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Meeting Report

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Summary

In September 1997, the IPCC/OECD/IEA Inventories Programme held an expert meeting in Australia on *Biomass Burning and Land-Use Change and Forestry*. The overall objective of the meeting was to identify ways of improving the land-use change and forestry chapter of the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (Guidelines).* The meeting addressed three main areas:

- biomass burning
- inventory data
- interpretation of IPCC Source/Sink Categories.

The main conclusions of the meeting are summarised below.

A key issue was the separation of anthropogenic from natural fires. Experts recognised that the separation is technically very difficult, but scientific information might help make an approximate assignment. As a starting point, the meeting considered two methods for estimating CO_2 emissions from and removals by land-use change and forestry. These were the *Comprehensive Flux* and *Carbon Stock* methods.

The *Comprehensive Flux* approach would employ similar principles to those in the *IPCC Guidelines*, but extend them to include CO_2 fluxes from all terrestrial carbon pools, including those due to changes in fire regimes. The *Carbon Stock* approach would be based on measurements of carbon stock in biomass, product pools, litter and soil.

These methods offer several benefits. First, both methods might provide greater consistency and transparency in national inventories than the present *Guidelines*. Second, these methods may provide more complete emissions data. Complete information is important; it may allow better separation of anthropogenic from natural fires. However, experts recognised that this distinction would remain technically difficult for both methods, and to some extent arbitrary. Some accounting options were proposed for this purpose, but none were tested for their feasibility. Experts agreed that further examination of these options would be valuable.

Under the *Guidelines*, emissions and removals of greenhouse gases from managed forests are included in national GHG inventories. Many experts considered that almost all forests are disturbed from their natural state, and should be classified as managed. Possible exceptions are boreal forests in remote parts of Canada and Russia.

1. Background

In the Compilation and Synthesis of National Communications, the UNFCCC Secretariat identified several problems in estimating and reporting greenhouse gas (GHG) fluxes from forestry and land-use change. In September 1996, IPCC-XII asked the *IPCC/OECD/IEA Programme on National Greenhouse Gas Inventories* to bring experts together to consider these issues. An Expert Meeting on *Biomass Burning and Land-use Change and Forestry* was held in Rockhampton (15-18 September 1997) at the invitation of the Australian Government. This report summarises discussions and incorporates recommendations from that meeting. (For details, see Annex I.)

2. Objectives of the meeting

The overall objective was to identify ways to improve the land-use change and forestry chapter of the *Revised 1996 IPCC Guidelines for National GHG Inventories (Guidelines).* Meeting participants were asked to:

- evaluate inventory methods for estimating emissions from biomass burning;
- identify sources of uncertainty in the land-use change and forestry categories of GHG inventories;
- provide guidance on how errors can be reduced, including through improvements in data collection;
- consider different interpretations of IPCC definitions for carbon sources and sinks ; and
- recommend options for possible revisions of the *Guidelines*.

3. Issues

The UNFCCC Secretariat noted a lack of uniform reporting of GHG inventory data for land-use change and forestry. This was largely attributed to:

Differences in methodology. Annex-I Parties used both the IPCC and their own national estimation methodologies. The *Guidelines* encourage the use of country-specific methods and data. But a flexible approach carries the risk of introducing inconsistencies between national GHG estimates, making them less comparable.

Variations in reporting carbon components. Parties do not include emissions and removals from the same set of carbon pools. For instance, some countries include flux estimates for soil carbon and harvested wood products, while others do not. (Solutions are pending. The *Guidelines* now contain a default method for soil carbon. A default methodology for emissions from harvested wood products is being developed.)

Inconsistent interpretation of the term anthropogenic. The UNFCCC makes it clear that only anthropogenic GHG sources and sinks are to be included in National Communications, but the limits of anthropogenic influence on natural systems are not well defined. Because of varying interpretations, countries attribute the land area of managed forests and fires differently.

Data quality. Some Parties reported a high degree of uncertainty in their estimates of GHG emissions and removals resulting from land-use change and forestry. Others were more confident about their estimates. Many Parties attributed the uncertainty of estimates to poor quality of data.

These problems should be put in context. Some participants noted that the uncertainties in estimation of carbon fluxes in land-use change and forestry are no higher for GHG estimates than for other biogenic sources (*e.g.*, waste).

The following sections summarise discussions on biomass burning, uncertainties and data acquisition and interpretation of IPCC Source/Sink categories.

3.1 Biomass burning

Participants considered:

What additional components of the IPCC Methodology are needed to estimate GHG emissions from forest and savanna fires more accurately?
To what extent can we distinguish between anthropogenic and natural fires in forested ecosystems and savannas?

The current *Guidelines* do not include methods to estimate CO_2 emissions from all types of biomass burning in a consistent way. Experts concluded that the IPCC Methodology does not adequately account for global CO_2 emissions from forest fires, nor for the subsequent uptake of CO_2 through regrowth. They suggested the Forest and Grassland Conversion section of the *Guidelines* be modified to include the effects of forest fires. The effects of other forest disturbances, such as pests and wind damage [windthrow], could also be incorporated in future revisions. There was no discussion of whether these disturbances should be classified under human impact.

With regard to non-CO_2 emissions from savanna burning, the participants agreed that the IPCC Methodology was the best currently available. They noted, however, that scientific advances are likely in this area, and suggested that the IPCC Methodology could and should be adjusted in future to reflect these advances. An example is more accurate estimation of biomass burned [fuel load]. The *Guidelines* provide regional defaults. Participants agreed that it would be better to incorporate algorithms that would allow *Guidelines* users to estimate fuel loads more accurately in order to reflect differences in climate, vegetation, soils, and animal grazing [herbivory].

Considerable discussion was devoted to the problem of distinguishing between natural and anthropogenic fires. As noted above, Parties to the Convention are obliged to report only anthropogenic sources and sinks, yet they are not consistent in their interpretation of what is or is not anthropogenic in origin.

However, the separation of natural from anthropogenic fires is technically very difficult. Despite advances in the use of satellite remote sensing to detect fires, these data do not indicate either the cause or the area burned by individual fires. Techniques are available to interpret the data, but the cost of doing so is currently prohibitive for most tropical countries, where wildfires frequently occur. Distinguishing between traditional uses of fire and other anthropogenic fires is also problematic. Science might help the policy community to approximate the degrees of anthropogenic influence.

Regardless of how a fire is classified, both emissions from fires and removals through regrowth should be consistently treated. For natural fires, emissions and removals should both be excluded from national inventories. Conversely, for anthropogenic fires, emissions and removals should be included.

Currently, the *Guidelines* adopt a land-use change approach to estimating CO_2. The method is based on rates of land-use change and carbon density per unit area, including soil carbon. The net flux of carbon for a given year is based on the release and uptake of that year, plus the delayed fluxes from previous years.

As a first step, experts suggested that *Guidelines* move towards comprehensive accounting of carbon fluxes from fires, both natural and anthropogenic. This approach would provide more complete emissions

data, for all sources and sinks, not just fires, but it would not avoid the need to distinguish between anthropogenic and natural fires. Participants discussed two possible approaches, based on '*Comprehensive CO_2 Fluxes'* and '*Carbon Stocks'*.

Comprehensive CO_2 fluxes. This approach would employ similar principles to those in the *Guidelines* and extend them to include CO_2 fluxes from all terrestrial carbon pools, including those due to changes in fire and other disturbance regimes. It would require additional data, some of which may already exist. It is technically feasible to develop a methodology to estimate changes in CO_2 fluxes, possibly using spreadsheets/workbooks. The feasibility of separating natural and anthropogenic fluxes, and the practicality of such an approach for developing countries were not discussed.

Carbon stocks. This approach is based on measurements of carbon stock in biomass, product pools, litter and soil. As a supplement to the current IPCC Methodology, participants suggested that guidelines could be given to countries to enable them to develop carbon stock accounts. Some countries, such as the USA, already have such an accounting system. The difficulty of determining the causes of changes in stock was recognised.

Both approaches might allow for greater transparency and consistency than the present system. The difficulty of separating anthropogenic from natural emissions and removals would remain. Participants developed a preliminary list of possible solutions. They suggested that a single global methodology may not be appropriate; rather, a set of global principles which recognises regional ecological factors could be developed. Further discussion is needed to assess their viability.

Nevertheless, some participants felt strongly that the definition and attribution of emissions from anthropogenic fires would require a policy decision under the Convention. Several cases illustrate this point. First, 'traditional' fires have been used to clear land for millennia. Some countries include the resulting emissions in their national inventories, whereas others argue they should be excluded. Second, prescribed burning pre-empts natural wildfires which would have resulted in greater 'non-anthropogenic' emissions. Yet countries are allocated anthropogenic emissions that would be excluded from national inventories. This current method of accounting provides a perverse policy incentive. Third, fires do not respect national boundaries. If a fire crosses a border, should these emissions be attributed to the country from which the fire originated? The question of what constitutes an anthropogenic fire, and how the resulting emissions and removals should be attributed to nations, remain unresolved. The same questions apply to accounting for removals of CO_2 through post-fire regrowth.

3.2 Uncertainties and data acquisition

Participants considered:

How can the sources of uncertainties of GHG estimates be identified?
How can guidance be given to countries on the acquisition and use of data?
How can errors in GHG emissions from land-use change and forestry be more explicitly reported in national inventories?

In compiling their GHG inventories, many countries experience difficulties with inadequate data. A key question was whether it would be better to use a default estimation methodology and data, or to omit estimates from the inventory. Participants agreed that it would generally be better to include all land-use change and forestry processes: the error arising from omitting estimates is probably greater than the error of their inclusion. To estimate default data, experts felt that ranges of values, or algorithms for calculating defaults, would be better than the universal values currently provided in the *Guidelines*.

The ecosystem classification in the *Guidelines* is based on Food and Agriculture Organisation (FAO) definitions. Appropriate classification of ecosystems is the first step in compiling land-use change and forestry inventories. Some participants felt that the IPCC classification did not correspond to commonly recognised ecosystems, thus contributing to uncertainty. Under the ecosystem classification scheme in the *Guidelines*, almost any wooded ecosystem is classed as a forest. This conflicts with most commonly accepted definitions of the term forest and other wooded ecosystems.

Alternatively, new hierarchical classification schemes based on biome and bioclimatic or environmental domains could explicitly link regional vegetation types with a global classification scheme. Some participants suggested that the IPCC could develop a global classification scheme in co-operation with other global scientific programmes (IGBP-GTCE, IGBP-DIS, IGAC, IGBP-LUCC, GEIA, FAO, GCOS, GTOS). Over the long term, this would ensure that any future IPCC classification system was consistent with the collection of field data. Ultimately, the harmonisation of forestry datasets would increase the precision of GHG emissions estimates.

Some experts disagreed that an alternative global classification system was needed. Inventories are compiled nationally and countries should be allowed to use their own system to classify lands. This IPCC system was developed to parallel the FAO default data on deforestation and biomass. The IPCC system focuses on tropical regions as this is where data are most needed.

Experts suggested that applying the concept of error to emissions estimates was more useful than uncertainty, which is, by definition, unquantifiable. However, under the Convention, the terms 'error' and 'uncertainty' are used interchangeably. Errors do not necessarily imply mistakes but encompass random variation (sampling error), and systematic bias (*e.g.*, measurement error, transcription error). Redefinition of a well-accepted term in the policy forum, such as uncertainty, may cause unnecessary confusion. Other experts suggest that this discussion on uncertainties is mainly a question of semantics. Uncertainty includes both quantifiable and unquantifiable errors.

In research, sensitivity tests are used to analyse the adequacy of algorithms for describing the environment. Using a range of values for parameters, emissions estimates are calculated for a particular algorithm. The observed effect on the magnitude of the estimates is a sensitivity test. Sensitivity testing of the IPCC Methodology could be further investigated by the research community to identify areas of the methodology for further improvement.

For some national inventories, a statistical approach to estimating the precision of estimates is currently not possible. Often national datasets on land-use change and forestry are too small for statistical analysis. As more national data become available, the estimation of error will become feasible.

There was concern that the treatment of below-ground carbon (roots and soil) is inadequate and harvested wood products are lacking altogether in the *Guidelines*. Discussion was deferred to future IPCC Expert Meetings.

3.3 Interpretation of IPCC Source/Sink categories

Participants considered:

Which categories require clarification?
What constitutes human influence and impact on a forest?
When is a forest under anthropogenic influence?
Should natural processes, such as CO_2 fertilisation, which are under indirect human influence, be classed as anthropogenic?
Are the averaging times for data input and inventory reporting appropriate?

Issues of definition and interpretation are often complex. They frequently have significant policy implications. Some possible solutions to problems were proposed by participants; others will be addressed in the continuing work of the IPCC. Topics discussed include:

Managed forests. There was a lively debate on what constitutes a managed forest. A precise definition of the term is critical because countries need to know what to include or exclude from their forest inventories. The *Guidelines* (Reference Manual, Chapter 5) recognise the difficulty of distinguishing between natural and managed forests. The *Common Reporting Framework* refers to managed forests as 'all trees planted or managed by man for profit, pleasure, wind or water-erosion protection etc.' The *Reference Manual* (Chapter 5) specifies that all existing forests should be counted, but notes that natural, unmanaged forests are not considered to be either an anthropogenic source or sink and are excluded from the calculations... Note: Forests classified as natural, or abandoned/regrowing, can be excluded from the woody biomass stocks accounting only if there is not significant current human interaction with these forests.

After a long discussion, the majority of experts agreed that almost all forests are disturbed from their natural state, and should be considered as managed. Possible exceptions were boreal forests in remote Canada and Russia. Others disagreed with these statements. There was no consensus on how to deal with other forest lands (*e.g.*, urban forests).

CO_2 fertilisation. The *Guidelines* can accommodate the inclusion of any human-induced emissions and removals (Volume 1; Overview) providing these processes are adequately documented. Enhanced carbon sequestration due to carbon dioxide fertilisation is an example. IPCC Working Group 1 defines enhanced carbon sequestration as a natural response to anthropogenic disturbance. Current estimates of Global Warming Potentials (GWP) are based on this premise. If CO_2 fertilisation is defined as an anthropogenic sink, absolute GWPs may need to be re-estimated as this would affect the atmospheric lifetime of CO_2. Participants did not address the significance of these varying interpretations. Further discussion was deferred to future IPCC meetings.

Woody plant encroachment. Atmospheric CO_2 is sequestered by woody plant encroachment through increases in biomass above ground and below ground, and possibly also in soils. Large areas in Australia, South and North America, and South Africa are affected by the phenomenon. It is indirectly caused by anthropogenic activities including land-clearing practices, animal grazing, and changing fire regimes.

The periodic clearing of woody weeds is counted as an emission source under the IPCC category of forest clearing. Experts recommended that national GHG inventories should therefore also include removals by sinks created by regrowth, *e.g.*, 'thickening'. When the periodicity of the cycle of clearing and regrowth is less than the averaging period for data used to construct an inventory, emissions and removals cancel out. In this case, it is unnecessary to include both sources and sinks in national GHG inventories.

Averaging periods for data input. For the preparation of national inventories, the current *Guidelines* recommend averaging inventory data over 3 to 20 years prior to the inventory year. The length of averaging periods is chosen to reflect the timescale of immediate and delayed emissions by sources and removals by sinks. Some participants said that these timescales would have to be re-examined after COP-

3, taking into consideration the availability of national and global forest inventories. The relationship between the delayed effects of emissions and removal processes and national commitment periods (targets) under the Kyoto Protocol have both scientific and policy implications.

As a follow-up activity, participants agreed to contribute additional default data for possible inclusion in the *Guidelines*.

4. Recommendations

Experts suggested that the *Guidelines* be amended as follows:

Managed forests. *Emissions and removals should be reported in national GHG inventories for all forests and wooded areas, unless a specific case can be made for their exclusion. When a specific case for exclusion is made, both emissions and uptake through biomass regrowth should be excluded*. The majority of experts noted that almost all forests can be considered as managed, with the possible exception of remote parts of Russia and Canada.

Forest fires. *To improve transparency in reporting, countries are encouraged to identify the total and anthropogenic emissions estimates for all forest fires, as far as possible.* This recommendation could be extended to include all sources and sinks where it is difficult to decide whether the cause is natural or anthropogenic. In all cases, both emissions and uptake through regrowth should be consistently reported in national inventories.

Natural processes under indirect human influence. *Any anthropogenic processes that cause increased biomass densities should be accounted for within the Guidelines through complete inventorying of biomass changes*. These processes include CO_2 fertilisation effects, if any, and woody plant encroachment.

Methodological approach. *A framework for full carbon accounting for land-use change and forestry is recommended.* This would be a fundamental change from the *Guidelines*; currently, some carbon components are optional. Two approaches were considered: comprehensive CO_2 flux and carbon stock. These approaches should yield the same net emissions and removals of CO_2, allowing for a degree of verification.

Causes in changes of flux and stock. For both approaches, solutions to identify causes in changes of emissions and removals would be necessary. There are conceptual and technical difficulties in separating anthropogenic from natural influences on biomass burning on a national basis. It is not possible to arrive at a general criterion to distinguish between these influences. It may be possible to make an approximate assignment of the human component. Both policy and scientific considerations are equally important.

Savannas. *Savannas should be reported under categories 5A1c, 5A1d, and 5A4 of the Guidelines.* Woody savannas are not clearly identified in the ecosystem categories in the *Guidelines*. This may lead to their omission when accounting for emissions by sources and removals by sinks.

Improvement of inventory data. *Sensitivity analysis is needed to identify and focus effort on key data that improve the precision and accuracy of GHG inventories*.

Uncertainties. *In national GHG inventories, estimates of uncertainty should be expressed on an ordinal scale rather than nominally as high, medium or low.*

National feedback. *Communication between the scientific community and Guidelines users should be a priority of the IPCC/OECD/IEA Inventory Programme on National GHG Inventories.*

Note: Only the key short-term recommendations are listed here. For further information, see Annex.

Glossary

Absolute error

The absolute deviation of x (a variate) from its 'true' value.

Accuracy

The exactness of an estimate. (*Accuracy* is to be contrasted with *precision*)

Confidence

Refers to confidence interval.

Confidence Interval

Define two statistics t_1 and t_2 (functions of sample values only) such that, θ being a parameter under estimate,

$$\Pr(t_1 \le \theta \le t_2) = \alpha$$

where α is some fixed probability, the interval between t_1 and t_2 is called a confidence interval.

Consistency

Concerned with the internal agreement of data or procedures. (*Consistency* is to be contrasted with *validity*)

Emission factor

A coefficient which relates the activity data to the amount of chemical compound emitted.

Error of estimation

In regression analysis where the regression equation is used to estimate the 'dependent' from given values of the 'independent' variates, the difference between the estimated and the observed value of the dependent variate.

IEA

International Energy Agency

IPCC

The Intergovernmental Panel on Climate Change. A special intergovernmental body established by UNEP and the WMO to provide assessments of the results of climate change research to policy makers.

OECD

Organisation of Economic Co-operation and Development

Precision

Repeatability of an estimate. In general the precision of an estimator varies with the square root of the number of observations upon which it is based. (*Precision* is to be contrasted with *accuracy*)

Uncertainty

The range of error of an estimate. (Also loosely defined as the range between the upper and lower quartiles)

UNFCCC

United Nations Framework Convention on Climate Change.

Validation

A procedure which provides, by reference to independent sources, evidence that an inquiry is free from bias or otherwise conforms to its declared purpose. (*Validity* is to be contrasted with *consistency*)

Verification

A procedure to test the internal agreement of data or procedures. (*Verification* is to be distinguished from *validation*)

ANNEX I Drafting Team Report

(Rockhampton, 19 September 1997)

Methodological issues

Comprehensive carbon fluxes

Currently, the *Guidelines* do not include methods to estimate carbon emissions from all types of biomass burning in a consistent way. The effect of fire on the net carbon flux must take into account the fire emission (immediate and delayed) and the processes of growth and redistribution of carbon and nutrients between biospheric pools.

Disturbances (fire, insects, diseases, etc.) form an integral part of the carbon cycle in forest ecosystems, and the methodology used to estimate the impact of these disturbances will need to be consistent with the methodology used to estimate biomass growth. Current methods account for all biomass regrowth; however, the impact of disturbances is effectively ignored. Including forest fires and other stand replacement disturbances in the reporting requirements can significantly improve the accuracy of national inventories of greenhouse gas emissions.

The IPCC Methodology for prescribed burning of savannas, being an annual accounting process, makes the simplifying assumption that there is no net change in carbon stocks as a result of fire. This is a justifiable assumption where there has been no change in fire regime, but is demonstrably untrue where the fire regime has changed over a longer time frame in both savannas and other recovering vegetation types such as forests. The inclusion of carbon fluxes in a robust way that is also consistent with other forms of disturbance (including forestry) requires a comprehensive system approach with changes in carbon in plant, detritus, soil, product and waste pools, tracked over time. It is technically feasible to develop a generic approach to estimate these changes. This will require two years to develop, and should be a target for the next IPCC methodology revision.

Recommendations

As an interim step towards taking a consistent account of the impacts of fire and other disturbances and of the biomass regrowth following such disturbances, the Expert Group encourages the approach outlined below, which does not require significant changes to the *Guidelines* over the long term.

- Carbon emissions from forest fires can be calculated by using the modified *Forest and Grassland Conversion* methodology. The name should be changed to reflect the inclusion of fires and disturbances caused by other agents that are not connected with land-use change (e.g., *Forest and Grassland Disturbance and Conversion*).

- The IPCC Methodology could encourage reporting of stand replacement disturbances on all territory that is included in biomass growth calculations. For some countries, this may mean the entire territory of the country. For others, certain territorial or administrative units may be excluded if there is no direct human impact there. Lands excluded on this basis should then also be excluded from biomass growth calculations. For disturbance agents other than fires, only stand replacement disturbances – i.e. disturbances that kill the greater part of main canopy trees - have to be included.

- Specific types of stand replacement disturbance may vary by ecological unit and by country. The most common types will include fire, windthrow, and pest and pathogen outbreaks; an 'Other' category will be offered to specify any other disturbance agents.

- Calculation of carbon emissions from fires follows *Workbook* sections 5.3 and 5.4. For other kinds of disturbance, only post-disturbance emissions need be calculated.

- Accounting for non-stand replacing fires can assume no net change in aboveground biomass unless available national data show otherwise. *Guidelines* for savanna burning to calculate non-CO_2 emissions can be followed.

- In the absence of country-specific information to the contrary, net emissions from soils may be assumed to be zero. This assumption needs to be researched.

Carbon stocks and fluxes

A stock-based approach requires calculation of the total amount of carbon storage in their natural systems over two time periods. The flux of carbon for a given year is derived from the difference between two stock estimates. By contrast, the "flux" method attempts to directly quantify emissions or sequestration for a given year by estimating the areas affected by the rate of carbon change for those areas.

The main benefits of a stock approach are summarised as follows:

- Understanding stocks can help to balance fluxes.
- Stock data may be easier to derive from data already being collected by countries for other purposes.
- Stock data are likely to be less variable over long periods of time.
- Methods could be more cost-effective and verifiable.
- Data will be needed for estimating total carbon budget.
- Stocks are also much better units for projecting carbon fluxes from land use.

Basic data requirements of a stock approach are: mass of carbon per unit of land area; area of land category; and volume of growing stock or another proxy for carbon.

A stock approach needs to be better defined in the methodologies. Reporting tables and methods for generating annual sequestration from carbon stock data are needed. Better data are also needed on soil carbon and its dynamics under various forms of disturbance and recovery from disturbance.

Recommendations

- We commend the 'stock-change' approach as being a valuable and practical overall integration of national annual CO_2 fluxes geographically disaggregated. However, to meet the objectives of the UNFCCC, the approach requires supportive information which permits disaggregation of the causes of changes in stocks. Such information about causes will focus attention on net emission control measures which are acceptable as criteria for meeting emission targets. It is necessary to develop guidelines on what supportive information is required.

- The IPCC Methodology could encourage estimation of forest carbon stocks. Even if data do not exist, default methodologies could be used to estimate carbon stocks in much the same way they are currently being used to estimate carbon sequestration.

- The stock approach can also be applied to other components of land-use change and biomass burning. Carbon emissions from long-term changes in carbon stocks due to unsustainable savanna burning could be estimated using a variant of this methodology.

- Recognising that some countries are already using this approach and others may move towards this approach, we recommend that the next revision of the *Guidelines* should provide more specific guidance on how to estimate emissions and/or removals by a stock change approach, and how to facilitate the transparent reporting of estimates generated using the approach.

- Nevertheless, while recognising that complete analysis of fluxes leads to an equivalent budget, and that some fluxes (especially of trace gases) are more readily measured and estimated directly, we recommend that the next revision of the *Guidelines* should also continue to offer guidance on how to estimate emissions and/or removals through a flux approach, emphasising that the fluxes reported also account for a closed carbon budget.

- Use of a stock-based approach does not mean the complete abandonment of the flux-based approach. Measurements of fluxes, obtained independently, can be used to cross-check estimates of change in stocks.

Trace gas emissions from savannas

The IPCC Methodology for calculating the total non-CO_2 trace gas emissions from savanna fires is considered to be the best available method. As with other inventory guidelines, the method is subject to continued review as scientific knowledge improves. In the medium term, however, its accuracy and implementation can be improved by providing better data, particularly with respect to fuel loads. Fuel load is sensitive to climate, vegetation structure, soil type, herbivory and period between fires. Given this complexity, and the high spatial variability in savannas, the use of a shared model of fuel loads and emissions, rather than unrepresentative point data or default values, may be the most effective way to improve accuracy at the national and global levels. The development of such a model is recommended and could be completed from existing components within two years.
The general approach used for estimating trace gas emissions from savanna burning could and should be used in all vegetation types that burn. In so doing, it is important to ensure consistency of the approach across all sectors affected by biomass burning (forestry, savanna, agriculture etc.). Additional data, such as fuel and fire-type specific emission factors, many of which already exist, will be required for the new vegetation types.

Anthropogenic and natural emissions and removals

The *Guidelines* should clarify the national reporting of total emission and uptake from fires. In addition to this, there is an expressed policy need to ascribe these net emissions to 'anthropogenic' or 'natural' fires. It is neither practical, nor sensible, to assign either the trace gas or CO_2 emissions and uptake resulting from fires to anthropogenic versus natural by classifying the cause of ignition of individual fires. Humans influence fire emissions and uptake by altering the fire regime in many direct and indirect ways other than by ignition. The indirect human effects on fire regimes may also have transboundary causes and implications; climatic change is one example.

There are conceptual difficulties in distinguishing anthropogenic and non-anthropogenic fluxes of trace gases and carbon pool changes associated with fire on a country-by-country basis. Accordingly, it is not technically possible to arrive at a general criterion for separating anthropogenic from natural causes in the national inventories.

Nevertheless, it is possible to make an approximate assignment of human effect by estimating the natural fire regime of a region and counting deviations from this as anthropogenic. There are several technically possible ways of doing this, some of which are outlined below. The appropriateness of the methods will depend on biome and fire regime. The use of one global method may not be appropriate but a set of globally principles which recognise regional ecological factors can be developed.

Recommendations

We emphasise that the following list is not exclusive but rather comprises examples of the methods that might be examined in association with the development process of the comprehensive and carbon stock approaches mentioned above. In both cases, the proportion of biomass growth attributed to natural disturbances should be excluded from the carbon uptake calculation.

- Define the natural emissions of trace gases and stocks of carbon to be those which would have resulted from what is believed to have been associated with the pre-industrial fire regime. The difference between the total emissions and the inferred natural emissions could then be assumed to be of anthropogenic cause. Regrowth associated with natural fires is excluded from the carbon uptake calculation.

- Define a particular observation period - for instance, the twenty-year period prior to 1990 - as the natural fire disturbance level, and then treat changes in fluxes of trace gases or carbon pool sizes resulting from any subsequent deviation from that as being anthropogenic. As above, regrowth due to natural disturbances is excluded from the carbon uptake calculation.

- Calculate a regionally specific natural disturbance regime on the basis of climate and other ecological data or by comparison with analogous regions. Justification and supporting documentation would be needed for such calculations.

Data generation and uncertainties

Data generation

Many countries have experienced difficulty in acquiring adequate data. Sometimes there are complete gaps in data for which default values might be used. An issue is whether it is better to use default data or to leave out estimates where data does not exist. Some defaults, such as for the rate of decay of aboveground slash may not be adequate. There is much scope for progressive improvement in default information including the development of algorithms rather than single standard numbers to calculate them.

Although the current soil defaults are considered adequate for the current *Guidelines*, there is scope for the use of more comprehensive soil taxonomies such as those of the FAO or the USDA, as a basis for devising region specific defaults. Such a system would include, for example, podsolic soils that are not represented in the current *Guidelines*. These soils occur in the boreal regions where there may be adequate national data making default data unnecessary. Overall, it was suggested that it will generally be better to include all processes using defaults than omitting them when local data are absent.

Most data currently being used have been acquired on a piecemeal basis. There is a strong need for a long-term approach in which time sequences of ecological data are generated to understand and predict the dynamics of change in GHG emissions.

It is important for inventory purposes to find means of distinguishing the effects of land use change, biomass burning, and forestry from the influences of atmospheric and climatic change and variability. Remote sensing co-ordinated with such long-term ground-based studies will provide a valuable route for interpolation and extrapolation of ground truth. For this purpose it will be useful to strive harder to co-ordinate existing national and international activities of various institutions and agencies that are already gathering aspects of the necessary datasets and in some cases have long periods of environmental monitoring data on hand. Internationally, IGBP-GCTE, IGBP-DIS, IGAC, GCOS and GTOS, IGBP-LUCC, FAO, and GEIA are some relevant agencies. However, the group did not feel that the role of the IPCC was to specify measurement and data collection and development techniques.

Recommendations:

- When country data do not exist, it is better to use default values, even if they seem inadequate, than to omit entire entries in the inventory.

- Some new default values in the areas of savanna and forest burning should be developed as options for the *Guidelines*, and should be provided to all countries as a supplementary document.

- Countries are encouraged to report directly to both the UNFCCC and IPCC, the problems and concerns encountered in preparing their national inventories, especially with regard to the use of activity data and default values.

- The long-term revision of the *Guidelines* should include optional ranges and in some cases algorithms for calculating defaults to replace single universal values.

- Soil defaults should be based on standard soil taxonomy, such as those of the FAO or USDA, to create region-specific values.

- Long-term data acquisition and development programmes should be established. These programmes should co-ordinate measurement of all relevant ecological information at chosen sites and be linked with remote sensing.

Uncertainties

We do need to determine sensitivity of the final net emissions figures to variation of values and parameters, and to determine standard errors of all terms of inventories. Such information gives guidance as to where most effort is needed. It is recognised, however, that there is always some irreducible level of error in all emissions estimates. For biological processes, that irreducible error will always be greater than for emissions from fossil fuels, where existing financial accounts facilitate estimation of emissions.

Statistical distributions of input information can provide estimates of error terms. Currently for most input information, the data availability is too slim to calculate errors. However, such information is essential in the long term to replace the current expert judgement of uncertainty as being low, medium or high.

Recommendations

- Except where they have a more rigorous basis to provide error analysis, countries could continue to use expert judgement to specify their uncertainties qualitatively.

- Pending a formal IPCC sensitivity analysis procedure, countries could attempt their own sensitivity analyses to guide priorities for data improvement.

- IPCC should develop, in the long term, a procedure for each country to conduct analyses of the sensitivity of the inventory to variation of variables and multipliers, such as emission factors and expansion factors.

- Future data acquisition should be structured in such a manner as to facilitate quantification of error terms in the inventories.

Definition of IPCC Source/Sink categories

Ecosystem classification

The relevant IPCC source/sink categories are:

- 4E: Prescribed Burning of Savannas
- 5A: Changes in Forest and Other Woody Biomass Stocks
- 5B: Forest and Grassland Conversion
- 5C: Abandonment of Managed Lands
- 5D: CO_2 Emissions and Removals from Soil

There is a concern that the overwhelming focus on forestry, reflected in the predominance of forest classes in the Land Cover/Ecosystem Types categories (Common Reporting Framework 5AC), does not clearly encompass a large suite of tropical and subtropical ecosystems that are not recognised by researchers and others as forests. These include wooded savannas. Woody savannas, which are formations with a continuous grass layer and a varying tree and shrub cover, are predominantly found in the tropics and subtropics. They occupy about 20% of the world's land surface. They are widely recognised under this terminology across continents with their most widespread distribution in the southern hemisphere (Africa, South America, Australia). They are not clearly identified in the ecosystem categories in the Land-use Change and Forestry Sector of the *Guidelines*. This may lead to their omission when accounting for emissions by sources and removals by sinks.

In the case of woody biomass and associated carbon stocks, the new definition of forests (woody biomass > 2m) is a problem in some countries that do not recognise their native vegetation formations in these terms. Better description is needed of the distinction between categories 5A (emissions and removals of CO_2 from decrease or increase in biomass stock due to forest management, logging, fuel wood harvesting, etc.) and 5B (conversion of existing forest and natural grasslands to other land uses and associated emissions of CO_2 and trace gases).

The current approach to ecosystem classification is an arbitrary categorisation approach that does not correspond in a consistent way with commonly recognised ecosystems. This would not be such an issue if a clearer hierarchical structure was apparent. Revision of the ecosystem classification system, in the long term, would improve both the reporting of, and uncertainties in, emissions estimates. Some guidelines need to be kept in mind. First, whatever classification system is proposed, it must enable consistent aggregation and disaggregation of data. Second, it must be compatible with other global land-cover classification initiatives. Third, it must be usable by all countries, whatever the state of national vegetation cover mapping. Fourth, it must be compatible at some scale of aggregation, with the present system. Finally, there should not be too many classes, which will complicate the process of drawing up and reporting national inventories, but it should be sufficiently comprehensive to encompass all land-cover classes in sufficient detail that people carrying out national inventories can recognise the ecosystem types in their region in a consistent way.

A second area of concern is the definition and distinction of plantations. In the present *Guidelines*, plantations are not clearly defined. Many forests in northern Europe, for example, are planted and managed, but are not considered by foresters there to be plantations.

The issue of comparability among national inventories submitted during one reporting period, or between inventories submitted by the same country in different years, may arise if different interpretations arise as to how particular local vegetation formations are classified in terms of the global scheme.

Recommendations

- The Expert Group recommended that Category 4E be modified to *Prescribed Burning of Savannas and Woodlands*. Woodlands is currently not a category within the ecosystems categories (see 5A: *Changes in Forest and Other Woody Biomass Stocks*). The definition of savannas given as a footnote to Section 4E of the Common Reporting Framework is inadequate since it implies only scattered trees in grassland. An alternative to changing the title of Section 4E would be to modify the definition of savannas to make it more compatible with current usage of the term, which encompasses a range in tree and shrub densities extending from almost closed canopy woodlands to open grasslands with few or no trees. The revised definition reads: Savannas are tropical and subtropical formations found in Africa, Asia, Australia, Latin America and southern North America, and which are characterised by having a more-or-less continuous grass cover and variable tree and shrub cover. Similar systems, in which both trees and grasses coexist, are found in some temperate regions.

- A clarification is needed of the intended use of the term 'plantations'.

- It is recommended that alternative approaches to the current land-cover/ecosystem classification system be explored in the long term. Two possible approaches are (i) a biome-based approach, such as is being used within the International Geosphere-Biosphere Programme; and (ii) an approach based on the use of bioclimatic or environmental domains. One or more workshops could be held in conjunction with other organisations seeking to develop a global ecosystem classification scheme. These include FAO (from which the current classification scheme was derived) and IGBP (who have various such schemes under development).

Unaccounted processes

Savannas are widely utilised for pastoralism. This contributes to a pronounced disturbance regime due to the pressures of grazing and changed fire incidence or intensity. Many of the trees and shrubs found in these regions are protected by thorns or are in other ways unpalatable to domestic stock. These adaptations enable such plant populations to thicken up or encroach on more open grassland areas. Conversely, pastoralists will often attempt to reverse these processes by clearing trees or shrubs. Land clearing is encompassed under Section 5B but bush encroachment ('thickening') is a more subtle process and not obviously catered for in the *Guidelines*. Given the areas of land involved, its impact on carbon sequestration could be overlooked, the more so because it occurs outside forests on lands where regular inventorying of biomass is uncommon. It is felt that attention should be drawn to the phenomenon so that its impacts are fully accounted for.

Recommendations

- It is recommended that savannas be recognised under the *Guidelines* by incorporating their carbon stocks and fluxes under categories 5A1C and D and 5A4. By including all savanna systems in one or more of these categories, biomass changes such as vegetation thickening will be fully included in the carbon budget. Similar recommendations could apply to ecosystems with analogous structures in other climatic zones.

Time periods for reporting

The extension of biomass burning to cover forest fires will require a re-assessment of the time periods of assessment. Current time periods for certain processes may be unrealistic in some cases (for example, changes in soil carbon).

Most of the *Guidelines* implicitly assume linear changes in some stock over time, whereas exponential change may be more appropriate. Whereas, exponential change is more realistic, it is recognised that not all countries would have the data to enable them to adopt this model conceptually.

Recommendations

- For changes in forest and other woody biomass stocks, it is suggested that a 10-year average be used rather than the current 3-year average. A 10-year average corresponds more closely with the time period of most national inventories, as well as inventories carried out by international agencies such as FAO. It may also more closely approximate the time scale of natural variability. Nevertheless, there is a potential sacrifice in sensitivity involved in moving to longer timeframes.

- In the short term, countries should continue to use whatever approach (linear versus exponential rates of change) is most appropriate to their circumstances, though the approach adopted should be indicated. In the longer term, a move towards the use of electronic spreadsheets will allow the more realistic non-linear nature of change to be taken into account.

Omitted categories

Herbivory by domestic livestock, wild large mammal herbivores, and insects is widespread in savannas, rangelands and, in the case of insects, boreal forests and other forest and woodlands systems. An estimate of the direct impact of domestic livestock is included under category 4, Agricultural Practices, but no allowance seems to have been made for the direct and indirect impacts of other herbivores. These impacts are not necessarily independent of human activities. For example, conservation policies and pressures from surrounding land users affect large herbivore dynamics and impact in conservation areas. Likewise, livestock management practices, particularly in relation to stocking rates, affect fuel loads and hence fire frequencies and intensities. Somehow, for a fuller understanding of these interactions and impacts, provisions need to be made for reporting livestock and wildlife number and their impacts.

Other issues

Short- versus long-term changes

The Expert Group agreed that a distinction should be made between possible short-term modifications to the detail in the *Guidelines*, but not to the procedures themselves, and longer-term revisions to the *Guidelines*. There is little to be gained in changing the *1996 Revised Guidelines* before they have even been used, but there may be a need to revise them further, or even to replace them with a different methodology, in the longer term.

Exchanging information and expertise

In reporting national inventories, countries should include contact details of technical experts involved in the preparation of the relevant inventory sectors / categories. Such information could be compiled and reported separately and a list distributed back to the technical experts. Contact details should include mailing address, fax, email where possible.

Facilitating the development of a network of technical experts and the sharing of national experience in preparing inventories could assist experts in improving their inventory estimates.

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