Verifying Sinks under the Kyoto Protocol

VERTIC Briefing Paper 01/03

Pete Smith

July 2001

VERTIC briefing paper

Executive Summary

- Article 3.4 of the 1997 Kyoto Protocol to the 1992 UN Framework Convention on Climate Change raises the possibility that activities involving agricultural soils, land-use change and forestry not dealt with under Article 3.3 might be used to help meet a party's emission reduction targets. Article 3.4 activities can be grouped under forestry management, cropland management, grassland management and re-vegetation.

- Verification refers to the activities and procedures for establishing the reliability of the data submitted by the parties for Article 3.4 activities. This usually means checking the data against empirical data or independently compiled estimates.

- Whether or not Article 3.4 is verifiable depends critically on what the parties decide is acceptable in terms of verifiability.

- At its most stringent, verifiability would entail the sampling of each georeferenced piece of land subject to an Article 3.4 activity at the beginning and end of a commitment period, using a sampling regime that gives adequate statistical power. Soil and vegetation samples and records would be archived and the data from each piece of land aggregated to produce a national figure. Separate methods would be required to deliver a second set of independent verification data. Such an understanding at the national level would be prohibitively expensive.

- At its least stringent, verifiability would entail the reporting of areas under a given practice (without georeferencing) and the use of default values for a carbon stock change for each practice, to infer a change for all areas under that practice.

- Intermediate in the range of verifiability is a scheme in which areas under a given practice are georeferenced (from remote sensing or ground survey), carbon changes are derived from controlled experiments on representative climatic regions and on representative soils (or modelled using a well-evaluated, well-documented, archived model) and intensively studied benchmark sites are available for verification.

- If the parties decide on a stringent level of verifiability, Article 3.4 is at present, and is likely to remain in the future, unverifiable. If less stringent levels of verifiability are adopted, a low level of verifiability might be achieved by most parties by the beginning of the first commitment period (2008-2012).

INTRODUCTION

Under two articles of the 1997 Kyoto Protocol to the 1992 UN Framework Convention on Climate Change (UNFCCC)[1], Annex I countries (industrialised countries and those with economies in transition) may use biospheric carbon sinks (land-use, land-use change and forestry (LULUCF) activities which remove carbon dioxide from the atmosphere in achieving their Quantified Emission Limitation or Reduction Commitments (QELRC). Under Article 3.3, forestry activities, limited to afforestation, reforestation and deforestation that have occurred since 1990, may be included in the accounting of emissions and assigned amounts from the first commitment period (2008-2012) onwards. Under Article 3.4, other activities, known as 'additional human-induced' (those relating to agricultural soils, land-use change and forestry), may also be included, but the question of the commitment period is left open.

Some parties, such as Canada and the US, suggest that Article 3.4 activities that have taken place since 1990 should be included from the first commitment period. Others, such as members of the the European Union, want these activities to be excluded until at least the second commitment period, except if the Conference of the Parties decides that the issues of 'scale, uncertainty and risk related to the sinks' are resolved.[2] Article 3.4 provides that the Conference of Parties (COP) decide on the modalities, rules and guidelines for incorporating sinks into the regime, 'taking into account uncertainties, transparency in reporting, verifiability' and the advice of the Intergovernmental Panel on Climate Change (IPCC) and the protocol's Subsidiary Body for Scientific and Technological Advice. To date such agreement has eluded the COP, partly because of the verification question.

What is verification?

The definition of verification used here is taken from the IPCC Good Practice Guidelines:[3]

> Verification – refers to the activities and procedures that can be followed to establish the reliability of the data. This usually means checking the data against empirical data or independently compiled estimates.

This differs from validation, which is defined as 'checking that the emissions and removals data has been compiled correctly in line with reporting instructions and guidelines'.

For verification of Article 3.4 activities, estimates are required for carbon fluxes and/or changes in carbon stocks that are independent of those used in a party's national report. This means that for a given human-induced activity, there must be at least two independent methods for assessing the size of an emission by a source or removal by a sink.

How will the Article 3.4 monitoring and verification framework function?

A three-level monitoring and verification framework for Article 3.4 has been agreed:

Level 1: Monitoring and self-reporting by parties on emissions and removals of Greenhouse gases by Article 3.4 activities according to IPCC reporting guidelines and good practice guidelines

Level 2: Validation and verification at the national level, including by peer and public review

Level 3: Validation and Verification at the International level by Expert Review Teams according to Article 8 of the protocol.

The format used by parties for their 1 August 2000 submissions for LULUCF under the UNFCCC is similar to, but not the same as, that used for national greenhouse gas inventories. Improvements to the format for Article 3.4 submissions are likely to be suggested by a new IPCC Working Group that is currently being set up to establish good practice guidelines for LULUCF submissions. Cross-referencing national greenhouse gas inventory submissions with LULUCF submissions would improve verifiability. Ideally, the formats of the two should be compatible. It is important in any event that the format for LULUCF data allow it to be reviewed annually alongside other inventory data. The 1 August 2001 submissions, such as that of Bolivia, reflect this need. Some countries are optimistic about their ability to deliver verifiability at the national level. For example, in its 1 August 2000 submission, Canada stated that:

> Verification of the national accounting framework will be accomplished through peer-reviewed data and acquisition procedures, models, parameter sets and reporting methods. Our system is based on a continuous forest inventory design with the plots being geo-referenced and relocatable, which facilitates quality assurance. Remote sensing data add independence to the system for detecting land use changes. Relevant remote sensing and modeling information will be archived in the form that they were used.

[1] The text of the Kyoto Protocol is available at: www.unfccc.de.

[2] 1 August 2000 submissions by Annex I Parties at: www.unfccc.de.

[3] Penman, J. et al, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change (IPCC)*, Institute for Global Environmental Strategies, Tokyo, Japan, 2000.

ARTICLE 3.4 ACTIVITIES

What are the possible 'additional human-induced activities'?

A wide-ranging but not exhaustive[4] list of 'additional human-induced activities' that might be considered for inclusion under article 3.4 has been compiled by the IPCC.[5]

Potential additional human-induced activities

Article 3.4 activity	Management options
Cropland management to provide higher Carbon inputs to the soil.	Organic fertilisation, residue incorporation, crop rotations, reduced bare fallow, cover crops, high-yielding varieties, integrated pest management, adequate fertilisation, water table management, site specific management, irrigation, other good management practices.
Irrigation water Management.	Irrigation in drought prone ecosystems and water table Management.
Conservation tillage.	Reduced tillage including chisel plough, ridge till, strip till, mulch till and no till.
Erosion-control practices.	Terraces, waterways, diversion channels, drop structures, chutes, vegetative strips and riparean zones, sustainable grazing.
Management of Rice Cultivation.	Irrigation, fertilisation, residue management to reduce methane emissions.
Grazing management.	Intensity, frequency, seasonality of grazing and animal distribution
Protected grassland / set-aside	Change from degraded cropland to permanent grassland
Grassland productivity improvements	Especially in tropics and arid zones: high productivity grasses and inclusion of legumes to increase biomass production
Fire management in grasslands.	Change in burning regimes
Agro-forestry at the margins of the humid tropics	Agro-forestry at high value products on land previously cleared for agriculture by slash and burn.
Replenishment of soil fertility through agro-forestry in sub-humid tropical Africa	Leguminous fallows, phosphate rock application, planting of trees producing high value products
Forest regeneration	Renewing tree cover by Human-assisted natural regeneration and enrichment planting
Forest fertilisation	Improvement in fertilisation – quantity and quality (timing, dosage)
Forest fire Management	Regulation of recycling of forest biomass from fires, maintenance of healthy forests and reduction of total Emissions of CO2 and other GHGs
Pest management	Management of pests to prevent Damage and tree mortality
Forest harvest quantity and timing	Alter when and how harvesting takes place, e.g thinnings, selection, clear-cut harvests. Also the total timber volume extracted, increasingm rotation time and time between harvests
Low-impact forest harvesting	Harvesting with minimum disturbance to soil, remaining vegetation and trees
Restoration of Former Wetlands	Restoration of wetlands on land formerly in agriculture, forestry or urban/industrial use by plugging drain ditches, restoring prior hydrological conditions or artificial water diversion
Restoration of Severely degraded land	Restoration of severely eroded and polluted land, reclamation of deserts, saline and alkaline soils. Also acidified, compacted, sealed, crusted, waterlogged and dumped soils

Source Compiled from IPCC, *Special Report on Land Use, Land-Use Change and Forestry (SR-LULUCF)*, Cambridge University Press, Cambridge, 2000, pp. 249-279.

Each of the activities differs in its potential to act as a biospheric sink for carbon and in the feasibility of its inclusion as an Article 3.4 activity. Critical to this feasibility is verifiability; if the biospheric sink is not verifiable it should not be considered under Article 3.4. Verifiability in turn mainly depends on the methods available to measure related carbon stocks and carbon fluxes.

Methods used for measuring changes in carbon stocks or carbon fluxes

As outlined in the IPCC SR-LULUCF, two types of methods are used to measure losses or accumulations of carbon on land: those that measure stocks of carbon and those that measure fluxes of carbon into and out of a given ecosystem. Measurement of stocks at the beginning of 2008 and at the end of 2012 (or at the date of commencement of the relevant activity

[4] F.B. Metting, J.L. Smith and J.S. Amthor, 'Science needs and new technology for soil carbon sequestration' in N.J. Rosenberg, R.C. Izaurralde and E.L. Malone (eds), *Carbon Sequestration In Soils: Science, Monitoring, and Beyond*, Batelle Press, Columbus, OH, 1999, pp.1-34.

[5] IPCC, *Special Report on Land Use, Land-Use Change and Forestry (SR-LULUCF)*, Cambridge University Press, Cambridge, 2000.

between 2008 and 2012) will yield the change in stocks that has occurred over the first commitment period. Alternatively, measuring the flux of carbon into or out of an ecosystem over the five-year period will also yield the net change. One method can be used to measure losses or accumulations of carbon on land while another, independent method is needed to verify the change.

Measurement methods for assessing losses or accumulations of carbon on land

Stock change measurements methods

- Vegetation inventory
- Stemwood volume – forest inventory
- Total tree biomass – allometry
- Wood products – models of wood products
- Soil and litter
- Woody debris – volume and mass measured
- Litter – sampling and carbon analysis – highly spatially variable
- Mineral soil – sampling and carbon analysis – highly spatially variable

(Sampling strategy, methods and sampling depth all need to be considered)

Flux measurement methods

- Chambers, eddy covariance – for scales less 1 km2
- Tall towers, balloons for convective boundary layer budgeting – Landscape, regional scale
- Flask measurements and flux measurements from aircraft; coupled with inversion analysis – continental scale.
- Remote sensing to determine geographic extent and change
- Current resolution (NOAA-AVHRR) is 1 km2 but 30m possible soon
- Geographic extent possible, vegetation type possible, residue over, tillage, and perhaps soil organic carbon and moisture content of bare soil will become possible in near future

Models

- To be used in combination with the above methods

Many parties, such as Australia, Canada and the US, are proposing a combination of direct measurement, existing inventories (for example, soil inventories or national soil maps), remote sensing, and simulation models to estimate losses or accumulations of carbon on land.[6] Whether or not these approaches can be considered to constitute verification depends on the level of verifiability considered acceptable by the parties.

Implications for verification

Included in the IPCC SR-LULUCF is a preliminary assessment of the possibility of monitoring, verifying and achieving transparency in various proposed Article 3.4 activities (see insert).

The IPCC, however, concentrated on the methods that could be used to measure a change in carbon stocks, rather than on the practical constraints on the use of such methods for verification. For example, the IPCC's statement that 'change in soil carbon can be verified through on-site sampling' means only that soil changes can be measured. Under a stringent definition this would only constitute verification if it confirmed the estimate of biospheric carbon storage using another method (or vice versa). As a method of verification, direct soil sampling would be extremely costly at Level One of the proposed monitoring and verification framework, and impossible at Levels Two (national peer and public review) and Three (international expert review teams).

Many measures rely on remote sensing to determine the geographic extent of an activity and on some combination of on-site sampling and modelling to determine the carbon change. For a number of activities, possible components of verification schemes include periodic monitoring using benchmark sites and the use of control and treatment sites. The IPCC SR-LULUCF does not provide a framework for the monitoring or verification of Article 3.4 activities. Nor does it assess the institutional requirements or existing institutional capacity for monitoring and verification.

The attraction of flux methods is that they are entirely independent of stock change methods to check stock change results. The IPCC report notes, however, that flux measurement methods are not yet sufficiently reliable to be used as the primary method of measuring losses or accumulations of carbon on land, and as such are of limited use at present as a verification method. Further, because the whole ecosystem exchange is measured, it is difficult to factor out the different contributions of soil, roots and above ground vegetation. Flux measurement equipment is expensive and does not exist for most sites. For most purposes then, verification will need to rely on repeat sampling in areas where an activity is taking place.

A significant generic problem with the estimation of changes in terrestrial biospheric carbon stocks relates to resolution (the smallest detectable change). Because the rate of change of most biospheric pools is slow, particularly in relation to the size of the pool, resolvable changes in stock are typically not easily obtained for the larger pools. Many Article 3.4

[6] See W.M. Post, R.C. Izaurralde, L.K. Mann and N. Bliss, 'Monitoring and verifying soil organic carbon sequestration' in Rosenberg et al, p. 41-66; R.C. Izarraulde, K.H. Haugen-Kozyra, D.C. Jans, W.B. McGill, R.F. Grant and J.C. Hiley, 'Soil organic carbon dynamics: measurement, simulation and site to region scale-up' in R. Lal et al (eds), *Assessment Methods for Soil Carbon. Advances in Soil Science*, Lewis Publishers, Boca Raton, Fl, 2000; *Setting the Frame*, Technical Report no. 1, National Carbon Accounting System of Australian Greenhouse Office, Canberra, Australia, 1999.

Monitoring, verifiability and transparency of potential Article 3.4 activities

Article 3.4 Activity	Monitoring, verifiability and Transparency
1) Cropland management to provide higher carbon inputs to the soil.	The change in soil carbon can be verified through ground-truthing (on-site sampling) and well calibrated models. Periodic monitoring using benchmark sites. Measure bulk density and soil organic carbon content to 1m every 5-10 years. Small depth increments.
2) Irrigation water management	See 1, plus: area irrigated detected by remote sensing
3) Conservation tillage	See 1, plus: soil sampling and measurement of residue return for a few sites. Ground survey and possibly remote sensing to assess area and residue coverage.
4) Erosion-control practices	See 1, plus: terraces, waterways etc are conspicuous and easily verified via remote sensing and ground-truthing.
5) Management of rice cultivation	See 1, plus: measurement of methane fluxes is technically challenging and expensive-methane fluxes variable in space and time - models may be of use.
6) Grazing Management	Rates of change from repeated field experiments (soil and vegetation) over time, for representative grassland types and grazing regimes. Models may help. Conventional vegetation mapping and remote sensing can be used to determine geographic extent of grazing lands. Rough estimates of past and current grazing intensity from animal stocking rate surveys.
7) Protected grassland and set-aside	No details given
8) Grassland productivity improvements	Repeat direct sampling of soils and vegetation. Could be scaled up. May also need statistics on area of improved pasture, fertilisation rates, and livestock density and characteristics.
9) Fire management in grassland	Changes by repeat sampling in a monitoring network. At plot level allometry and stem growth increment can be used. Verification and auditing by satellite imagery to confirm# integrity of registered sites and auditing undertaken on a subset of these sites.
10) Agro-forestry at the margins of the humid tropics	See 1, plus: biomass in shrubs and small trees using published algorithms, combined with soil sampling and GIS. Methods open for review and replicable over time.
11) Replenishment of soil fertility through agro-forestry in sub-humid tropical Africa	See 10.
12) Forest regeneration	All activities can be verified at varying accuracy and cost. The capacity varies between countries and combinations of methods might be applied. Control plots used to estimate enrichment of soil carbon from planting. Land based measures: yield models (if available), historical inventory data for similar stands and combination of methods.
13) Forest fertilisation	See 12.
14) Forest fire management	Very difficult for wildfire. Post-event monitoring has been used to produce models. Difficult to do.
15) Pest management	Linking to changes in carbon stock not currently possible. Effective methods for predicting and preventing outbreaks do not yet exist. Mitigation may be impossible or impractical in remote areas. Separating pest management effects from others difficult or impossible.
16) Low-impact forest harvesting	Measurement should be possible. Assumptions and methodologies to monitor are easily explained for replication and assessment of impacts
17) Restoration of former wetlands	See 5, plus: wetland area verified by remote sensing (regionally) or repeated surveys (locally).
19) Restoration of severely degraded land	See 1, plus: extent or effectiveness of vegetation cover monitored by satellite. Height and location of soil may need to be referenced if erosion may occur. Organic pollutants may confound.

Source Compiled from IPCC, *Special Report on Land Use, Land Use Change and Forestry (SR-LULUCF)*, Cambridge University Press, Cambridge, 2000 pp. 249-279.

activities include a soil carbon component (see Table 2). The measurement of changes in soil organic carbon in the mineral horizons provides a good example of the difficulties faced when trying to demonstrate a stock change over a relatively short period. Such change may be difficult to measure in some soils over a 5-year commitment period because, although potentially large in absolute terms, they may be small compared with background levels. It is sometimes possible to measure the rate of change in soil organic carbon stock during a commitment period, but because of high spatial variability many sub-samples may be required to obtain a mean with an acceptable standard error.

In a recent paper the minimum detectable difference in soil organic carbon was calculated as a function of variance and sample size for soil organic carbon changes after 5 years under a herbaceous bioenergy crop.[7] The authors showed that the smallest difference that could be detected was about 1 tonne of carbon per hectare, and this could only be done using exceedingly large sample sizes. The minimum difference that could be detected with a reasonable sample size and a good statistical power (90% confidence) was 5 tonnes of carbon per hectare. Most agricultural practices will not cause the soil to accumulate this during a 5-year commitment period.[8]

Cost is also a factor in verifiability. In some cases, the cost of demonstrating the change in stocks to the required level of accuracy and precision may exceed the benefits accrued from the increase in stocks. The cost of demonstrating a change in soil organic carbon stock could be decreased by developing locally calibrated models that can use more easily collected data, but there are further verification issues associated with such an approach.

A further difficulty associated with verification is demonstrating that any changes in carbon stock are due to direct human-induced activity. Measured changes in carbon stocks or fluxes may not be attributable to human activity. Fertilisation of trees or other vegetation by increased atmospheric carbon dioxide concentrations or from increased nitrogen deposition might increase carbon stocks but are not regarded as direct human-induced activities. Ecosystem models have been suggested as a possible way to delineate human-induced and indirect/natural factors, but even advocates of the use of biospheric sinks, such as the US, do not favour such complex methods. The June 2001 Pronk paper suggested instead a discounting mechanism for 'forest management' under Article 3.4 which allows only a certain percentage of the total carbon change to be claimed (with the remainder excluded to allow for natural and indirect carbon accumulation).[9]

In addition to discounting, a cap ('boundary condition') is proposed by the Pronk paper that allows only a certain percentage of a party's QELRC to be met by LULUCF activities ('second' and 'third tier' of Article 3.4 and/or Article 6 and 12) activities. Applying a low 'boundary condition' on LULUCF credits could help to circumvent some verification problems, since it is likely that many parties could claim Article 3.4 credits higher than levels currently suggested by the 'boundary condition'.[10]

WHAT LEVEL OF VERIFIABILITY IS ACCEPTABLE?

Whether or not Article 3.4 is verifiable depends critically on what the parties decide verifiability is. At its most stringent, verifiability would entail the sampling of each georeferenced piece of land subject to an Article 3.4 activity at the beginning and end of a commitment period, using a sampling regime that gives adequate statistical power. Soil and vegetation samples and records would be archived and the data from each piece of land aggregated to produce a national figure. Separate methods would be required to deliver a second set of independent, verification data. Such an undertaking at the national level would be impractical and prohibitively expensive. At its least stringent, verifiability would entail the reporting of areas under a given practice (without georeferencing) and the use of default values for a carbon stock change for each practice, to infer a change for all areas shown to be under a given practice. Some scientists have argued that even the area claimed to be under a given practice will, for practical purposes, be unverifiable.[11]

Intermediate in the range of stringency of definitions of verifiability is a scheme in which areas under a given practice are georeferenced (from remote sensing or ground survey), changes in carbon are derived from controlled experiments on representative climatic regions and on representative soils (or modelled using a

---

[7] C.T. Garten and S.D. Wullschleger, 'Soil carbon inventories under a bioenergy crop (Switchgrass): measurement limitations', Journal of Environmental Quality, vol. 28, 1999, pp.1359-1365.

[8] P. Smith, D.S. Powlson, M.J. Glendining and J.U. Smith, 'Preliminary estimates of the potential for carbon mitigation in European soils through no-till farming', Global Change Biology, no. 4, 1998, pp. 679-685.

[9] In June 2001, the President of COP6, Jan Pronk, presented a document containing new proposals for the resumption of the conference in July 2001, which is referred to as the 'Pronk paper'. Available at: www.unfccc.de.

[10] M. Meinshausen and B. Hare, ‚CoP-6 President's text, 11th and 19th June 2001 – A quantitative analysis', Greenpeace background report, 2001 at: www.greenpeace.org.

[11] S. Nilsson, A. Schvidenko, V. Stolbovoi, M. Gluck, M. Jonas and M. Obersteiner, 'Full carbon account for Russia', International Institute for Applied Systems Analysis (IIASA) Report IR-00-21, 2000 at: www.iiasa.ac.at.

well-evaluated, well-documented, archived model) and intensively studied benchmark sites are available for verification. Many of the proposed schemes for carbon accounting under Article 3.4, such as those by Australia, Canada and the US, fall into the intermediate category.

The IPCC SR-LULUCF states that:

> Few if any, countries perform all of these measurements routinely, particularly soil inventories. Some Annex I parties may use existing capacity with minimal modification to implement the various articles of the Protocol; however, some other Annex I Parties may need to significantly improve their existing measurement systems in order to develop operational systems.

While some parties are confident that they currently, or will in the near future, have the capacity to meet low or intermediate levels of verifiability, others, such as Australia and Ireland, are having to invest significant sums of money to achieve this.

IMPLEMENTATION OF A FRAMEWORK TO ACCOUNT FOR AND REPORT ARTICLE 3.4 ACTIVITIES

Data availability and uncertainty

Only 15 of the 27 countries that submitted data for their 1 August 2000 submission included estimates for Article 3.4 activities (see Table 3); the others submitted estimates only for Article 3.3 activities or text only. The supporting material provided with their submissions, on data sources, models and assumptions, provides enough information for validation (checking that the emissions and removals data has been compiled correctly in line with reporting instructions and guidelines), but not for full verification. Much more information would be required for national peer review or review by an International Expert Review Team.

Few, if any, countries perform all of the measurements needed to report LULUCF activity emissions and sinks routinely. Australia and Ireland, for example, do not yet have detailed soils maps or soil inventories. Other studies have revealed that even the geographic extent of forestry in Europe is uncertain. Given that the geographic extent of many Article 3.4 activities will be difficult to assess, accurate data for the commitment period may be difficult to obtain.

Even more problematic will be establishing these figures for the baseline year, 1990, for which statistics on Article 3.4 activities do not exist in most countries. If net-net accounting, based on carbon fluxes, is to be used for article 3.4 activities, as currently proposed by the Pronk paper for cropland, grazing land management and re-vegetation, parties might face verification difficulties. Net-net accounting calculates fluxes during the commitment period minus five times the fluxes in 1990. Such fluxes are even more difficult to estimate than carbon stocks in 1990. Given these difficulties, data availability will be an issue when attempting to implement a verifiable framework for Article 3.4 activities.

Article 3.4 activities included in 1 August 2000 submissions

Party	Article 3.4 activities in 1 August 2000 submission
Australia	Re-vegetation
Bolivia	None
Canada	Forest, cropland and grazing land management and shelterbelts
Chile	None
Costa Rica	None
EU-Austria	None
EU-Denmark	None
EU-Finland	Forest management
EU-France	Forest management
EU-Germany	Forest management
EU-Ireland	None
EU-Italy	Fire prevention, grazing to forestry conversion
EU-Netherlands	Forest, cropland and grazing land management
EU-Portugal	Forest management
EU-Sweden	Forest management and conservation
EU-UK	Forest management, soil carbon under bioenergy crops
Iceland	Re-vegetation
Indonesia	None
Japan	Forest management, urban greening
New Zealand	None
Norway	Forest fertilization
Poland	None
Russian Federation	None
Switzerland	Carbon forestry, cropland management, crop to grassland conversion, grassland management
USA	Forest, cropland and grazing land management
Samoa (for AOSIS)	None
Tuvalu	None

All parties, even those optimistic about the achievement of a verifiable carbon accounting system, recognise the importance of uncertainties. However only a few indicated in their 1 August 2000 submissions where the main sources of uncertainty lie. Canada, for example, stated that:

> Uncertainties of estimates within our approach may arise in a number of ways. These include: the use of retrospective information, inconsistencies in sampling schemes and approaches (which we will strive to minimise), timing of measurements, mis-classed information, sampling intensity, the use of models, and reporting errors. We note that stability of definitions and accounting approaches within and across commitment periods will help to reduce uncertainties. Uncertainty will be reduced further through research and development in relation to models and other components of our system.

A few parties provide quantitative estimates of uncertainty for certain components of their estimates. For example, a minor uncertainty (<5%) associated with the area estimate for land categories was given by the Netherlands, 10% uncertainty for the second forest inventory was given by Spain; a carbon pool size uncertainty of around 25% was provided by the UK, full quantitative (preliminary) estimates of uncertainty associated with carbon stocks and area estimates were given by Austria, and estimated uncertainty for soil figures in Norway was reported to be as high as 100%. Few parties provide estimates of uncertainty associated with 3.4 activities, and where these are given, such as in the submissions by Canada, the Netherlands and Japan, they are usually descriptive ('high' versus 'low') rather than quantitative. The US is the only party to have provided a quantitative estimate of uncertainty associated with Article 3.4 activities.

Emission estimates from agricultural soils are extremely uncertain and the uncertainties remain largely unquantified.[12] In an analysis of just one component of uncertainty, a 50% uncertainty about the mean value was found.[13] This estimate did not include uncertainty arising from the geographic extent of suitable land, the baseline condition, and land-suitability. Hence, even when there is good experimental data, the total uncertainty associated with an estimated carbon stock change is likely to be very large and often unquantifiable.[14]

IS VERIFICATION BY 2008 REALISTIC?

Where no infrastructure exists, the measurement of carbon to the required degree of precision and accuracy is an expensive and logistically complex exercise. Most countries do not currently have the infrastructure required for regular measurement of biospheric carbon (although all Annex I countries have a regular forest inventory in place). Most developed countries and some developing countries have at least part of the infrastructure in place: certifiable analytical laboratories equipped to measure the carbon content of soils and biomass; a national forest and soil inventory system; accurate soil and vegetation maps on which to base the sample stratification; trained field, analytical and statistical staff; and a physical infrastructure which allows access to remote sites. But even where this capacity exists, the incremental cost of performing a national carbon inventory may be substantial. Australia, for example, is investing an additional $5 million annually to upgrade its carbon accounting system.[15]

It is anticipated that most parties could develop the capacity by 2008 for monitoring and self-reporting on emissions and removals of greenhouse gases by Article 3.4 activities in accordance with IPCC reporting and good practice guidelines, although for some this will require considerable investment. For most, if not all parties, data availability will be a problem, especially for 1990 and especially if net-net accounting is adopted. Even if this is possible, in most cases the figures provided for Article 3.4 activities will be verifiable only at the lowest level.

For verification at the national and international level, independent estimates on emissions and removals of greenhouse gases by Article 3.4 activities will be absent. The verification process will probably be confined to scrutiny of the data and methods provided for in an attempt to answer questions such as: Is the carbon accumulation rate per hectare within the range of experimental results? Does the model used produce reliable and robust results? Scientific peer review works on this basis. Reported measurements are not repeated; instead the reviewer checks whether the methods are transparent and rigorous (so that the results could be reproduced if required), that the results are reasonable and well explained, and that the conclusions are justified by the data. This low level of verification, combined with a low level of verifiability associated with the data, is probably the best level of verifiability achievable by 2008.

No party will be able to provide data on change in carbon stock for every piece of land on which an activity has taken place and even if it did, this could never be fully verified. Even if a verification team made randomly selected spot checks, each piece of land would need to be sampled at the beginning and end of the commitment period with a sufficient number of samples to demonstrate the detectable difference with

[12] S. Subak, 'Agricultural soil carbon accumulation in North America: considerations for climate policy', Global Environmental Change, no. 10, 2000, pp.185-195.

[13] P. Smith, D.S. Powlson, J.U. Smith, P.D. Falloon and K. Coleman, 'Meeting Europe's climate change commitments: quantitative estimates of the potential for carbon mitigation by agriculture' Global Change Biology, no. 6, 2000, pp. 525-539.

[14] Subak.

[15] IPCC, Special Report on Land Use, Land-Use Change and Forestry (SR-LULUCF).

the required level of confidence. This would be very expensive.

The parties that believe that Article 3.4 activities can be monitored and verified at a national level, such as Australia, Canada and the US, are putting in place schemes that will provide the most robust estimates of emissions and removals of greenhouse gases by Article 3.4 activities. Whether or not this is considered sufficient, given the uncertainties in the data and lack of independent information, needs to be decided by the COP.

CONCLUSION

A recent analysis of Article 3.3 activities concluded that the Kyoto Protocol will ultimately be unverifiable due to uncertainties and leakage.[16] Article 3.4 activities are frequently intrinsically more difficult to measure and verify than Article 3.3 activities. If the parties decide on a stringent level of verifiability, Article 3.4 is at present, and is likely to remain in the future, unverifiable.[17] If less stringent levels of verifiability are adopted, a low level of verifiability might be achieved by most parties by the beginning of the first commitment period.

Dr. Pete Smith is a Senior Lecturer in Soils and Global Change in the Department of Plant and Soil Science at the University of Aberdeen, UK.

[16] S. Nilsson *et al.*

[17] Royal Society, The role of land carbon sinks in mitigating global climate change, Royal Society, London, July 2001. Outline available at: www.royalsoc.ac.uk

VERTIC

VERTIC is the Verification Research, Training and Information Centre, an independent, non-profit making, non-governmental organisation. Its mission is to promote effective and efficient verification as a means of ensuring confidence in the implementation of international agreements and intra-national agreements with international involvement. VERTIC aims to achieve its mission through research, training, dissemination of information, and interaction with the relevant political, diplomatic, technical, scientific and non-governmental communities.

Current funders: Ford Foundation, Joseph Rowntree Charitable Trust, Rockefeller Family Philanthropic Offices, W. Alton Jones Foundation, the John D. and Catherine T. MacArthur Foundation and Landmine Monitor.

Baird House
15/17 St. Cross Street
London EC1N 8UW
United Kingdom

Tel: +44 (0)20 7440 6960
Fax: +44 (0)20 7242 3266
Email: info@vertic.org
Web: www.vertic.org

ISBN 1-899548-26-2