DOI: 10.1007/s00267-003-9118-1

A Method Countries Can Use to Estimate Changes in Carbon Stored in Harvested Wood Products and the Uncertainty of Such Estimates

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ABSTRACT / A method is suggested for estimating additions to carbon stored in harvested wood products (HWP) and for evaluating uncertainty. The method uses data on HWP production and trade from several decades and tracks annual additions to pools of HWP in use, removals from use, additions to solid waste disposal sites (SWDS), and decay from SWDS. The method is consistent with IPCC guidance for estimating emissions from SWDS. Uncertainty is postulated in the form of probability density functions for 14 variables, using Monte Carlo simulation. Results for the United States suggest that uncertainty is most sensitive to uncertainty in production data for solidwood products, the factor used to convert products to carbon, and the proportion of solidwood and paper in SWDS. Uncertainty in the use (service) life of solidwood products has a limited effect because an error offsets changes in products in use and in SWDS. The method provides a starting point for meeting the aims of the IPCC *Good Practice Guidance.*

The storage of carbon in woody biomass in forests is supplemented by the storage of carbon in harvested wood in wood and paper products. Under the United Nations Framework Convention on Climate Change, the guidelines of the Intergovernmental Panel on Climate Change (IPCC) allow countries to estimate carbon storage in harvested wood in wood and paper products (HWP) if they can provide a method. The revised 1996 IPCC guidelines provide a default method for estimating change in carbon stored in HWP:

…the recommended default assumption is that all carbon in biomass harvested is oxidised in the removal year. This is based on the perception that stocks of forest products in most countries are not increasing significantly on an annual basis. …The proposed method recommends that storage of carbon in forest products be included in a national inventory only in the case where a country can document that existing stocks of long term forest products are in fact increasing. If data permit, one could add…to…the changes in forest and other woody biomass stocks…to account for increases in the pool of forest products. This information would, of course, require careful documentation, including accounting for imports and exports of forest products during the inventory period. (IPCC 1997)

The IPCC (2000) provides good practice guidance for how countries should estimate carbon emissions and changes in sinks for various sectors. Efforts are underway to provide guidance for estimating carbon change related to land use, land use change, and forestry that could include guidance related to HWP. The method for estimating carbon change in HWP suggested in this paper seeks to meet objectives for good practice guidance, as defined as follows:

Good Practice Guidance assists countries in producing inventories that are accurate in the sense of being neither over- nor underestimates so far as can be judged, and in which uncertainties are reduced as far as practicable. *Good Practice Guidance* further supports the development of inventories that are transparent, docu-

KEY WORDS: Carbon sequestration; Harvested wood products; Estimation methods

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Published online December 4, 2003.

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mented, consistent over time, complete, comparable, assessed for uncertainties, subject to quality control and assurance, efficient in the use of the resources available to inventory agencies, and in which uncertainties are gradually reduced as better information becomes available. (IPCC 2000, Section 1.1)

The objective of this paper is to present a general method for estimating recent and current-year additions to carbon stored in HWP and to discuss a key concern in making these estimates: evaluating the uncertainty of the estimates.

The paper focuses on estimation methods, not alternate accounting approaches. Accounting approaches differ in how the change in carbon stocks (or emissions) associated with exports and imports are assigned to countries. Three identified accounting approaches are the stock change approach, the atmospheric flow approach, and the production approach (IPCC 1999). In this paper, we use the stock change approach to illustrate the estimation method. The estimation method can be adapted to make estimates for the other accounting approaches.

The estimation method focuses on changes in carbon stocks and not on emissions from stocks as they are burned or undergo decay. Total emissions in a year could be estimated as the carbon in timber harvested for products and fuel in the year minus additions to carbon stored in wood and paper.

Methods

Two general methods could be used to estimate change in HWP carbon stocks. The first is to use direct estimates of HWP inventories in use and in waste disposal sites at two points in time and to calculate the change in carbon stored. For some countries, such inventory information may be available for wood in housing stocks, but it is generally not available for other wood and paper uses or for waste sites. The second method is to use data from a number of decades in the past and estimate, up to the present time, annual additions to pools of HWP in use, removals from use, additions to solid waste disposal sites (SWDS), and decay from SWDS. Direct inventories of carbon stocks in housing or structures taken two or more times can also be used to aid in estimating use life; these data can be used in the second method, as has been done for Finland (Pingoud and others 2001).

We propose using the second type of method, tracking additions to and removals from products in use and products in SWDS. This method is intended to be consistent with the tier 2 method used for the waste management sector (see IPCC 1997, Module 6; IPCC 2000, Ch. 5). The tier 2 method estimates methane emissions from SWDS by beginning several decades in the past and tracking additions to the pool of waste in SWDS and methane emissions from the pool. The factors used by a country to compute amounts of HWP carbon retained in SWDS should be consistent with the factors used to compute methane emissions from SWDS.

An Excel spreadsheet, developed by Kim Pingoud, implements the estimation method shown in this paper and can provide estimates for any country where United Nations Food and Agriculture Organization (FAO) data and estimation parameters are available. Contact Ken Skog for more information about the availability of this spreadsheet.

Estimating Annual Change in Carbon Stored in HWP

The method for estimating annual change in carbon stored in HWP is termed the first-order decay method because carbon in each of four carbon pools is estimated to leave the pool at a constant percentage rate of the pool contents. Calculation methods are shown for the stock change accounting approach.

$$\text{Change in carbon held in HWP in a country in year t (Tg/yr)} = (SWU_t - SWU_{t-1}) + (PU_t - PU_{t-1}) + (SWDS_t - SWDS_{t-1}) + (PDS_t - PDS_{t-1}) \quad (1)$$

where SWU_t is total carbon in solidwood products in use in year t (Tg) (solidwood products include lumber, veneer, wood panels, and other products that use solid wood rather than wood fiber, as is used in paper), PU_t is total carbon in paper products in use in year t (Tg), $SWDS_t$ is total carbon in solidwood products in disposal sites in year t (Tg), and PDS_t is total carbon in paper products in disposal sites in year t (Tg)

Carbon in Solidwood and Paper Products in Use. Amounts of carbon in solidwood and paper products in use are computed for the current year by beginning calculation in the year 1900 and continuing recursively to the current year using equations 2 and 3:

$$SWU_t = [SWU_{t-1} + (SWP_t + SWIM_t - SWEX_t) * CSW] * [1/(1 + SWdiscard)] \quad (2)$$

$$PU_t = (PU_{t-1} + (PP_t + PIM_t - PEX_t) * CP) * [1/(1+Pdiscard)] \quad (3)$$

where SWP_t is solidwood products produced in year t (cubic meters), $SWIM_t$ is solidwood products imported in year t (cubic meters), $SWEX_t$ is solidwood products exported in year t (cubic meters), CSW is carbon weight per unit of solidwood products (Tg C per cubic meter),

PP_t is paper products produced in year t (metric tons), PIM_t is paper products imported in year t (metric tons), PEX_t is paper products exported in year t (metric tons), CP is Carbon weight per unit of paper products (Tg per metric ton), SWdiscard is the fraction of all solidwood products in use in a year that are taken out of use by the end of that year, and Pdiscard is the fraction of all paper products in use in a year that are taken out of use by the end of that year.

Equations 2, 3, 7, and 9 are derived as approximations to continuous additions and discards from carbon in the four pools: solidwood products in use, paper products in use, solidwood products in SWDS, and paper in SWDS. The derivation of this approximation for equation 2 is as follows. Begin with the estimated change over a time interval, Δt

$$(SWU_t - SWU_{t-1})/\Delta t = -Swdiscard * SWU_t + (SWP_t + SWIM_t - SWEX_t) * CSW$$

We approximate continuous additions and discard by using time steps of one year; that is, $\Delta t = 1$. Solving this equation for SWU_t gives equation 2. This is the backward Euler estimation method. It is used instead of the forward Euler method because it takes into account decay from additions in the current period and it is more stable for high discard rates, that is, for short use life such as that of paper.

Carbon in Solidwood and Paper in Disposal Sites. Solidwood and paper carbon in disposal sites is held in three types of stock: (1) permanent stock, (2) stock undergoing complete anaerobic decay, and (3) stock undergoing complete aerobic decay. Our method assumes that wood and paper exposed to aerobic conditions decay rapidly and completely, and we do not include these data. That is, the amount we include in SWDS is only the amount in permanent stock and the amount undergoing anaerobic decay.

$$SWDS_t = SWDS\_perm_t + SWDS\_an\_decay_t \quad (4)$$

$$PDS_t = PDS\_perm_t + PDS\_an\_decay_t \quad (5)$$

where SWDS_perm is total solidwood carbon in disposal sites that is never emitted (Tg), SWDS_an_decay is total solidwood carbon in disposal sites that is undergoing anaerobic decay (Tg), PDS_perm is total paper product carbon in disposal sites that is never emitted (Tg), and PDS_an_decay is total paper product carbon in disposal sites that is undergoing anaerobic decay (Tg).

Carbon in solidwood. Amounts of solidwood carbon in disposal sites are computed for the current year by beginning computations in the year 1900 and continuing recursively to the current year using equations 6 and 7.

$$SWDS\_perm_t = SWDS\_perm_{t-1} + SWU_t * SWdiscard * SWWSf_t * CF_t * (1 - DOCfwood) \quad (6)$$

$$SWDS\_an\_decay_t = [SWDS\_an\_decay_{t-1} + SWU_t * SWdiscard * SWWSf_t * CF_t * DOCfwood] * [1/(1 + SWan\_decay\_decay)] \quad (7)$$

where $SWWSf_t$ is the fraction of total discarded solidwood products (includes amounts recovered for recycling) sent to disposal sites in year t, CF_t is the fraction of wood or paper sent to disposal sites that is held in anaerobic conditions, DOCfwood is the fraction of wood held in anaerobic conditions that decays to CO_2 and CH_4, and SWan_decay is the fraction of solidwood undergoing anaerobic decay that decays to CO_2 and CH_4 in a year.

Carbon in paper products. Amounts of paper product carbon in disposal sites are computed for the current year by beginning computations in the year 1900 and continuing recursively to the current year using equations 8 and 9.

$$PDS\_perm_t = PDS\_perm_{t-1} + PU_t * Pdiscard * PWSf_t * CF_t * (1 - DOCfpaper) \quad (8)$$

$$PDS\_an\_decay_t \; [PDS\_an\_decay_{t-1} + PU_t * Pdiscard * PWSf_t * CF_t * DOCfpaper] * [1/(1 + P\_an\_decay\_decay)] \quad (9)$$

where $PWSf_t$ is the fraction of total discarded paper products (includes amounts recovered for recycling) sent to disposal sites in year t, DOCfpaper is the fraction of paper held in anaerobic conditions that decays to CO_2 and CH_4, and P_an_decay is the fraction of paper undergoing anaerobic decay that decays to CO_2 and CH_4 in a year. If independent annual estimates are available of wood and paper sent to SWDS each year, these estimates may be used instead of the terms (SWU_t * SWdiscard * $SWWSf_t$) and (PU_t * Pdiscard * $PWSf_t$) in equations 6 and 9.

Data Sources for Production and Trade

Data on solidwood and paper product production and trade from 1961 to 2001 are available for most countries from the FAO forest products database (United Nations Food and Agriculture Organization

Table 1. Data and parameters for probability density functions

Uncertain data or parameter	Variable
1. Solidwood production and trade, 1961 to current year	SWP_t, $SWIM_t$, $SWEX_t$
2. Paper production and trade, 1961 to current year	PP_t, PIM_t, PEX_t
3. Solidwood conversion to carbon weight	CSW
4. Paper conversion to carbon weight	CP
5. Increase rate in production and trade, 1900 to 1961	r
6. Solidwood in use, discard rate	Swdiscard
7. Paper in use, discard rate	Pdiscard
8. Fraction solidwood to anaerobic decay, 1900–1950	$SWWSf_t * CF_t$
9. Fraction solidwood to anaerobic decay, 1951 to present	$SWWSf_t * CF_t$
10. Fraction paper to anaerobic decay, 1900–1950	$PWSf_t * CF_t$
11. Fraction paper to anaerobic decay, 1951 to present	$PWSf_t * CF_t$
12. Solidwood decay limit, anaerobic SWDS	DOCfwood
13. Paper decay limit, anaerobic SWDS	DOCfpaper
14. Decay rate in SWDS	SWanaerobic_decay

2002). Data on production and trade (SWP_t, $SWIM_t$, $SWEX_t$, PP_t, PIM_t, and PEX_t) from 1900 to 1961 are estimated for the model using an estimated rate (r) of increase in production that occurred between 1900 and 1961.

Production and trade data for $t = 1900$ to 1960 were estimated using equation 10:

$$\text{Production (or trade)}_t = [\text{average production (or trade) for 1961 to 1966}] * e^{(r*(t-1961))} \quad (10)$$

Uncertainty of Estimates

The uncertainty of change in carbon stocks in year t (equation 1) can be estimated by first postulating the uncertainty associated with the data and parameters in equations 2–10. The uncertainty for data and parameters is specified in the form of probability density functions (pdfs). Once input and parameter uncertainties are defined, the pdf for the result of equation 1—the change in carbon stock—is determined by Monte Carlo simulation. This is a model simulation method where repeated samplings of input pdfs defined for equations 2–9 produce pdfs for all terms in equation 1 and ultimately for estimates of carbon stock change. Monte Carlo simulations are a convenient numerical method for probabilistically quantifying model inputs and results and for formulating uncertainty analyses (Morgan and Henrion 1990, Vose 1996, Smith and Heath 2001). The results of Monte Carlo simulations provided in the following text are based on median Latin Hypercube sampling and 2000 iterations or samples drawn from each pdf.

Table 1 indicates 14 probability density functions that are used to provide random variables for the Monte Carlo simulation. The types of probability density functions used are as follows:

1. Normal distributions with 95% confidence interval specified as percentage of expected value
2. Triangular distributions with specified mode, and minimum and maximum values
3. Uniform distributions with equal probability for any value in a specified range

The pdfs for the variables in Table 1 were judged to be independent of one another; that is, there are no cross correlations. However, note that by using a single decay rate for wood and paper in SWDS and a single pdf for the decay rate, we are assuming any error in this decay rate is the same for wood as for paper. Certain pdfs pertain to, or shift, entire time series, such as the pdfs for production and trade data, and the series on the fractions of discarded wood or paper that is subject to anaerobic conditions in SWDS. The pdfs that shift entire time series are numbered in Table 1 as 1, 2, 5, 8, 9, 10, and 11. The other pdfs pertain to parameters that are fixed over the entire period from 1900 to 2000.

Since little documented information is available on the data and parameter uncertainties for the model, results are intended to only suggest possible uncertainty of results and identify data and parameters that are likely to determine the uncertainty of changes in carbon stocks. Uncertainties in FAO data are based on the authors' knowledge of US industry surveys, and uncertainties in parameters are based on the authors' review of other HWP carbon studies and judgment. The intention is to provide information to help determine if more intensive efforts are warranted to improve estimates of input uncertainties and further evaluate model uncertainties.

The Monte Carlo simulations produce pdfs for the change in the four stocks of carbon—solidwood products in use, solidwood products in SWDS, paper products in use, and paper products in SWDS—and for the total change in carbon stocks. The central values of these pdfs can be expressed as the median (50th percentile), and the range of likely values can be expressed as the central 95% of the pdf (from the 2.5th percentile to the 97.5th percentile). If our model is correct, our results suggest that we may have 95% confidence that the stock change estimates are at least as large as the 5th percentile value of the pdfs.

Contributions to uncertainty of estimates—the contribution of uncertainty in input data and parameters—is evaluated for each estimate of carbon stock change. Allocation of the effect of input uncertainties is based on iteratively eliminating each input uncertainty and repeating the Monte Carlo simulation to determine the effect on the resulting pdf (that is, reduction in 95% confidence interval). The contribution to uncertainty for a variable is proportional to the reduction in uncertainty when its uncertainty is removed (see Vose 1996 or Smith and Heath 2001).

Sensitivity of stock change estimates to changes in data and parameters is estimated by observing the effect of a 1% change in each type of data or parameter. Sensitivity analysis identifies the effect of a change in a single parameter on stock change, while the uncertainty analysis described in the previous text identifies the effect of change in uncertainty in a parameter on the uncertainty of the stock change estimate.

Example for United States

Data, Parameters, and Uncertainty

Data on wood and paper products production and trade for the United States are from the FAO database (United Nations Food and Agriculture Organization 2002). Values for parameters are shown in Table 2 and Figures 1 and 2. Estimates of the uncertainty associated with data and parameters are shown in Table 2 in the form of probability density functions and 95% confidence limits. Estimates of the portion of wood and paper exposed to anaerobic decay (variables 8–11) are based on the narrative history of the shift in waste disposal from open dumps and burning to sanitary landfills, the percentage of paper recycled, and current estimates of the portion of discarded waste sent to landfills (Environmental Protection Agency 2002a,b, Howard 2001).

Results

Given our data, parameters, uncertainty estimates, and calculation methods, an estimated 55.8 teragrams (Tg) or million metric tons were added to carbon stored in HWP in the United States in 2000 (Table 3). This is similar to a previous estimate of 57.5 Tg by Skog and Nicholson (1998) using a more detailed method. The distribution of estimates was obtained by Monte Carlo simulation that provided 2000 separate estimates using samples from the data and parameter distributions. The overall change estimate given here and estimates for change in each of the four pools in Table 3 is the median estimate (50th percentile). Because of differences in the distributions of parameters affecting calculations and the asymmetry of some distributions, the median estimates for the pools do not add to the median estimate for total change. The largest carbon additions were to solidwood products in use and solidwood products in SWDS (24.1 and 17.7 Tg, respectively), which account for about 75% of the total change. The remaining 25% of the change is mostly in paper in SWDS (13.3 Tg). The estimated 95% confidence interval for total change in carbon stocks is 44.0 to 67.1 Tg, or about ± 21% of the median value.

Accompanying the level of uncertainties specified in Table 2 are four sources of uncertainty that contribute the most to the overall uncertainty in change in carbon stocks in 2000 (Table 4). Uncertainty in the following data and parameters account for 75% of the uncertainty in the total carbon change:

1 Uncertainty in solid wood products production and trade data
2 Uncertainty in the solidwood to carbon conversion factor
3 Uncertainty in percentage of solidwood products disposed of in SWDS (anaerobic conditions)
4 Uncertainty in percentage of paper products disposed of in SWDS (anaerobic conditions)

Uncertainties associated with solidwood products are important, with the exception of the solidwood product discard rate. Uncertainty in the discard rate is a key factor in the uncertainty in change in both solidwood products in use and solidwood products in landfills. However, uncertainty in the discard rate has little effect on total change because an error in the discard rate increases the storage estimate for one pool and decreases the storage estimate for the other pool (Table 5).

The effect of uncertainties associated with paper products is relatively small, with the exception of the proportion going to SWDS. This is due to the fact that

Table 2. Probability distributions for uncertain data and parameters for United States

Variable	Value(s)	Uncertainty (95% confidence interval)
1. Solid wood production and trade, 1961 to current year	FAO database 1961–2000	Normal distribution ± 15%
2. Paper production and trade, 1961 to current year	FAO database 1961–2000	Normal distribution ± 15%
3. Solidwood conversion to carbon weight	2.25E-07 TgC/m^3	Normal distribution ± 14%
4. Paper conversion to carbon weight	4.50E-07 TgC/adt	Normal distribution ± 14%
5. Increase rate in production and trade, 1900–1961	0.47%/year	Normal distribution ± 80% (resulting confidence interval for production in 1900, ± 30% of mean)
6. Solidwood in use discard rate/service life	1.98%/year (half-life = 35 years) (Skog and Nicholson 1998)	Normal distribution ± 30% (Half-life confidence interval, 27–50 years)
7. Paper in use discard rate/service life	69.3%/year (half-life = 1 year)	Normal distribution ± 30% (Half-life confidence interval, 0.8 to 1.4 years)
8. Fraction solidwood to anaerobic decay, 1900–1950	7.5%	Uniform distribution range −100% to +100% of mean (i.e., of 7.5%)
9. Fraction solidwood to anaerobic decay, 1950–2000	See Figure 1	Weighted transition from 1950 to 2000 Uniform distribution ± 100% of 7.5% in 1950, to normal distribution ± 30% in 2000
10. Fraction paper to anaerobic 7.5% decay, 1900–1950	7.5%	Uniform distribution range −100% to +100% of the mean (i.e., of 7.5%)
11. Fraction paper to anaerobic decay, 1951–2000	See Figure 2	Weighted transition from 1950 to 2000 Uniform distribution ± 100% of 7.5% in 1950 to normal distribution ± 30% in 2000
12. Solidwood decay limit, anaerobic SWDS	3% (Micales and Skog 1997)	Triangular distribution, mode 3%, minimum 0%, maximum 15%
13. Paper decay limit, anaerobic SWDS	28% (Micales and Skog 1997)	Normal distribution ± 30%
14. Decay rate in SWDS	5%/year (half-life = 14 years) (IPCC 2000, waste sector)	Triangular distribution, mode 5%, minimum 3%, maximum 15%

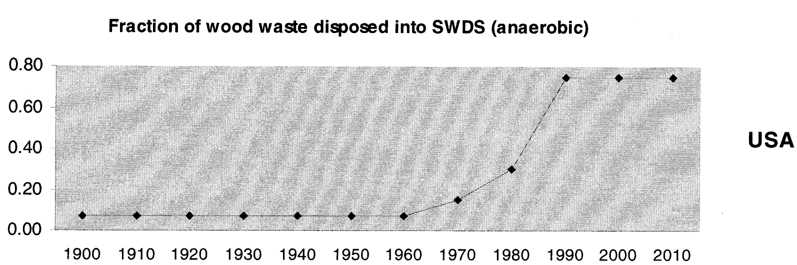

Figure 1. Fraction of wood waste subjected to anaerobic conditions in SWDS.

almost all the contribution of paper products consists of additions to SWDS, and there is little effect from factors that affect the change in paper in use.

The uncertainty in growth in wood and paper production and trade prior to 1961 has only a small effect because the half-life of wood in use plus the half-life of wood in landfills is limited [49 years (35 + 14); see Table 2], and the effect of an error in use life offsets changes in the solidwood products in use and SWDS pools.

In addition to estimating the effect of uncertainty in the data on the uncertainty in the results, we estimated the effect of a change in the data on the results. The total carbon change estimate is most sensitive to a 1% change in the

1 solidwood products production and trade data,
2 solidwood to carbon conversion factor,
3 percentage of solidwood products disposed of in SWDS (anaerobic conditions), and

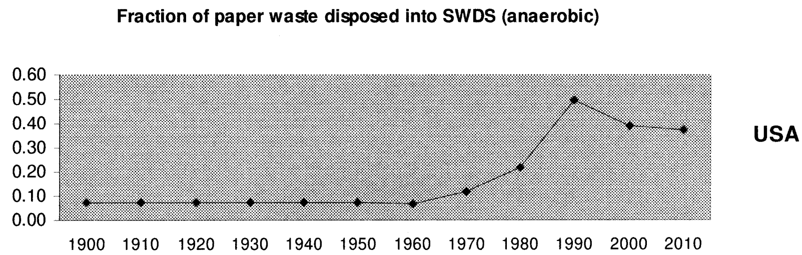

Figure 2. Fraction of paper waste subjected to anaerobic conditions in SWDS.

Table 3. Carbon added to harvested wood products in use and SWDS in 2000

	Carbon added (Tg)				
		SWP		Paper	
Confidence interval	Total	In use	In SWDS	In use	In SWDS
50th percentile	55.8	24.1	17.7	0.3	13.3
2.5th percentile	44.0	18.8	10.9	0.1	9.6
5th percentile	46.1	19.5	12.5	0.2	10.3
97.5th percentile	67.1	30.2	24.7	0.8	17.3

Table 4. Change in carbon stored in wood and paper products in 2000 and contribution to uncertainty

		SWP		Paper	
	Total	In use	In SWDS	In use	In SWDS
	Carbon added (Tg)				
	55.8	24.1	17.7	0.3	13.3
Confidence interval	Change in carbon stored				
2.5th percentile	−21%	−22%	−38%	−64%	−28%
97.5th percentile	+20%	+25%	+39%	+138%	+30%
Variable	Contribution to uncertainty				
1. SWP data	*18%*[a]	34%	19%		
2. Paper data	6%			14%	24%
3. SWP conversion	*17%*	32%	17%		
4. Paper conversion	5%			14%	21%
5. Growth to 1961	1%		1%		< 1%
6. SWP discard rate	3%	33%	19%		
7. Paper discard rate	2%			70%	1%
8,9. SWP fraction to SWDS	*21%*		40%		
10, 11. Paper fraction to SWDS	*19%*				30%
12. SWP decay limit	< 1%		2%		
13. Paper decay limit	4%				13%
14. SWDS decay rate	3%		2%		11%

Values in italic type indicate variables contributing more than 15% to overall uncertainty in carbon stored in HWP in 2000.

4 percentage of paper products disposed of in SWDS (anaerobic conditions).

It is not surprising that the uncertainty of results is most sensitive to the uncertainty in these same (most influential) variables. The assumed uncertainty in any of the less sensitive variables is not so great as to produce a large effect on overall uncertainty.

Discussion and Conclusions

For the US example, our results suggest where it may be most important to improve data and parameter estimates to decrease uncertainty in the carbon stock change estimate by

1 decreasing uncertainty in solidwood products production and trade,

Table 5. Sensitivity of estimated change in carbon stock to changes in data and parameters

		SWP		Paper	
	Total	In use	In SWDS	In use	In SWDS
Confidence interval	Carbon added (Tg)				
50th percentile	55.8	24.1	17.7	0.3	13.3
	Change in carbon addition for 1% change in data or parameter (%)				
1. SWP data	0.75	1.00	1.00		
2. Paper data	0.25			1.00	1.00
3. SWP conversion	0.75	1.00	1.00		
4. Paper conversion	0.25			1.00	1.00
5. Growth to 1961		0.03	0.03		
6. SWP discard rate	−0.05	−0.48	0.47		
7. Paper discard rate	−0.01			−2.76	0.02
8. SWP fraction to SWDS	0.33		1.00		1.00
9. Paper fraction to SWDS	0.24				
10. SWP decay limit	−0.01		−0.02		
11. Paper decay limit	−0.05				−0.21
12. SWDS decay rate	−0.03		−0.01		−0.11

2 decreasing uncertainty in the factor to convert solidwood products to carbon, and
3 decreasing uncertainty in the proportion of solidwood and paper going to SWDS.

To support estimation results, these variables and their uncertainty estimates would be the most important to study and document fully.

It is notable that uncertainty in the use life of wood products (discard rate) may not be of key importance in estimating total carbon additions because an error in use life generates offsetting errors in the estimates for the products in the use pool and the SWDS pool.

This first-order decay method supports, in part, the objectives identified for IPCC *Good Practice Guidance* for making estimates: it is accurate, transparent, documented, comparable, assessed for uncertainties, and subject to quality control, and it can gradually reduce uncertainties.

Accurate —includes products in use and products in SWDS pools (providing neither over- nor underestimates). The method falls short of being accurate in that it does not estimate trade in secondary wood products.

Transparent —all data and calculation methods can clearly be seen.

Documented —clearly indicates what data and parameter estimates need to be documented.

Comparable —all countries can use FAO data or data in the FAO format, and the method provides types of parameters countries can use and compare to one another. However, comparability between countries will also be dependent on the accounting methods used; countries need to use comparable accounting approaches.

Assessed for uncertainties —allows for assessment of uncertainty using estimates of uncertainty in the data and parameters.

Subject to quality control —subject to quality control to the extent that studies can be conducted to verify needed data and sensitive parameters.

Gradually reduces uncertainties —serves as a basis for further reducing uncertainties as improvements are made to data and parameter source and partial inventories of products. For example, the method may be improved by using survey estimates of wood and paper added to landfills, or inventory of wood in structures over time.

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