the range of default CRW_{ij}. Values appropriate to national circumstances can also be developed.

Using Tier 2b, the removal factor is C_{ij}. Updated Table 8.2 provides defaults carbon accumulation rates for tree species classes for use at Tier 2b. These estimates of broad species classes are based on various allometric equations and limited field data from urban areas in the USA and are averages for trees of all sizes (not just mature trees). Additional default carbon accumulation rates for common tree species in East Asia are based on a Japanese study for planted trees in urban parks. Averaged C_{ij} for all trees in city area are almost within the range from 0.005 to 0.01 tonnes C (tree)$^{-1}$ yr^{-1}. Where large trees are dominant in the city area the upper range value may be used for C_{ij}, otherwise, the lower range value is used for C_{ij}. Tiers 2a and 2b methods provide biomass estimates for total combined above-ground and below-ground woody biomass. Additional explanation may be needed around here about new default parameters for Tier 2b. If required below-ground biomass can be estimated separately using a root: shoot ratio of 0.26 (Cairns *et al*., 1997). If trees in Settlements are subject to similar or same management implemented in Forest Land, the updated root: shoot ratio of relevant category in Table 4.4 in Chapter 4, Volume 4 (Forest Land) may also be applied.

For Tiers 2a and 2b, the default assumption for ΔC_L where the average age of the tree population is less than or equal to 20 years is zero. This is based on the assumption that urban trees are net sinks for carbon when they are actively growing and that the active growing period (AGP) is roughly 20 years, depending on tree species, planting density, and location. Thereafter, the method assumes that the accumulation of carbon in biomass slows with age, and thus for trees older than the AGP, increases in biomass carbon are assumed to be offset by losses from pruning and mortality. For trees older than the AGP this is conservatively accounted for by setting $\Delta C_{G_{wood}} = \Delta C_{L_{wood}}$. Countries can define AGP depending on their circumstances.

When kind of perennial crop (e.g. home garden, hedgerows) are allocated in Settlements, countries may estimate C stock changes based on the estimation method of perennial wood provided in Chapter 5, Volume 4 (Cropland) by applying the default carbon accumulation ratio provided in Tables 5.1 to 5.4 in Chapter 5, Volume 4 (Cropland).

Other woody perennial types

Countries may, for any perennial type, develop their own values for CRW_{ij} (in Equation 8.2) and C_{ij} (in Equation 8.3). A conservative assumption of no change in any of these components (i.e., $CRW_{ij} = 0$ and $C_{ij} = 0$) can also be applied.

Herbaceous biomass

Tiers 2a and 2b both assume no change in herbaceous biomass in *Settlements Remaining Settlements*. Using this method, an equation of $\Delta C_{G_{Herbs}} = \Delta C_{L_{Herbs}}$ is applied. ΔC_B is estimated based on the difference between increment and losses in woody biomass only.

TABLE 8.1 (UPDATED)
TIER 2A DEFAULT CROWN COVER AREA-BASED GROWTH RATES (CRW) FOR URBAN TREE CROWN COVER BY REGION

Region	Default annual carbon accumulation per ha tree crown cover [tonnes C (ha crown cover)$^{-1}$ yr^{-1}]	SD	Source
Global default	2.8	0.45	[1]
Cold temperate and Boreal	2.1	0.34	[2]

References

[1] Nowak et al., 2013: average of 28 US cities and 6 US states; [2] Pasher J. et al., 2014: study on Canada.

TABLE 8.2 (UPDATED)
TIER 2B DEFAULT AVERAGE ANNUAL CARBON ACCUMULATION PER TREE IN URBAN TREES BY SPECIES CLASSES

Ecological zone	Broad species class	Default annual carbon accumulation per tree (tonnes C yr^{-1})	SD	Sources
Temperate (native species in east Asia)	Zelkova	0.0204	0.008	[1]
	Ginkgo	0.0103	0.008	[1]
	Oak (*Quercus myrsinaefolia* BLUME)	0.0095	0.002	[1]
	Camphor tree (*Cinnamonum camphora* PRESL)	0.0122	0.004	[1]
All	Mixed trees at city level	0.005 – 0.01	0.005	[1],[2],[3],[4],[5],[6],[7],[8]

References

[1] Tonosaki, 2018; [2] Chaparro and Terradas, 2009; [3] Liu and Li, 2012; [4] Yang et al., 2005; [5] Nowak and Crane, 2002; [6] McPerson, 1998; [7] Vaccari et al. 2013; [8] Paoletti et al., 2011.

Tier 3

For Tier 3, countries should develop plant type-specific biomass increment factors appropriate to national circumstances. Country-specific parameters and growth equations should be based on the dominant climate zones and particular species composition of the major settlements areas in a country, before making estimates for less extensive settlements. If country-specific biomass increment parameters are developed from estimates of biomass on a dry matter basis, they need conversion to units of carbon using either the default carbon fraction (CF) values in Table 4.3 in Chapter 4, Volume 4 (Forest land) or a carbon fraction that is more appropriate to the circumstances.

Under higher tiers, the assumptions for ΔC_L should be evaluated and modified to better address national circumstances. For instance, based on national availability of country-specific information, i.e. age-dependent and/or species-specific carbon losses in settlement trees, countries may estimate a loss factor, documenting the resources and rationale used in its estimation process, or may use country-specific active growing period (AGP). In this case, it is *good practice* to use urban vegetation type specific AGP based on detailed categorisation of urban area with vegetation. This is because management of urban trees are not implemented in an uniformed way, and carbon accumulation ratio and growing years depend on management type of urban trees/urban area with vegetation, such as street trees, trees in urban park without frequent pruning and/or urban green area treated as more natural state (Nowak et al., 2013; Chaparro and Terradas, 2009; Jo, 2002).

When countries consider applying data collected in other countries, it is *good practice* to assess how similar the conditions (climate, urban structure, tree types) are compared to the country from which data originate; where needed, adjustment may be also applied to resolve dissimilarities. If a country adopts the stock-difference method (Equation 2.8), Chapter 2, Volume 4 and/or applying National Forest Inventory for urban trees, it should have representative sampling and periodic measurement system to estimate the changes in biomass carbon stocks.

8.2.1.3 CHOICE OF ACTIVITY DATA

No refinement.

8.2.1.4 UNCERTAINTY ASSESSMENT

No refinement.

8.2.2 Dead organic matter

No refinement.

8.2.3 Soil carbon

No refinement.

8.3 LAND CONVERTED TO SETTLEMENTS

This section provides elaboration on methods.

Land Conversion to Settlements occurs due to expansion of urban area, construction of transportation infrastructure and other reasons/purposes. Urban extent has been increasing globally over the last three decades (Seto et al. 2011). In areas that are primarily rural, even if land uses are not changing quickly, land devoted to residential uses can occupy a significant portion of the landscape. Transitions of Forest Land, Cropland, Grassland, and Wetlands to Settlements can have important impacts on carbon stocks and fluxes (Imhoff et al., 2000; Milesi et al., 2003).

Estimation of annual greenhouse gas emissions and removals from *Land Converted to Settlements* includes the following:

- Estimates of annual change in C stocks from all C pools and sources:
- Biomass (above-ground and below-ground biomass);
- Dead organic matter (dead wood and litter);
- Soils (soil organic matter).
- Estimates of non-CO_2 gases (CH_4, CO, N_2O, NO_x) from burning of above-ground biomass and dead organic matter.

8.3.1 Biomass

8.3.1.1 CHOICE OF METHOD

This section provides elaboration on methods.

The general approach for calculating the immediate change in live biomass accruing from the conversion to Settlements is represented by Equations 2.15 and 2.16 in Chapter 2. The mean annual biomass increment resulting from the transition is represented by the difference between the biomass in the settlement land-use category immediately after the transition (B_{After}) and the biomass in the previous category (B_{Before}).

This method follows the approach in the *Guidelines* for other land-use transitions: the annual change in carbon stock in biomass due to land conversion is estimated (using Equation 2.16) by multiplying the area converted annually to Settlements by the difference in carbon stocks between biomass in the system prior to conversion (B_{Before}) and that in the Settlements after conversion (B_{After}).

In the higher tiers, it is necessary to add growth during the year of inventory (ΔC_G) and subtract loss (ΔC_L) to obtain the net change in carbon stocks on *Land Converted to Settlements* (Equation 2.15). It should be noted that growing periods of trees, other perennial woody biomass and herbaceous biomass are different. For example, of the default assumption in other chapter and sectors, the growing periods is 20 years for tree biomass in *Settlements Remaining Settlements* (Tier 2, see section 8.2.1) and land converted to grassland achieve their steady-state of biomass during the first year following the conversion (Tier 1 see Section 6.3.1.1, Chapter 6, Volume 4). There is no default for shrubs. When estimate ΔC_G, it is *good practice* to reflect differences on the growing period and/or carbon density under steady-state for each tree species or vegetation type.

Tier 1

For Tier 1, in the initial year following conversion to the settlement land use, the most conservative approach is to set $B_{\_After}$ to zero, meaning that the process of development of settlements causes carbon stocks to be entirely depleted. Under Tier 1, estimation of growth during the year of inventory (ΔC_G) and subtract loss (ΔC_L) are not necessary since these estimations are only covered in Equation 2.16, Chapter 2, Volume 4 (for Tier 2) and also this carbon stock change is not estimated under Tier 1 in *Settlements Remaining Settlements*. This is a consistent approach explained in "Step by step method for implementation".

When potential gains of carbon are expected in *Land Converted to Settlements* and information on crown cover area or number of trees in *Land Converted to Settlements* is available, country can apply the default method of Tier 2 in *Settlements Remaining Settlements* for estimating ΔC_G and ΔC_L also for Tier 1.

Tier 2

At Tier 2, country-specific carbon stocks can be applied to activity data disaggregated to a level of detail adapted to national circumstances for the estimation of $B_{\_Before}$. At the higher tiers, the area of each land-use or land cover type converted to another type in a settlement (examples of land use and land cover types are described in Section 8.2) should be recorded, because that area is associated with the amount of carbon both before and after the conversion. Settlement land-use or land cover types are likely to differ in carbon density. For estimations of ΔC_G and ΔC_L, country can be use country-specific factors. Alternatively, default estimation consistent with Tier 2 in *Settlements Remaining Settlements* are also possible to be applied. For both cases, the information on crown cover area or number of trees in Land *C*onverted to *S*ettlements is necessary for estimation.

Tier 3

At Tier 3, countries can use the stock difference method (Equation 2.8) or other advanced estimation methods that may involve complex models and highly disaggregated activity data including, if available, more detailed information about $B_{\_After}$ on a country- or biome-specific basis. The method using National Forest Inventory is also covered by Tier 3. In this case, country should also take into account the guidance of Chapter 4, Volume 4 (Forest Land) as appropriate.

8.3.1.2 CHOICE OF EMISSION/REMOVAL FACTORS

This section provides elaboration on methods.

This section refines guidance by updating Table 8.4 and provides further explanation for the Tier 2 and Tier 3 guidance. The updated Table 8.4 provides more complete information on how to use $B_{\_Before}$ and suggests the use of consistent factors with other chapters' default factors. The guidance on Tier 2 and Tier 3 are enhanced to clarify how to choose and use emission/removal factors under higher tiers.

Tier 1

Tier 1 methods require estimates of the biomass of the land use before conversion and after conversion. It is assumed that all biomass is cleared when preparing a site for settlements, thus, the default for biomass immediately after conversion is 0 tonnes C ha^{-1}. Updated Table 8.4 provides default values for biomass before conversion ($B_{\_Before}$).

TABLE 8.4 (UPDATED)
DEFAULT BIOMASS CARBON STOCKS REMOVED DUE TO LAND CONVERSION TO SETTLEMENTS

Land-use category[1]	**Carbon stock in biomass before conversion (B_Before) (tonnes C ha^{-1})**	**Error range %**
Forest Land	See Chapter 4, Volume 4, Tables 4.7 to 4.12 for carbon stocks in a range of forest types by climate regions. Stocks are in terms of dry matter. Multiply values by a carbon fraction (CF) in Table 4.3, Chapter 4, Volume 4 consistent with what used in Forest Land estimation to convert dry matter to carbon.	See Section 4.3, Chapter 4, Volume 4 (Land Converted to Forest Land)
Grassland	See Table 6.4, Chapter 6 for carbon stocks in a range of grassland types by climate regions. Multiply default carbon fraction (CF) 0.47 (for herbaceous biomass for Grassland, see page 6.29, Chapter 6) to convert dry matter to carbon.	± 75%
Cropland	For Cropland containing annual crops: Use default of 4.7 tonnes of carbon ha^{-1} or 10 tonnes of dry matter ha^{-1} (see Updated Table 5-11, Chapter 5, Volume 4). For Cropland containing perennial crop: Use carbon stocks in Updated Table 5.4, Chapter 5, Volume 4, as appropriate.	± 75%

[1] The table includes the land-use categories most commonly converted to Settlements. For the remaining land-use categories refer to relevant chapters in Volume 4.

* Note that the condition of forests that are converted to Grassland or Cropland is not likely to be typical of the forest type in general, i.e. the carbon stocks are probably lower than average (Carter et al., 2017; Puhlick et al., 2017). Specific values for disturbed forest may be appropriate.

[#] Represents a nominal estimate of error, equivalent to two times standard deviation, as a percentage of the mean.

Tiers 2

Tier 2 methods replace the default data by country-specific data for B_{Before}. For calculation of ΔC_G and ΔC_L, country country-specific data can be used. The default factors of Tier 2 in *Settlement Remaining Settlements* may also be used when country-specific data is not available. In this case, countries should follow the guidance on either Tier 2A or Tier 2B in Section 8.2.1, *Settlements Remaining Settlements*, i.e. using the default annual carbon accumulation ratio provided in Table 8.1 or Table 8.2 for ΔC_G and ΔC_L considered to be zero noting that all lands contained in *Land Converted to Settlements* are within the duration of the default AGP (=20 years).

Tiers 3

Tier 3 involves detailed modelling or measurement data relevant to the conversion processes. Countries may use average biomass stocks data for their estimations in Settlements instead of using carbon accumulation ratio. In this case, it may take more than one year to reach the average biomass stocks following land conversion. Countries should consider the appropriate activity data to reflect the years to reach the average biomass stocks in its estimation. When countries estimate annual carbon accumulation resulted from the establishment of trees, shrubs or herbaceous biomass differently, they also need to consider the growing years in each tree or vegetation type. Each removal factor should be multiplied by the appropriate activity data, i.e. areas under growing years in each tree or vegetation type.

8.3.1.3 CHOICE OF ACTIVITY DATA

This section provides an elaboration on methods.

Activity data for estimating changes in biomass on land areas converted to Settlements can be obtained, consistent with the general principles set out in Chapter 3, through national statistics, from forest services, conservation agencies, municipalities, survey and mapping agencies. Cross-checks should be made to ensure complete and consistent representation of annually converted lands in order to avoid possible omissions or double counting. Data should be disaggregated according to the general climatic categories and settlements types. For Tier.2 and Tier 3, data related to green covered area, in land areas converted to Settlements is necessary. Tier 3 inventories will require more comprehensive information on the establishment of new settlements, with refined soil classes, climates, and spatial and temporal resolution. All changes having occurred over the number of years selected as the transition period should be included with transitions older than the transition period (default 20 years) reported as a subdivision of *Settlements Remaining Settlements*.

Higher tiers require greater detail but the minimum requirement for inventories to be consistent with the IPCC Guidelines is that the areas of Forest Land conversion can be identified separately. This is because forest will usually have higher carbon density before conversion. This implies that at least partial knowledge of the land-use change matrix, and therefore, where Approaches 1 and 2 from Chapter 3, Volume 4, are used to estimate land area will be needed, supplementary surveys may be needed to identify the area of land being converted from Forest Land to Settlements. As pointed out in Chapter 3, Volume 4, where surveys are being set up, it will often be more accurate to seek to establish directly, areas undergoing conversion, than to estimate these from the differences in total land areas under particular uses at different times.

Step by step method for implementation

Tier 1

Use default values for B_{before} from respective land-use category chapters (Forest Land, Grassland, etc) and assume that B_{After} equals zero in Equation 2.16, Chapter 2, Volume 4.

Step 1: Apply Equation 2.16 , Chapter 2, Volume 4. to each land-use type converted to settlement lands;

Step 2: Add up the biomass changes over all the land-use types; and

Step 3: Multiply the result by 44/12 to obtain the amount of CO_2 equivalents emitted (the sum obtained in Step 2 will be a negative number) from the land conversion.

Tier 2

The typical steps to implement a Tier 2 method (the case of using the default assumption for ΔCG and ΔCL) are:

Step 1: Use the methods described in Chapter 3, Volume 4, including where relevant cadastral and planning records or the analysis of remote sensing images (or both), to estimate the change in area between the present and the last area survey.

Step 2: Define — as a first approximation — settlement land-use types on the basis of the proportion of green area. For instance, three tentative land use classes could be: Low (less than 33percent green space), Medium (from 33 to less than 66percent green space), and High (more than 66percent green space). Each one of those classes can be assigned with an average carbon content, obtained from the species surveyed in similarly defined classes for accounting biomass changes in Section 8.2.

Step 3: Draw a land-use conversion area matrix for the land-use transitions defined in Step 2.

Step 4: Estimate with equations the biomass stocks of the defined land-use types and the converted land-use types (to obtain B_{Before} and B_{After}), apply Equation 2.16, Chapter 2, Volume 4. to each non-empty cell of the land-use change matrix, add up the changes in carbon stocks, and multiply the sum by 44/12 to obtain the emission/removal of CO_2 equivalents.

Step 5: Calculate ΔC_G, using either Method A or Method B in Section 8.2.1, *Settlements Remaining Settlements* (the choice of method will depend on the applicability of the emission and removal factors, as well as the availability of activity data). This will be used in Equation 2.15, Chapter 2, Volume 4.

Step 6: Calculate ΔC_L, using Methods as described in Section 8.2.1.3, *Settlements Remaining Settlements*.

Step 7: Calculate the change in carbon stocks in live biomass resulting from the land-use transition to Settlements, accounting for the biomass increment, biomass losses, and biomass change due to land-use conversion as given in Equation 2.15, Chapter 2, Volume 4.

8.3.1.4 UNCERTAINTY ASSESSMENT

No refinement.

8.3.2 Dead organic matter

No refinement.

8.3.3 Soil carbon

No refinement.

8.4 COMPLETENESS, TIME SERIES CONSISTENCY, QA/QC AND REPORTING

No refinement.

8.5 BASIS FOR FUTURE METHODOLOGICAL DEVELOPMENT

The section is updated by deletion of the sentences no more relevant.

Gaps in this methodology exist because sufficient data are not available to quantify all of the pools and fluxes of greenhouse gases in Settlements. Obvious gaps include:

Methodology for estimating emissions of non-CO_2 greenhouse gases (N_2O and CH_4);

Detailed methodology to account for carbon stocks other than live biomass and soils (specifically, dead wood and litter);

Discussion of carbon stocks and fluxes from turfgrass and turf management;

Non-CO_2 greenhouse gases. While some evidence exists to support the idea that nitrous oxide fluxes may be enhanced in urban areas relative to the native condition (Kaye *et al*., 2004), this result likely depends on the native condition (i.e., the climate and region in which the settlement is located) and the management regime typically applied in that settled area. Additional data are required before conclusions about the impact of settlement on non-CO_2 greenhouse gas fluxes can be drawn.

Dead wood and litter. Dead wood is a class variously composed of fallen or pruned branches or trees, or dead standing trees not yet replaced with live individuals. This dead wood may be burned or disposed of as solid waste, used for composting, left to decay either in-site or off-site. This material is treated in this methodology as a loss from the live biomass term. Because dead wood is likely to be carried off-site in settlements (rather than left on-site to decay as in forests), a more detailed methodology developed in the future might account for the proportion of dead wood taken to landfills, disposed of in compost piles, burned, or left on-site to decay. The portion taken to landfills or composted might be treated as harvested wood products (HWP) or as waste, both of which are treated in other sections of the *Guidelines*.

Turfgrass and turf management. Turfgrass biomass consists of roots, stubble, thatch, and above-ground components. Though estimates of turfgrass productivity have been published (Falk, 1976; Falk, 1980; Qian *et al*., 2003), grass decomposes quickly and there is little information about the overall accumulation of biomass in the longer-lived components of turf biomass. Turfgrass allocation to the above-ground and below-ground components also depends on the management and mowing regime. Because of the lack of generalizable information on this topic, as well as the lack of activity data quantifying the area covered by turfgrass in Settlements, there is currently no detailed methodology describing carbon removed by turf systems. A more detailed methodology would require additional information on turf productivity, turfgrass turnover, and allocation to different plant components as it varies with management regime. Of course, the activity data required to implement this methodology would include information on management regimes and the proportion of Settlements covered by turfgrass.

Land classes. A more detailed methodology would benefit from a consistent set of definitions of land classes within Settlements that could be applied to any country regardless of its climate, native vegetation, or typical settlement regime. This would make Settlements parallel to other land uses – Forest Land, Grassland, Cropland, Wetlands – which are easily defined based on a set of measurable and objective parameters. Some research has been applied in this direction (Theobald, 2004), but current classifications are inconsistent. While the rate of carbon sequestration per unit of tree crown cover is fairly consistent, for example, the overall rate of carbon storage per unit of settlement area depends entirely on the relative amounts of tree and turfgrass cover within that settlement. This land classification would be part of the set of activity data collected by countries, and the detailed methodology could be developed and applied consistently based on those land cover data. This type of land-use classification would also enable countries to account for changes in carbon storage resulting from management changes within areas broadly classified as Settlements. For example, when vacant plots are developed, the adventitious vegetation remaining in the non-built areas might be replaced with landscape species differing in ability to store carbon.

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