5.6 TIME SERIES CONSISTENCY AND RECALCULATIONS

5.6.1 Introduction

Greenhouse gas inventories for LULUCF categories typically rely upon numerous data inputs, assumptions, and models brought together in a consistent and transparent way. Because a major interest in an inventory is its trend, it is critical to ensure that inventory totals estimated for different years are as comparable as practically possible. According to the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (*GPG2000*, IPCC, 2000), it is most appropriate to use the same methodology and consistent sources of data for all inventory years. If this is not possible, time-series consistency can be approximated using techniques described in this section. Recalculations imply changes in earlier estimates due to changes in methodology or methodological refinements.

It is anticipated that the use of recalculation methodologies in LULUCF category inventories will be particularly important for two reasons. First, the development of inventory methods and interpolation/extrapolation tools (models) for this sector is ongoing and it is anticipated that changes to the methods of many countries will occur over time due to the complexity of processes involved. This will be the result of either changes in tiers or modification of national methods. The second reason that recalculation issues are important is that certain data needed to calculate an inventory for the LULUCF categories may not be collected annually. For example, forest inventory data may be compiled only once in a five or ten year period. In these cases, methods are needed to extrapolate and interpolate from infrequent data to develop an annual time series.

This section discusses general issues of time series consistency and the use of recalculation in the LULUCF sector. Section 5.6.2 considers the impact of methodological change and methodological refinements (either data or models) and the associated recalculation techniques that can be used to ensure the consistency of the inventory over time. The issue of developing annual inventories when data are only available at a lower frequency (e.g., every 5 years) is covered in Section 5.6.3. Issues particular to the Kyoto Protocol are addressed in Section 5.6.4.

5.6.2 Time Series Consistency and Methodological Change

As inventory methods improve and more relevant data become available, it is *good practice* to apply this new information if it improves the reliability and accuracy of the inventory.[22] When modifying methods or input data, care must be taken to ensure that changes in the inventory through time reflect real changes in emissions or removals and not simply the pattern of methodological refinements. For example, if a country moves from a Tier 1 method in one year to a higher tier in the next, any change in emissions and/or removals between the two years will reflect both the different methods as well as real changes. When different methods are used in two different periods there is potential for the time series to be *inconsistent* for the two periods. The standard method for ensuring consistency is to *recalculate* the estimates using the same method for all inventory years, if possible. The purpose of this recalculation is to ensure that the entire time series reflects the new data and/or method. If it is not possible to use the new data or methods throughout the time series, alternatives must be considered.

The *GPG2000*, Section 7.3, Recalculations, describes methods for recalculation and time series consistency and it should be referred to for a general description of *good practice guidance* in this area. The discussion in the *GPG2000* is not sector-specific and can be applied directly to the LULUCF sector. However, given the ongoing refinement of data and methods in this sector, it is anticipated that the use of recalculation techniques will be particularly important. Following the *GPG2000*, it is *good practice* to *recalculate* previously reported inventory estimates when:

- *Errors have been identified in the previous inventory data, models, or methods that affect the inventory level or trend*. If errors are corrected in follow-up inventories, but recalculation is not conducted to correct prior inventories, erroneous reporting of the inventory would result;
- *Available data have changed*. The availability of data is a critical determinant of the appropriate method, and thus changes in available data may lead to changes or refinements in methods. As inventory agencies gain experience and devote additional resources to preparing greenhouse gas emissions inventories, it is expected

[22] New methods or data that are not judged to improve the ultimate inventory estimate and therefore are not used, may provide useful information for analyzing uncertainty, QA/QC, and verification.

that data availability will improve.[23] Overall, though, inventory agencies should choose methods and collect data consistent with the identification of key source and sink categories, as discussed in Section 5.4.5.

- *The previously used method is not consistent with good practice guidance for that source/sink category* as described in Chapters 2, 3 or 4.
- *A source/sink category has become key*. A source or sink category might not be considered key in the base year, depending on the criteria used, but could become key in a future year. For example, a country might launch afforestation programs that could result in a considerable increase of afforested lands, or experience large conversions of forested areas in urban developments which could result in sizable increase of deforestation. Inventory agencies anticipating these types of significant changes and resulting changes to higher tier methods in a category may want to consider this possibility before it becomes key.
- *The previously used method is insufficient to reflect mitigation activities in a transparent manner.* As techniques and technologies for reducing emissions or enhancing removals are introduced, inventory agencies should use methods that can account for the resulting decrease changes in emissions or removals in a transparent manner. Where the previously used methods are insufficiently transparent, it is *good practice* to change or refine them.
- *The capacity for inventory preparation has increased.* Over time, the human and/or financial capacity to prepare inventories may increase. If inventory agencies increase inventory capacity, it is *good practice* to change or refine methods so as to produce more accurate, complete or transparent estimates, particularly for key categories.
- *new methods become available.* In the future, new methods may be developed that take advantage of new technologies or improved scientific understanding. For example, remote-sensing technology and site specific modelling is making it feasible to estimate emissions from land clearing activities more accurately than by using simple aggregate emission factor/activity data. Inventory agencies should ensure that their methods are consistent with the *IPCC Guidelines* and with this report.

Once the need for recalculation is determined, there are a variety of approaches that may be considered to address potential inconsistencies in the time series. The choice of recalculation method typically depends on the data that are available to perform the recalculations. *GPG2000* discusses several methods, and these are summarised in Table 5.6.1. The approaches described in *GPG2000* are conceptually fully applicable to the LULUCF sector.

TABLE 5.6.1
SUMMARY OF APPROACHES TO OBTAIN CONSISTENCY IN TIME SERIES

Approach	Applicability	Comments
Total Recalculation	Required data are available for all time periods.	• *Good practice*, if possible.
Interpolation	Data needed for recalculation using the new method are available for intermittent years during the time series.	• Emissions estimates can be linearly interpolated for the periods when the new method cannot be applied.
Trend Extrapolation	Data for the new method are not collected annually and are not available at the beginning or the end of the time series.	• Most reliable if the trend over time is constant. • Should not be used if the trend is changing (in this case, the surrogate method may be more appropriate). • Should not be done for long periods.
Overlap	Data necessary to apply both the previously used and the new method must be available for at least one year.	• Most reliable when the overlap between two or more sets of annual emissions estimates can be assessed. • If the relationship between the two methods during the period of overlap is irregular, this approach should not be used for recalculation.
Surrogate	Emission factors or activity data used in the new method are strongly correlated with other well-known and more readily available indicative data.	• Multiple indicative data sets (singly or in combination) should be tested in order to determine the most strongly correlated. • Should not be done for long periods.

[23] In some circumstances data collections may be reduced which can also lead to a change or refinement in method.

It is not feasible to list all possible issues that may arise when recalculating or to provide detailed recommendations about the appropriate recalculation technique in all instances. Each case should be treated on its merits and the recalculation methodology chosen should be based on a trade off between the cost to implement it and the overall impact on the time series consistency.

Over several years of inventory preparation, a variety of methodological changes may occur. In simple cases (e.g., when moving between tiers), sampling or experimentation may provide country-specific emission factors. In this case, it is *good practice* to recalculate the time series incorporating these new emission factors, with the available activity data. More complicated situations can also arise. For example:

- The instruments used to collect activity data may change through time, and it is impossible to go back in time to apply the new instrument. For example, clearing events can be estimated by the use of satellite imagery, but the satellites available for this work change or degrade through time. In this case, the overlap method is most applicable.
- Some data sources may not be available annually because of resource constraints. In this case, interpolation between years or extrapolation for years after the last year with measured data available may be most appropriate.
- Emissions and removals from LULUCF typically depend on past land use activity. Thus, data must cover a large historical period (20-100 years), and the quality of such data will often vary through time. Overlap, interpolation or extrapolation techniques may be necessary in this case.
- The calculation of emission factors will typically require a combination of sampling and modelling work. Time series consistency must apply to the modelling work as well. Models can be viewed as a way of transforming input data to produce output results. In most cases where changes are made to the data inputs or mathematical relationships in a model, the entire time series of estimates should be recalculated (see Table 5.6.1). In circumstances where this is not feasible due to available data, variations of the overlap method could be applied.

5.6.3 Recalculation and Periodic Data

National resource or environmental inventories, such as national forest inventories, only in rare cases cover the entire country on an annual basis. Instead, they are generally carried out every fifth or tenth year, or region-by-region, implying that national level estimates can only be directly obtained once the inventory in every region has been completed.

When data are available at a frequency that is less than annual, several issues arise. First, the estimates need to be updated each time new data become available, and the years between the available data need to be recalculated in some way. The second issue is producing inventories for years after the last available data point and before new data are available. In this case, new estimates should be extrapolated based on available data, and then recalculated when new data become available.

The choice of method to achieve time series consistency will depend on the particular data available. If surrogate data (i.e., alternative datasets that can be used as a proxy for missing data) are available, they can be a useful guide for extrapolating the trend in periodic data and subsequently interpolating the same data following the next data collection cycle. If there are no available surrogates or other information, then the only technique available is to extrapolate, with a recalculated interpolation of the estimates when the new observations are available. Thus, it is *good practice* to attempt to find reliable surrogate data to guide extrapolation and interpolation when the fundamental data used for the inventory estimates are not available annually. Two examples of practical approaches are given in Box 5.6.1 and Box 5.6.2.

BOX 5.6.1

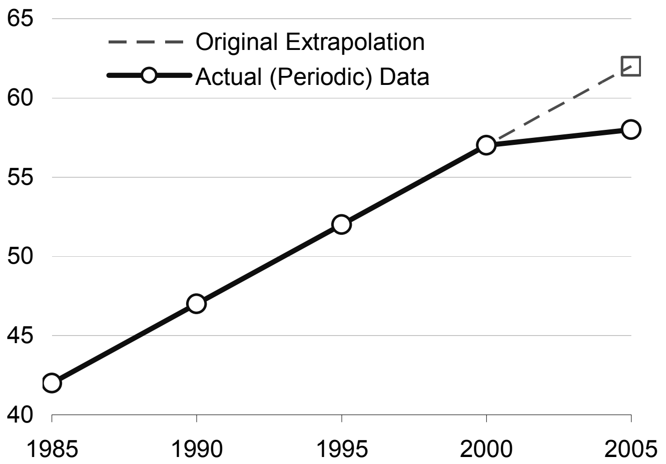
EXAMPLE CASE WHERE A NATIONAL FOREST INVENTORY IS CONDUCTED EVERY 5 YEARS

Consider a case where a national forest inventory is conducted every 5 years. Estimates of several types of required data (e.g., tree growth) will therefore only be obtained at certain intervals. On the assumption that growth is on average reasonably stable between years, inventory estimates for the years after the last available data should be made using extrapolations of past estimates (i.e., tree growth trends). In Figure 5.6.1, a biomass estimate for 2003 for a plot is obtained in this way, although the latest measurement was made in 2000. The trend between 1995 and 2000 is simply extrapolated linearly. In practice, a log scale might be used to accommodate exponential behaviour but this is not considered for this simple example. Also, extrapolation can be improved using surrogate data or more sophisticated modelling taking into account parameters influencing the parameter we want to extrapolate.

BOX 5.6.1 (CONTINUED)
EXAMPLE CASE WHERE A NATIONAL FOREST INVENTORY IS CONDUCTED EVERY 5 YEARS

Next, once the new data for 2005 are collected (Figure 5.6.1), the estimates for the intermediate years (2001-2004) need to be recalculated using an appropriate approach (e.g., a combination of interpolation and surrogate approaches). In this example, the estimates for all of these intermediate years (2001-2004) would be recalculated, since the estimate for 2005 turned out to be lower than the extrapolated trend.

FIGURE 5.6.1
RECALCULATED ESTIMATE FOR 2003 BASED ON LINEAR EXTRAPOLATION



BOX 5.6.2
EXAMPLE OF MODELLING THE EMISSIONS OF A SITE OVER TIME

Consider modelling the emissions of a site over time. This might be useful in a country-specific approach if the inventory was based on tracking either a sample or complete population of sites.

Typically, it would not be cost-effective to physically visit all sites annually to assess land-use change. Instead remote sensing technologies could be employed to measure changes such as clearing, with the much greater coverage of the technique offsetting the lower precision of the data compared to ground visits. Because of the costs of acquiring and processing the remote sensing data, it might not be either feasible or cost effective to generate the remotely sensed data on an annual basis. Instead, it might be generated every several years and the intervening periods interpolated.

When a clearing event is identified through periodic surveys or remote sensing, it is necessary to allocate emissions to one or more of the years preceding the event. In the absence of any surrogate or additional information indicating which year or years the event took place, it is *good practice* to allocate emissions from the clearing event in equal increments to each year. For example, if remote sensing shows that a particular site was forested during 1997, but was cleared by 2000, then the clearing may have occurred in 1998, 1999 or 2000.

The presence of surrogate information may change the approach to the analysis. In making estimates in the period before new satellite data become available, (i.e., for the original 1999 and 2000 inventories) extrapolation from previous years is necessary, perhaps with the use of administrative records. It is *good practice* to make the most reliable extrapolation possible, subject to the best available data and resource constraints, recognising that estimates will be revised in the future when more detailed information is available.

As an extension for the uncertainty analysis for this category, the clearing event could be randomised to one of the three years (i.e., assigned to each year with probability 1/3). Analogously, a Monte Carlo approach could repeatedly assign the clearing event to a random year and then calculate the uncertainty in the emissions or removals for the sector. This would incorporate the additional uncertainty in the exact time of clearing into the estimate. If approximate clearing rates are known from administrative records, it may be used to adjust the interpolation probabilities. For example, if the clearing rate in 1998 is estimated to be twice that of 1999 and 2000 then we could estimate the probability for the above example to be 1/2 that it was cleared in 1998 and 1/4 that its was cleared in 1999 or 2000.

5.6.4 Issues under Kyoto Protocol Articles 3.3 and 3.4

In general, *good practice* for ensuring time series consistency and performing recalculations for estimates of LULUCF prepared under the Kyoto Protocol reporting of supplementary information will be similar to those for any other inventory estimates. However, there are some special issues that are specific to Articles 3.3 and 3.4 that it is *good practice* to take into account:

- The need to report on an annual basis the geographical location of the boundaries of the area that encompass land subject to the activity. During the commitment period under the Kyoto Protocol, it will be necessary to update the identification of such areas if new lands are brought under Articles 3.3 and 3.4. Thus, it will be necessary to ensure consistent representation of these areas over the period back to 1990 or the onset of any activities under Articles 3.3 and 3.4, as well as to adequately track shifts among categories in those lands. It is *good practice* to use the methods described in Section 5.6.
- The need to make recalculations due to updated information on non-annual data (see Chapter 4 for a more detailed description on how to deal with non-annual data).

5.6.5 Reporting and Documentation

In all cases, the calculations performed to ensure time series consistency should be carefully documented because of the complicated processes and large temporal and geographical scales typically involved in the LULUCF sector. The *good practice guidance* provided in *GPG2000* on documentation of time series consistency applies fully to this sector. The *GPG2000* states that clear documentation of recalculations is essential for transparent emissions estimates, and to demonstrate that the recalculation is an improvement in accuracy and completeness. In general, the following information should be provided whenever recalculations are undertaken:

- The effect of the recalculations on the level and trend of the estimate (by providing the estimates prepared using both the previously used and new methods).
- The reason for the recalculation (see Section 7.2.1, Quantitative approaches to identify key source categories, of *GPG2000*, for further discussion of this issue).
- A description of the changed or refined data, models, assumptions, factor values, and/or method.
- Justification for the methodological change or refinement in terms of an improvement in accuracy, transparency, or completeness.
- The approach used to recalculate previously submitted estimates.
- The rationale for selecting the approach, which should include a comparison of the results obtained using the selected approach and other possible alternatives, ideally including a simple graphical plot of emissions or removals versus time or relevant activity data, or both.