

International Review of New Zealand's
Carbon Monitoring project

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1 Executive Summary

The New Zealand Ministry for the Environment (MfE) has responsibility for the country's carbon monitoring project (CMP). The overall aim of the project is to develop a framework national system for monitoring C in indigenous forests and scrubland, and in soils, to ensure that New Zealand can meet its reporting requirements under the Framework Convention on Climate Change, and to assist meeting other national and international reporting requirements.

The CMP is being undertaken on contract by two main research providers: Forest Research and Landcare Research. The first three-year phase of the project ended in June 1999. MfE appointed an international review panel to assess whether it and other stakeholders could have confidence in the approach and systems being developed by the research providers. The review had to assess the international credibility of the approach being developed, identify gaps that should be addressed, and comment on the versatility of the carbon monitoring system (CMS) to monitor key indicators in forest management, land use and biodiversity.

The stop-start nature of the project, due to funding arrangements, makes it difficult to plan field work, and the management of the CMP should be adjusted to ensure continuity of effort. Ongoing funding for the CMS is of concern, and better coordination among research providers and stakeholders will help to ensure optimum application of scarce resources.

The CMS proposes to use a stock approach to estimate C changes in forest and scrub. This requires a reliable base line estimate of total C. The proposed CMS will be based on a nationally uniform square grid containing a permanent sample plot system. Estimates of C stocks will be determined by using allometric relationships to the tree and shrub diameter and height measurements and to measures of dead wood volume. The main spatial data source will be a land use data base being developed by the Ministry of Agriculture and Forestry (MAF), MfE, Department of Conservation (DoC) and other stakeholders. The panel found this methodology to be sound and according to international practice. Weak points of the work to date on estimating a 1990 base line are: limited data to develop allometric relationships, the sampling of dead wood and litter, and the lack of accurate maps of land cover/land use (LC/LU).

Refinements to the grid sizes planned for the CMS should be made to account for abandonment of grazing lands and succession of the present scrub lands, and nested plots should also be considered. The cost/benefit of estimating C at varying levels of precision for various LC/LU classes need to be addressed. The CMS should take into account that C pools will change at different rates in different ecosystems and plan the grid size and plot sampling design accordingly.

New Zealand's C estimates for forests are more accurate than for scrublands, but a recent test of the system provided credible results for scrub. The estimates of *total* forest and scrub C are satisfactory to meet the reporting requirements of the FCCC, but they are not accurate enough yet to provide a basis for future monitoring of *changes* in C stocks.

The system being developed to monitor soil C is a modification of the IPCC approach. New Zealand's land area has been stratified into climatic and soil classes, overlain by land cover/land use (LC/LU) classes to derive climate/soil/land use cells. Climate and soil class are regarded as constant over time, while LC/LU changes. Coefficients of change are being developed to estimate changes in soil C as a function of land use change over time. CoCs represent the change in equilibrium soil C when moving from one land use class to another, within one soil-climate class. The climate and soil classifications have been completed and tested. The conceptual approach for monitoring soil C is a significant improvement on the IPCC methodology, but much work needs to be done to estimate and validate appropriate CoCs for calculating changes in soil C stock.

Problems with the soil CMS include dealing with new LC/LU types that either fit into more than one category, or do not fit into any existing category; and the lack of an established relationship between the old vegetation cover map and the new land cover data base. Alternative approaches to estimating CoCs, such as long-term experiments, carefully selected paired plots or chronosequences are endorsed as a check of CoCs derived from statistical procedures. The classification developed for the next iteration of LCDB must meet the needs of both the soils and the forest and scrub inventories, as well as other stakeholders. Acquisition of a ground receiving facility should be seriously considered to insure the maximum data availability and timeliness.

The international credibility of the CMS would be enhanced by international, peer-reviewed publication of methodologies and results and by the implementation of a sound quality assurance and control plan. This should cover field sampling, sample preparation, laboratory techniques, and carbon analysis.

The development and implementation of the CMS is threatened by the small number of skilled researchers available in New Zealand. The programme is vulnerable to the loss of individual scientists.

Lack of integration between the forests/scrub and soils programmes is potentially problematical. There is a need for spatial and temporal consistency in the estimation of C in soils, forests and scrub that may not be attained if the forest/scrub and soils programmes continue to develop in isolation from one another. Integration should be improved by the information system being developed and by the integration of spatial information through the use of one LCDB. The CMP Steering Committee could also improve the integration of programmes by actively promoting the harmonising of approaches adopted by the soil and vegetation researchers.

The CMP has much potential to assist various stakeholders, particularly DoC, MAF and MfE and some of the research providers, through the contribution it could make to the development and testing of environmental indicators, performance measures and monitoring methodologies. Furthermore, the implementation of the CMP will strengthen New Zealand's key soil and vegetation data bases. The forest and scrub ecosystem information provided by the repeated measurement of a nationwide network of plots will be of particular assistance to DoC's monitoring of ecosystem condition and trend and the indigenous vegetation. The use of soil C as an indicator of soil and ecosystem health is yet to be used in New Zealand, but this indicator offers good potential. The CMP appears to be less useful to MAF at present in its development of a system for considering applications for sustainable management of forests for timber production. This is because C sequestration is not a factor in the approval process. If, however, the ability of the forests to sequester C becomes an important factor in the approval process, the information provided by the CMP will become far more important to MAF.

The CMP will provide important contributions for New Zealand's international reporting requirements under the UNFCCC, UN/FOA/TBFRA-2000 and Montreal Processes. Reporting under the FCCC involves annual rates of change in C stocks for land use changes and for the forestry sector. Currently, there are no reporting requirements for indigenous vegetation that is not under direct human management. Sustainable management of indigenous forests for timber is not likely to cause significant changes in C stocks. The most important reporting areas on indigenous forest and scrub lands are changes in biomass C stocks of lands reverting to scrub and seral forest and changes in soil C stocks. These reporting requirements can be met by the CMP if it is revised according to the suggestions made in the report. The CMS will be able to fulfil the needs of the TBFRA-2000 (forest and scrub area, growing stock, net annual increment, above and below ground biomass, and average annual change in forest and scrub land area), and enable New Zealand to report on a range of indicators under the Montreal Process.

2 Goal, Key Research Objectives, and Priorities of the CMP

2.1 Overall Goal

The overall goal of the CMP is to develop a framework for New Zealand for a national system for monitoring carbon in indigenous forest and scrubland, and in soils, as a significant contribution to New Zealand's greenhouse gas inventory and to further advance New Zealand's reporting commitments under the Framework Convention on Climate Change (and likely future reporting under the Kyoto Protocol).

2.2 Key Research Objectives and Research Providers

The project was established with three objectives for its first three years (July 1996 to June 1999):

- a) to evaluate and collate existing data to establish a base line estimate of C storage in soils, indigenous forests and scrubland
- b) to develop a framework for a national system for monitoring C in soils, indigenous forests and scrublands
- c) to develop an effective information management system (to be reviewed separately, later).

The main research providers for this project are Landcare Research and Forest Research. Both of these organisations are Crown Research Institutes (CRIs) owned by the New Zealand government.

2.3 Research Priorities

In a letter sent to research providers in August 1998, MfE provided the following additional guidelines on the project's goals and priorities:

- the emphasis for the project should be on the development, testing, design and implementation options for a national monitoring system for soils, indigenous forest and scrub by the end of Year 3 of the project
- options for the monitoring system should explore complementarity with other forest and soil monitoring objectives for other outputs, such as the outputs of the Environmental Performance Indicator Programme¹ and DoC
- the development of a robust framework for the monitoring system is an important aspect of the work to provide the structure for the system and integrate its component elements
- subsequent data collection and research activities could then aim at defining the processes and data in each component part, where appropriate.

¹ The overall purpose of the EPI Programme is to develop and use indicators to measure and report how well New Zealand is looking after its environment.

3 Objective and Terms of Reference of the Review

3.1 Specific Objective of the Review

The specific objective of the review was to assess whether MfE and its key stakeholders can have confidence in the approach and systems being developed and proposed for the CMP by the research providers, prior to consideration of implementation. As part of this, the review panel had to assess the system's credibility and likely international acceptance.

3.2 Terms of Reference

The terms of reference of the review were to:

- a) assess and comment on the robustness, scientific and technical merits and credibility of the approach and systems being developed and proposed by the research providers
- b) assess and comment on the overall consistency, compatibility and practicability of the approaches being proposed, keeping in mind the project's overall goal of a single national framework for monitoring C, and changes in C over time, as the basis for New Zealand's international reporting on land use change and forestry under the FCCC
- c) identify and assess any gaps, issues and possible improvements that should be addressed in future work, including priorities and suggestions for possible approaches to address and resolve identified issues
- d) assess and comment on the robustness and versatility of the proposed approaches as a basis for monitoring other key indicators or parameters relating to sustainable forest management and land use, forest health and condition, and biodiversity
- e) provide clear conclusions and recommendations for future development of the framework and national monitoring system.

The focus for the review was on the framework(s) for the monitoring system(s) being developed for both indigenous forests and scrubland and for soils.

The information management system component of the overall CMP is at an earlier stage of development and will be reviewed separately.

4 Members of the Review Panel

The review was undertaken by a panel of five members, appointed by MfE after seeking nominations from the Steering Committee and the research providers.

The members of the review panel were:

- Dr Margriet Theron (chairperson), Dean of the Faculty of Forestry and Technology at Waiariki Institute of Technology, Rotorua. After 20 years in forestry research, she became Planning Manager of the Forest Research Institute in 1986. During six years at the Ministry of Research, Science and Technology (MoRST), she chaired 11 major reviews of the quality and relevance of government-funded science, and represented New Zealand at APEC, OECD and other science policy meetings. She is the deputy chairperson of the Board of Directors of the Horticulture and Food Research Institute of New Zealand, and an auditor of the New Zealand Universities' Academic Audit Unit. She has been on the National Council and chairperson of the Rotorua Branch of the Forest Industry Engineering Association.
- Dr Sandra Brown, Senior Programme Officer, Forest Carbon Monitoring, at Winrock International, Oregon, where she designs and implements C monitoring plans for forestry C offset pilot projects, including projects in Bolivia, Brazil and Belize. Her research career includes 20 years at the University of Illinois, where she became Professor in the Department of Natural Resources and Environmental Studies in 1993. Her research focused on the role of tropical forests in the global C cycle. She has been cochair of the Standing Expert Group on Land Use Change and Forestry for IPCC/OECD, is a convening lead author of a chapter for the IPCC Special Report on Land Use, Land Use Change and Forestry, and has served on various international committees related to land use change and forestry, and climate change.
- Colin O'Loughlin, a forestry consultant from Christchurch. His 25 years of research in forest hydrology and slope stability included projects in forest establishment and hydrological resources in China, Malaysia and Canada. From the position of Director of the Protection Forestry Division of the Forest Research Institute (FRI) in Christchurch he moved to Wellington in 1986, where he had overall responsibility for FRI. Since leaving the Ministry of Forestry in 1992 he has been actively involved in reviews of and consulting on sustainable land management, environmental forestry, and national science strategies. He has been a member of the Executive Committee of the New Zealand Institute of Forestry.
- Dr Keith Paustian, Senior Research Scientist at the Natural Resource Ecology Laboratory at Colorado State University. His research has involved studies of carbon and nitrogen dynamics in agricultural, grassland and forest ecosystems, at process and ecosystem scales. His current work is on organic matter and C dynamics in soils, focusing on land use and management effects on soil C sequestration. He is currently involved in assessing soil CO₂ flux and C sequestration potential in soils at national and regional scales in the US. He has been cochair of the IPCC/OECD Working Group on Methodologies for Country Inventories of Greenhouse Gases: CO₂ Emissions from Soils, and is a lead author of the IPCC Special Report on Land Use, Land Use Change and Forestry.
- Dr Andy Whitmore is Head of Soil Science at Silsoe Research Institute in Bedfordshire, where his current research is on physical aspects of C sequestration and its importance to C modelling. He has worked on computer simulation models of the nitrogen and C cycles in soil for most of his professional career. He worked on the development of the

forerunner of the Sundial nitrogen modelling system and on changes in soil organic matter with changing land use. In 1991 he moved to the Institute for Soil Fertility Research in the Netherlands where he worked on changes in C and N stocks in soils and on manipulating organic matter cycles for optimum benefit. He participated in a review of C sequestration potential of soils, and is lead author for the IPCC Special Report on Land Use, Land Use Change and Forestry.

The review panel was supported by Stuart Calman, Senior Policy Analyst at MfE. Stuart chairs the Steering Committee on the CMP, develops the annual research contracts and work programme for the project, and coordinates the annual reviews of research outputs. He represents New Zealand at technical and expert level meetings of IPCC, OECD, and UNFCCC. His projects at MfE include planted forest C projections, emission trading, C charge design, and compiling the greenhouse gas inventory for land use change and forestry.

5 Review Panel's Approach to the Review

The review panel was provided with copies of all the CMP reports prepared by the research providers, as well as with various other background documents. Each member of the panel then prepared an issues paper which was circulated to the research providers, stakeholders, and the other members of the panel.

The review panel met in Wellington from 18 to 22 October 1999. A timetable for the week is attached as Appendix A. On the first two days of the meeting, the panel had discussions with the researchers and members of the Steering Committee for the project (participants are listed in Appendix B), and then drafted the review report. The groundrules followed during the presentations are set out in Appendix A.

The panel provided initial verbal feedback to the research providers and stakeholders on 21 October 1999.

The Steering Committee and research providers were given the opportunity to provide comments on the factual correctness of the draft report. These comments were considered by the review panel, and included as appropriate before the report was finalised.

In this report, recommendations have been printed in bold.

6 The Steering Committee and Stakeholders, and their Requirements of the Project

6.1 Membership of the Steering Committee

The following stakeholders are represented on the Steering Committee for the CMP:

- MfE (Chair)
- MAF
- DoC.

MoRST was a member of the Steering Committee until 1998 but has not been attending meetings since then. MoRST has a catalytic role in national research projects, such as the CMP, but once a sound working relationship has been set up among policy agencies (such as MfE) and research providers, MoRST exits from operational issues. The Ministry would have an ongoing interest in any research provider ownership issues which may arise from this review. On the invitation of the chairperson of the panel, MoRST attended one session of the review discussions.

6.2 Funding and Overall Management of the Project

MfE holds the financial and contract control over the project. Funding for the project comes from Vote Environment, under the Green Package. Some sub-projects have been jointly funded separately by stakeholders.

The Steering Committee holds a major meeting in July or August of every year to review the reports produced on the work of the previous financial year, which runs from 1 July to 30 June. Priorities are then set for the new financial year. With the complexities involved in contracting with a number of research providers and the scope of the CMP's activities, it takes several months before work programmes are finalised and the researchers can restart their work on the project. Although the date of signing off on contracts has become earlier during the first three years of the project (January for Year 1; December for Year 2; November for Year 3), the researchers commented on the negative impacts on the project caused by these delays. The stop-start nature of the project makes it difficult to plan the field work, which largely takes place over the summer. All the researchers involved in this project are also working on other projects. The delays in signing the contracts for this project mean that researchers' work programmes have to be revised in substantial ways, late in each financial year. The annual project management timetable for this review is quite different from the timetable for PGSF projects, which comprise the main workload for most of the researchers involved in the CMP. **The management and funding of the CMP should be adjusted to enable continuity of research effort and earlier assurance of funding for each financial year.**

6.3 Needs of the Stakeholders

It is recognised that the project will provide a significant tool for the collection of data of interest to DoC, MfE and MAF. The non-carbon issues of interest to these stakeholders include:

- indicators of biodiversity and environmental performance (DoC and MfE)
- sustainable land and indigenous forest management, including Montreal Process and TBFRA-2000 reporting (MfE and MAF)
- forest condition and trend as a component of conservation estate management and performance reporting (DoC).

The extent to which the needs of these various stakeholders are being met is discussed in Chapter 10.

7 Review of Forest and Scrub C Projects

7.1 Background

The proposed CMS for estimating C changes in indigenous forest and scrub will use a stocks approach. The approach depends on having a reliable base line estimate of total C stock against which estimates of C stocks in the future can be compared. The proposed system for monitoring C stocks in indigenous forests and scrub will be based on a core network of ground-based 20 m x 20 m permanent plots on which the heights and diameters of trees and shrubs are measured, as well as measurement made of dead wood. The location and intensity of sampling will be determined by a nationally uniform square grid. The principal spatial data source to be used is the Land Cover Data base being developed by MAF. Satellite imagery data and other spatial information will be used to provide estimates of the areas of forest and scrub.

In the three years that the CMP has been under way, the focus has been directed at developing a monitoring system and providing a 1990 estimate of forest and scrub C stock. The spatial data for determining areas of vegetation were based on the Vegetative Cover Map developed in the 1980s. The relatively poor spatial resolution of this map, which creates problems in distinguishing forest from scrub and scrub-grassland communities, is regarded as a weakness.

A large part of the data used for estimating a base line is based on the NVS plots where their location coincides with the grid squares. No pre-sampling stratification was attempted but post-sampling stratification was carried out. Estimates of the per hectare values of C stocks in the forest cover were determined by applying allometric relationships to the tree and shrub diameter and height measurements and measurements of dead wood. The use of allometric relationships based on limited biomass information is regarded as a weakness in the system used to provide a 1990 base line C estimate.

The overall monitoring system was tested across an east-west transect in the South Island in 1998. Fifty-nine sample plots (forest 41, scrub 18) related to a 9 km x 9 km grid were measured. The exercise revealed that 96 percent of the C on the transect was contained in forest.

Currently, efforts are being made to upgrade the base line C estimate using improved spatial information and new approaches for estimating the C stocks of trees and shrubs.

7.2 Progress to Date in Forest and Scrub Projects

At the time of the review, the following had been achieved:

- A 1990 estimate of the C in indigenous forests and scrublands had been made based on land cover area estimates from the VCM and vegetation data, coupled with biomass studies, from the NVS. The C in forest vegetation was estimated to be about 920 Mt C \pm 50 Mt, at about 95 percent confidence or within \pm 5 percent of the mean. The carbon in other woody vegetation and scrub was estimated to be about 527 Mt C; no estimate of the

error was given. These estimates do not include all C pools; lacking was an estimate in coarse woody debris.

- A draft CMS for forest and scrub has been developed that is not integrated with the soil C monitoring work. The draft monitoring system proposes to sample permanent plots located in a nationwide 9 km grid and to make use of the existing NVS data base, supplemented by additional plots if needed to fill in gaps in the grid. The system has been tested successfully in the South Island transect and showed that about 60 plots could be measured during a summer of field work.
- Data gaps and future research needs have been identified.

7.3 Issues to be Resolved in Forest and Scrub Projects

7.3.1 Land cover/land use (LC/LU) data bases

There are clearly problems in arriving at a consistent base line map of LC/LU for the 1990s, and yet this is a key data base for estimating future changes in C stocks. The main problem seem to be in delineating the boundaries of the scrub, mixed-scrub, and forest classes. For the development of a base line map, the scrub classes must be differentiated as it will be the changes in the area and C stocks of these classes that have the potential to sequester significant C stocks. Regrowth of woody vegetation through afforestation has been identified in the Kyoto Protocol as a means for meeting national commitments.

It is also necessary, as pointed out by the researchers, that change detection in the future must have a reliable base line. **Effort must be taken to use all available existing data bases, both spatial (LCDB, VCM, digitised products of forest inventory data, DEM, soil, etc.) and point field data, to produce a reliable base line map for a relatively narrow point in time.** The focus of the present efforts appears to be on 1996 to 1998, but every effort needs to be taken to develop a reliable base line data base for as close to 1990 as possible. Every effort must be made to resolve any major inconsistencies, so that the resulting product serves as a “true” base line for future monitoring.

All the various users and stakeholders of this LCDB must come to an agreement as to the minimum number of LC/LU classes they can live with for the foreseeable future, with some agreement as to how greater resolution may be attained in the future with the launching of new satellite sensors or aerial remote sensing technology.

Once a reliable LC/LU data base is produced, this can then serve as the base line for monitoring future changes in LC/LU. **The use of coarser satellite products, such as the 1 km² AVHRR data base on a regular basis to screen for relatively large areas potentially undergoing LC/LU changes, should be investigated.** Confirmation of these changes could be established by a combination of ground truthing and higher resolution imagery or any new sensors operational in future years.

7.3.2 Overall monitoring and sampling design

A systematic grid for C monitoring in New Zealand is appropriate. However, the 9 km grid may not be suitable for future monitoring of changes in the scrub lands and to capture C changes from new lands coming into this class from abandonment of agriculture. The grid may be too large to sample adequately the relatively small areas of new scrub lands entering this class and to sample adequately the C stocks of the existing classes. On the other hand, the grid may be too fine for sampling large areas of forests likely to undergo little change. The Review Panel is concerned about enough sampling plots on the 9 km grid being available to sample to the desired precision level if the scrub lands were further subdivided based on seral stage. **Tests should be made of how the grid could be resolved into smaller or larger grid sizes, including the application of nested grids, to address the sampling of changes in area and C stocks of the scrub lands and of large areas of forests.**

The proposed systematic sampling of locating sample points at the grid intersections is simple but can be problematic if cycles are present. **The pros and cons of selecting plots within a grid cell in a randomised manner should be investigated.**

The targeted level of precision based on sampling error only appears to be ± 5 percent with 95 percent confidence. Accounting for other errors, including only the C stocks, the actual level of precision is likely to increase. It is not clear why the 5 percent level was targeted. **Researchers should discuss with the stakeholders what level of precision they require, giving consideration to cost and international reporting needs.** For the 1990 base line C stock, a lower level of precision may suffice, but for future monitoring of changes in C stocks, especially in abandoned pastures and scrub lands undergoing increases in C stocks (afforestation), a higher level of precision may be desired. **A method for estimating C stocks and their changes at varying levels of desired precision in different LC/LU classes, and the implications for cost, need to be addressed.**

Although the panel appreciates the effort and historical value of the NVS plots, their design is not optimal for a CMP. Also, the history of the establishment and purpose of the plots make one question if they really represent the population of interest for C monitoring and if they are optimal for C monitoring. **The use of circular nested plots of varying radii needs to be considered,** maybe four plots for forests to measure seedling/saplings, small trees (<20 cm dbh), medium trees (20-60 or 70 cm), and large trees (>60 or 70 cm dbh). For scrub lands, only one plot might be needed, though this could be tested depending upon the size of the shrubs. **The use of a nested plot sampling scheme should be introduced through time by partial replacement in future sampling.** New plots could use the nested plot design and the old plots be replaced gradually as they are re-sampled. **All plots should be spatially located using a differentially corrected GPS.**

Procedures for monitoring disturbance (both “natural” and anthropogenic, and of relatively large scale, tens to hundreds of hectares) and how this may affect C pools, is not explicitly addressed in the monitoring plan. **Explicit evidence should be provided that the researchers have given consideration to monitoring disturbance effects, how important these are to C stocks, how their plan addresses this, or what additional data need to be collected to incorporate this into the plan.**

The Review Panel did not see any reference in the various reports to the formulation of a quality assurance/quality control plan. A QA/QC plan needs to address procedures for checking that the field measurements are made correctly and that the field data are analysed correctly. **A QA/QC plan should be developed for future implementation, and all field, laboratory, and analytical techniques should be coordinated among the various research teams, to add**

credibility to the CMS. Standard operating procedures are a key component of a QA/QC plan to maintain continuity of measurements and analysis through time, and should be prepared.

7.3.3 Measurements and analysis of field data

As recognised by the researchers, the current methods for converting live tree measurements to biomass C are inadequate. The simplest approach to converting tree measurements is to develop allometric regression equations of biomass per tree versus dbh alone or dbh and height. Experience by one member of the panel² has shown that r-squares of 0.95 and higher can be obtained for such regression equations by pooling data for multiple hardwood species from different locations within a country and from different countries. The advantage of pooling species is that a larger data base can be obtained that spans the range of diameter classes likely to be encountered.

Researchers should identify areas where active tree harvesting in indigenous forests is taking place and spend time there destructively harvesting and measuring, using standard techniques, a selection of trees to obtain the necessary biomass data for the development of allometric equations. It is not necessary to do detailed measurements of all the components; rather focus on the total aboveground biomass and stemwood biomass. It may be impractical to harvest examples of the giant trees – detailed measurement of the main stem and branches to obtain volume may suffice.

Researchers should seek out data for analogous forests in other parts of the world – e.g. relevant data do exist for Nothofagus forests of southern Chile. It might be possible, after some initial testing, that such data could be added to the New Zealand data base.

Root measurements are costly and very time consuming and current methods are not highly standardised. **The present approach of estimating the C pool in roots from the literature³ should be continued.** If cost-efficient methods become available in the future, field measurements could be used to test the validity of the literature values.

Measurements of CWD are presently made on all dead lying wood in the sample plots. It is not clear if the line intersect method was considered. This is a fast and cost-efficient standard method for measuring lying dead wood. Also, standing dead trees are generally considered part of the CWD, and it appears that standing dead was not included. **The line intersect method should be used as this could be a more time and cost efficient method for measuring CWD.**

A minor point: the formula used in report 34 for estimating the volume of the dead log seems to be wrong; this should be revisited.

² Sandra Brown has developed many regression equations for her work on forest carbon budgets for both tropical and temperate forests and has found that pooling all species, stratified by general climatic groupings (e.g. dry, seasonal, moist lowland and wet forests in the tropics), has resulted in highly significant biomass regression equations with r-squares of 0.95 and higher (Brown, S., 1997, Estimating biomass and biomass change in tropical forests: a primer, FAO Forestry Paper 134, FAO, Rome, Italy; Schroeder, P., Brown, S., Mo, J., Birdsey, R. and Cieszewski, C., 1997, Biomass estimation for temperate broadleaf forests of the US using forest inventory data, Forest Science 43: 424–34; Brown, S. and Schroeder, P., 1999, Spatial patterns of aboveground production and mortality of woody biomass for eastern US forests, Ecological Applications 9: 968–80.

³ e.g. Cairns, M., Brown, S., Helmer, E.H. and Baumgardner, G.A., 1997, Root biomass allocation in the world's upland forests, Oecologia 111: 1–11.

It is quite common to collect a sufficient number of samples of dead wood of different density classes from the plots to obtain a mean value per density class. How well do the wood densities used from other studies (report 34) match the actual values in the plots? No attempt to check this appears to have been made. **In future work, sampling various density classes of dead wood should be encouraged.** We suggest that researchers investigate if a device is available (check with forest equipment suppliers) to develop more objective measures of wood density. If one is not available, it might be valuable to see if one could be developed – a large market for such a product potentially exists. Decomposition class of CWD is not as important as its density class and decomposition class does not always correlate well with density.

At present the fine litter pool is “covered” by the soils work. Although measured and analysed by the soils group, the values are not reported anywhere. See Sections 8 and 9 for further discussion and recommendations on this C pool.

Sampling the shrubs is difficult, but the methods used to date are adequate.

7.3.4 Monitoring changes in C stocks

The main objective of the CMS is to provide a means by which changes in C pools over time can be monitored. Some indigenous ecosystems will change a lot, whereas others will change little. For instance, scrub lands formed from abandoned pastures and new lands entering this class are likely to show change. In addition, some classes of conifer-broadleaf forests susceptible to animal browsing are also likely to show changes in vegetation C and possibly in soil C if soil erosion results from forest damage. As mentioned above, the CMS should take this into consideration and be designed accordingly. At present the monitoring plan makes no suggestion as to the frequency and intensity of future monitoring. **The ongoing monitoring system should address which LC/LU classes and C pools need to be monitored and over what time frames and at what scales.**

It is likely that future monitoring may not need to replicate all the measurements made to develop the C base line. A set of indicators could be developed for some less accessible areas where no to little change in C is expected. C is not the only variable of interest and there are other stakeholders who may have other needs that require more intensive monitoring. **The future monitoring programme needs to find a balance between the needs for C and the needs for other environmental variables. All stakeholders should develop a minimum list of needs.**

There are two basic ways to measure change in C stocks:

- a) take the difference between the C stocks measured at two points in time or
- b) measure the change in C pools directly from a base line, akin to change detection methods in analysis of remote sensing data.

Although the transect study (report 34) discusses method (b) and implies it will be used, the method proposed in the draft monitoring system is method (a). Such an approach has the potential to result in a change estimate with a high error bar. **It is preferable, if possible, to measure the change in C pools directly from the permanent plots, but to apply this method, the processes causing the change must be conceptualised correctly.**

There appears to be a misunderstanding in report 34 about how to estimate the net change in C stocks through time. The gain from tree growth is just the growth of the surviving trees plus growth on ingrowth (new trees coming into the minimum diameter class); no correction for mortality is needed. One does not need to subtract mortality if the trees are tagged, as they are.

The change in the dead wood pool is the difference between input of dead wood from mortality and loss through decomposition. **To maintain a high level of precision in the monitoring of change in C pools, the CMS should attempt to measure the change directly in aggrading systems in particular.**

7.4 Robustness and Credibility of Monitoring Systems for Forest and Scrub

7.4.1 Criteria for evaluation

It is desirable that the direction in which the forest and scrub monitoring system is proceeding provide a solid foundation on which to build. For evaluating robustness and credibility of the CMSs the review panel used the following criteria:

- technical and scientific merit
- feasibility
- ability to meet clients' needs.

These criteria will be discussed in the following sections.

7.4.2 Technical and scientific merit

The system for monitoring forest and scrub has been developed by some of New Zealand's best forest researchers. It incorporates plot sampling techniques which have been developed over many years and which have been upgraded and modernised. The overall sampling scheme, which has affinities with the National Forest Health Monitoring System used in the USA, is based on a systematic sampling approach across the indigenous forest and scrub lands and has been scientifically designed and tested to provide information at a range of spatial scales (Allen *et al* 1999, Allen *et al* 1998, Lawton and Calman 1999). The plot design enables forest composition, structure, wood volume, ground cover and seedling abundance to be measured. Over the years an efficient data base management and analysis system appears to have been developed. Nevertheless, the monitoring system is not without weaknesses. The problems associated with the sampling design, estimation of biomass, and sampling of dead wood and litter, remain to be resolved. There is also room for improvement of plot design and introduction of a system of quality assurance.

Particular merits of the monitoring system are:

- Measurement of coarse woody debris. The attempts to measure CWD in plots during the 1998 survey of the South Island transect is commendable and, apart from some Scandinavian countries, has not been attempted elsewhere on a regional or national scale.
- Measurement of scrub. Measuring scrub is a challenging task. The review panel is satisfied that the scrub monitoring system adopted during the transect monitoring exercise met this challenge and provided credible results.
- Ground truthing and confidence intervals. The vegetation plot sampling system provide solid ground truthing for the LCDB. Furthermore, the system provides an estimated

confidence interval which is generally not available for other vegetation monitoring systems.

- Overall, the system developed to date is based on existing data, is sound and is in line with CMSs in other countries although somewhat more advanced than many.

7.4.3 Feasibility

The review panel used the following criteria to assess the feasibility of the forest and scrub monitoring system:

- success of a field test
- cost efficiency
- availability of skilled personnel
- degree to which the system can be understood and implemented.

The determination of the C stock across a transect of the South Island in 1998 provided a recent test of the forest and scrub monitoring system based on the application of a 9 km x 9 km grid and the measurement of 59 plots. The transect project provided confirmation that the monitoring system is practical but also revealed that there are opportunities to improve the design of the plot network.

The financial and practical feasibility of implementing the CMS in the future is certainly not assured and depends on a number of factors additional to the monitoring system itself. The system is not cheap to implement. The forest researchers estimate that costs amount to more than \$100,000 per year if spread over a 10-year period. However, research management explained to the panel that these costs are only approximate and need to be refined to take into account economies of scale, use of technicians rather than high level scientists, and the like. At this stage it remains unclear what the real costs of the monitoring programme might be. **An accurate estimate of all costs (fixed and variable) of the monitoring system options should be made as soon as practicable.**

The small number of skilled science personnel capable of further developing the monitoring system and ensuring that it is implemented correctly remains a threat to the future smooth functioning of the forest and scrub CMS.

The system adopted for vegetation C monitoring is reasonably straightforward and easy to understand. Thus there should be only a small chance that properly trained field crews would misinterpret the field sampling requirements of the system.

7.4.4 Ability to meet clients' needs

The prime requirement of the CMP is to provide a system capable of generating a base line estimate of C stocks and monitoring the change in C over time in indigenous forest, scrub and soils to enhance New Zealand's ability to meet its reporting commitments and obligations under the FCCC and the Kyoto Protocol. There are also additional reporting requirements and a number of national data requirements to which the monitoring project could contribute (see Section 6.3).

The design of the CMS for forest and scrub has been directed at the need to provide information on the changes in C stocks. Any acceptable monitoring for the detection of changes in C stocks should be simple in design and should produce estimates of C change with an acceptable degree of reliability.

Estimates of C stocks in indigenous forests will probably attain a reasonable degree of reliability under the proposed monitoring system. However, estimates of the C stock in scrub lands may be less acceptable because of the problem with assessment of their extent. The review panel also notes that no error estimate has been provided for this land cover class in the national base line.

For reporting to meet the requirements of the FCCC, the review panel feels that the most recent upgraded 1990 base line estimate of forest and scrub C stock is satisfactory. However, as an estimate for providing a basis for future monitoring of changes in C stocks, the present base line estimate needs improvement.

The panel also considers that the basic design of the monitoring system for forest and scrub, the use of permanent sample plots and the various C pools that have been identified, are valid. But the proposed C monitoring plan for the indigenous vegetation contains a number of weaknesses as identified in Section 7.3. Until these weaknesses are rectified the overall monitoring system is not ready for implementation as it will not meet the needs of the major client.

8 Review of Soil Carbon Projects

8.1 Background

The main system being prepared for implementation is a modification of the IPCC approach. It involves the stratification of New Zealand's land area according to broad climatic and soil classes, within which major LC/LU types are identified. It assumes that climate (i.e. temperature and moisture regimes), key soil properties (involving texture, clay mineralogy, and drainage) and land use are the major determinants of soil C levels and the "drivers" of soil C change. Maps of the climate, soil and land use classifications are overlain to derive a set of climate/soil/land use categories or "cells" that cover nearly all (93 percent) of New Zealand. Climate and soil type classifications are viewed as constant over time, while LC/LU changes over time.

Estimates of soil C levels (mean and variance) for each cell are based on the existing New Zealand soil pedon data, reclassified into the aforementioned climate/soil/land use divisions. Existing data were supplemented by new sampling and measurements to populate under-represented cells. Soil C levels are multiplied by the area for each climate/soil/land use cell to obtain a total soil C inventory for New Zealand.

To estimate changes in soil C storage over time (and thereby net atmosphere-soil CO₂ exchange, as required for FCCC reporting) a set of "coefficients of change" (CoCs) is being derived. The CoCs represent the change in soil C when moving from one land use class to another (within soil-climate classes). The system is designed to estimate the average change in C per transition and multiply this by the change in land use area.

The rationale behind this approach (which differs from the forest survey) is that future changes in land use will largely drive sinks or sources of C. Since these changes in land use may well take place on small plots of land only, it is argued that a grid-based sampling network would be an extremely inefficient way of picking up the changes. In addition, sole reliance on a field survey scheme would entail waiting for 10 years or more to re-sample soils in order to estimate C change.

8.2 Progress to Date

8.2.1 Mapping and area stratification

A classification of New Zealand climate into seven temperature/moisture regimes has been completed and tested. The panel's initial reservations that decadal changes in climate (i.e. global warming) might compromise the system, have been dealt with; any changes are likely to be slow and small relative to the width of the temperature and moisture classes.

The soil classification, based on the IPCC approach but with the addition of a podzol class, was completed and tested. A total of seven soil classes are represented, three of which represent 93 percent of the land area of New Zealand. Tests using existing soil pedon data showed that the categories accounted for 31 percent of the variance, climate for 8 percent and soil plus

climate for 32 percent. Use of more soil taxonomic categories explained little additional variance in soil C (report 31, p 10).

Data on land use practice were originally taken from the VCM of New Zealand (Newsome 1987, report 39, p 7) from which 47 categories were identified. These were re-allocated into 11 categories appropriate for the soil CMS. No plans have been made to revise the VCM (completed in the mid-1980s) and the CMS plans to make use of the LCDB, which is nearly complete.

Soil and climate categories were combined into 18 classes which, when multiplied by 11 land use categories, yielded 198 possible "cells". After eliminating classes not found in New Zealand and collapsing very minor categories still further, the number of combinations was reduced to 39 which accurately categorises about 93 percent of New Zealand soils. Existing data of the amounts of soil C in these classes were progressively supplemented with data held by Forest Research and others. Some cells remain unsampled (<17, report 32, p 2, report 39) or under-sampled. At the end of 1998/99 only one class covering more than 10,000 km² remained under-sampled. This class was estimated to contribute 35 percent to the error variance and this and other missing or under-sampled categories remain a high priority.

8.2.2 The 1990 base line

Once the land use in 1990 was estimated from the VCM, successive updates to the soil C data base has led to progressively more precise estimates of the national estimates of soil C:

- 1,144 Mt (0-10 cm, report 3 1997)
- 1,208 ± 66, 1,532 ± 107, 1,944 ± 278 Mt (0-10 cm, 10-30 cm and 30-100 cm, respectively (report 11)
- 1,148 ± 50, 1,413 ± 80, 1,631 ± 193 Mt (report 32).

Additional data have become available as a result of an e-mail appeal to many New Zealand scientists and additional sampling during 1998/99. This has resulted in approximately 10 percent more samples being available for inclusion in the data base, but updated estimates of the soil C 1990 base line are not yet available. Care must be taken, however, not to bias the conclusions with unrepresentative results or results using techniques that give systematically different result from those already in the data base. Data were captured for three or four (depending on depth) of the missing land use soil-climate categories. Additional data points were also captured for other under-represented cells.

The accuracy of the prediction from the system for assessing the 1990 base line was evaluated during 1998/99. Soil C was measured at 72 locations within the Benmore Range in the Waitaki Basin. Within the test area there were five distinct climate categories but only one land use category and one soil class. The monitoring system predicted an estimate of 1.6 Mt C while the actual measured value derived from the survey was 1.2 Mt C. Comparisons of soil C base line stocks were also done using the FAO soil map of the world data for New Zealand and the results were consistent with the new base line estimates.

Some testing of the RothC C dynamics model has been carried out and results appear promising.

8.2.3 Soil pedon data base and new sampling

Existing soil pedons have been matched with climate/soil/land use cells, and gaps have been identified for future sampling. In the New Zealand National Soils Data base, approximately 2000 samples from 389 profiles (pedons) had the necessary parameters (carbon, dry bulk density, sample depth and a grid reference) to enable the information to be mapped. Additional soils information were obtained from Forest Research, which together with the NSD provided 636 profiles with data for the 0–0.1 m depth interval. New field sampling of under-represented soils, 38 sites in 1997/98 and 20 sites 1998/99, has been carried out over the past two years and additional pedon data from PGSF research has been added to the overall data base.

8.2.4 Coefficients of change

Preliminary estimates of CoCs have been obtained using ANOVA of soil pedon data. Screening and reality checking of CoCs using paired plot data, benchmark sites, modelling and other auxiliary sources has been discussed (report 7, p 11; report 39, p 10) but little validation work of this nature has been done to date.

8.3 Issues in the Monitoring of Soil C

8.3.1 Use of stratification procedures for soils and associated data

A fundamental assumption in the use of stratification is that the stratification is not itself subject to change. For example, if climate changes in New Zealand due to increasing levels of GHG then the areas of land defined by current climate classes will change. Scientists responsible for the stratification have considered this issue and pointed out that likely changes in temperature over the next 50 to 100 years (1 to 2°C) would be small in relation to the climate class width (7°C). Any actual shift of land from one climate class to another was in any case expected to be small.

A more serious problem with stratification is how it deals with “new” LU/LC types that either fit into more than one category or do not fit with any existing category. An example of the former is the anticipated increase in area of abandoned land that reverts to a mixture of scrub and exotic pine. In addition to problems in quantifying eventual “equilibrium” C levels for classes not previously found, there is the potential for double counting, i.e. C change may be counted twice, as both scrub and as exotic forest. An example of where something does not fit into the stratification scheme is where land is subject to browsers or other disturbances such as erosion. Within the current stratification, these might be defined as a land use change but since these disturbances may apply across many land uses, disturbance may need to be considered as a separate layer in the GIS. The review panel notes information that the potential impact on New Zealand’s terrestrial C balance of forest herbivory or soil erosion is the subject of some current research by Landcare Research, funded by the PGSF.

It is crucial that the information used to compile the stratified classes is accurate. Some doubts remain as to whether or not the soils maps used to identify areas of New Zealand belonging to a particular soil class are all of the same quality. **It might be worthwhile to use uncertainty analysis to quantify error magnitude in a selection of soil classes to check if this error is the**

same everywhere and to ensure that sampling intensity on the ground reflects the imprecision, i.e. sample more closely where the uncertainty in soil (or other class) is greatest.

8.3.2 Assessment of land use change in the future

Future estimates of the change in soil C will depend on the main driver: land use change. It is proposed that this information will be derived from the LCDB. However, for the 1990 base line estimate, LU/LC areas have been estimated from the VCM data base. Thus, a reference or mapping between the two data bases is critical. **The procedure for relating the current strata to those which will be derived in the future from the LCDB should be made explicit.**

Based on information supplied regarding ongoing work of the project development team for LCDB II, the next iteration of the data base appears to be well suited to meet CMS objectives. These specifications include an assessment frequency of five years (which should be adequate to inventory and assess land use change) and likely adoption of Landsat 7 as base imagery, but with provision for use of higher resolution satellite imagery and/or aerial photography to increase accuracy of quantifying land use change. **It is critical that the classification developed for the next iteration of LCDB meet the needs of both the soils and the forest and scrub inventories, as well as other stakeholders where possible. Acquisition of a ground receiving facility – which has apparently been discussed repeatedly in the past – should be seriously (re)considered to ensure the maximum data availability and timeliness.**

Since soil C changes resulting from management and land use changes can continue over several years to decades, information on land use patterns over the past 20 or more years is relevant. Such information is not available from the VCM or from spatial land cover classifications using satellite imagery, such as the LCDB. However, land use statistics, while not fully spatial in the sense of LCDB, may be useful in estimating past rates of land use change for estimating current soil C change. In addition, such data could provide an additional check on estimates of land use distribution and changes over time, as inferred from future LCDB sequences (i.e. over five-year intervals). **Existing land use statistics should be explored as an auxiliary source of information on historical land use change (i.e. land use history) in relation to the soil C monitoring programme.**

8.3.3 Coefficients of change approach

There appears to be a generally good understanding within the project of the pros and cons of the CoC approach to estimate soil C change. The advantages to the approach are:

- a) it can be implemented in the short term (i.e. by the end of the project period)
- b) it conforms closely to the concepts of the IPCC approach
- c) it makes use of existing information but can be readily updated as new information becomes available.

Chief disadvantages are:

- a) representation of change over time
- b) potential difficulty in obtaining robust, accurate, sufficiently precise and unbiased estimates of CoC
- c) error estimates in the stock changes are less well defined compared with fully empirical estimates of stock change.

With respect to representing change over time, the researchers recognise that the method counts the full change in soil C *directly* following a land use change (i.e. as a step function). While strictly incorrect (i.e. C levels change over many years), the researchers note that the predictions may still be acceptable for inventory reporting and policy purposes since the total amount of C “released or sequestered as a result of land use change will still be correctly estimated” and “that if land use change occurs at a relatively constant rate then the net emission or sequestration in any year will still be correctly estimated” (report 38, p 6).

The derivation of CoC has been based on analysis of the soil pedons, classified by climate/soil/land use, where the soil C data base can be viewed as a large, multi-factor experiment. It is not a complete factorial experiment, however, because many combinations of the key factors do not exist in New Zealand. Furthermore, there is the potential for bias in the derivation of the CoC due to what might be called the “land selection” bias. For example, within a climate-soil “cell” originally covered by forest, pastures may have been established on more fertile soils compared to what remained in forest. Other factors which control C levels, such as drainage and slope steepness, are likely to have influenced land use decisions such as which pastures to abandon and where to plant exotic forests. Because the soil-climate categories are necessarily broad, these within-cell biases are difficult or impossible to filter out. **Alternative approaches to estimating CoC, i.e. long-term experiments, carefully selected paired plots or chronosequences, are strongly encouraged as a check of CoCs derived from the broad-based (e.g. ANOVA, GLM) statistical procedures.** Subsequent derivations of CoCs from the pedon data should also explore within-cell stratifications, such as by land use history and topography (slope, aspect), when sufficient data have been collected.

The limited ANOVA tables shown do not make it clear whether or not significant interactions exist between land use change and soil-climate. The table (report 23) appears to show that treating moist temperate HCA as a special case eliminates the problem. The lack of a full series of land use changes, however, does not permit one to draw this conclusion in general and it is clear that **the interaction between land use change and soil-climate class needs to be investigated for all relevant land use changes.**

Even within the ANOVA tables shown, it appears that other interactions exist, other than in the moist-temperate HCA class. Some combinations remain under-sampled, e.g. humid temperate podzol/exotic forest; temperate sand with improved and unimproved pasture; exotic forest and scrub. Some of the CoCs derived from these analyses may not be sensible in magnitude, sign or both. Although it may appear sound to rely on tried and tested statistical techniques to derive the CoCs it appears **essential that all CoCs are subject to common-sense scrutiny by a scientist to ensure that (a) sufficient data have been used to derive them and (b) the coefficients are sensible in sign and magnitude.**

8.3.4 Full C accounting on forest and scrub plots

Currently, only coarse woody litter (>10 cm diameter) is routinely collected as part of the biomass inventory. While procedures have been developed to sample forest floor (including fine litter <10 cm) and soils for C, these measurements have not been integrated into the regular sampling scheme. For instance, in the pilot transect on the South Island, there appears to have been a lack of coordination between the projects and litter C was not reported, which led to confusion (even if only in the minds of the review panel).

The lack of fine litter and soil measurements violates the principle of full C accounting and introduces potential bias in estimating changes in C stocks. For example, between-system differences in size class distribution of litter produced will result in errors if total accounting of

all litter is not made. Furthermore, land use change can result in situations where litter and soil C respond in opposite directions (e.g. pasture to forest conversions), so that excluding either component introduces serious bias. **Litter samples and underlying soil samples should be taken (using cores to ensure that bulk density can be determined) at all biomass survey plots. Explicit inclusion of a soils component in the forest/scrub surveys will also help to integrate the two parts of the CMS.**

It is recognised that a detailed soil classification and sampling, conducted by an expert pedologist, is not economically feasible on a routine basis at all the forest and scrub inventory plots. However, a slightly modified procedure could be implemented and yet be compatible with other data collected so far. Sampling depth should be a minimum of 0.1 m but samples to 0.3 m would be preferable. It may not be cost-effective or feasible to sample to 1 m depth on a routine basis in forested soils, but where possible the data would be useful. Samples should be carefully georeferenced, e.g. with respect to marked trees or buried “ball-markers” (inexpensive passive antennas used to relocate underground objects) so that those locations can be avoided in subsequent re-sampling of the plots. Using the present scheme of compositing five cores seems reasonable. Regular field personnel could be trained to recognise soil characteristics sufficient to classify soils into any of the seven soil categories. Routine laboratory measurements such as texture, pH, cation exchange capacity could be added to ensure proper classification of soils and would yield valuable supplemental information for potential modelling (and other) applications including soil quality monitoring (at least on production systems). Samples could be split and made available for the soil fertility measurements currently being done on “grab samples” (not a recommended practice) from the biomass plots. Since much of the cost is in collection and processing of the soils, there is good potential for synergisms. **Opportunities to leverage the additional costs of more widespread soil sampling through collaboration with other programmes such as soil quality investigations should be pursued. After a full remeasurement period, the data would be invaluable as a validation of the soil C change estimates based on CoC.**

The project managers admit that the costings for soil sampling and analysis as presented in the survey reports are not definitive and the panel has in parts of this report tried to make suggestions as to how the costs may be addressed. Where the additional labour is included in the forest/scrub survey to take soil samples, much additional information could be obtained for relatively little extra cost. **Accurate costing should be made of the additional costs to sample soil as a part of the forest/scrub survey including the costs of simply sampling to 10 cm or to 30 cm.**

8.3.5 Inclusion of soil C measurements in a national grid-based inventory system

Given the argument that soils and litter should be measured at the forest/scrub plots, the question arises whether a grid based system should be extended to cover the entire country, since soil carbon monitoring is designed to include all lands. Analyses of this and alternative sampling schemes have been addressed relatively extensively in report 38. The panel’s recommendation for soil and litter sampling in the forest/scrub plots is based on the fact that the C stock and stock change estimates there are wholly dependent on the survey data, and thus excluding litter and soil stocks introduces a potentially serious bias for the forest and scrub systems.

The situation is somewhat different for the overall soils monitoring effort. The arguments against a comprehensive, national-scale sampling-based approach are the high cost and lack of efficiency (i.e. assuming that soil C is essentially static in many “stable” ecosystems). In

addition, the slower rate of change relative to the background levels of C soil mean that a relatively long remeasurement interval would be needed to get estimates of stock changes. Thus the panel supports the general rationale for the use of a more model-based approach (e.g. CoC, possibly evolving into a dynamic simulation approach) where the key measured elements are land use change and characterising representative C stocks for climate/soil/land use combinations. Nevertheless, additional soil measurements in non-forested permanent plots could supply valuable validation data. This may be consistent with the concept of benchmark sites which have been discussed in several reports. The key to establishing such sites will be to select them in an unbiased fashion and ensure that all climate/soil/land use combinations are represented. **Efforts should be made to establish benchmark sites, particularly for land use types which are expected to undergo significant changes, e.g. abandonment of pastures. One option which may be explored is to locate very recently abandoned lands as potential benchmark sites.**

A related issue is the need to account for the recruitment of new land into the forest and scrub categories. **Provisions need to be made, with explicit plans, to account for the recruitment of new forest and scrub areas (e.g. via pasture abandonment) as part of the grid-based forest and scrub monitoring procedures.**

8.3.6 Quality control and quality assurance

Several issues concerning quality control were raised. Most notable were the discrepancies reported in C analyses done in Rotorua and Palmerston North. Although this may have represented an isolated case of mislabelled data, it illustrates the need to improve and better document quality control and quality assurance procedures.

There were questions whether all soil samples were fully ground prior to analysis in the Leco carbon analysers. All soil samples should be carefully sub-sampled and finely ground (ball or roller-mill) – 2 mm sieved only samples are not acceptable. Common analytical standards should be used across laboratories and periodic sample splitting and blind checks should be performed. Archiving procedures for survey plot soil samples need to be developed and implemented. **QC/QA procedures should be defined and implemented, including field sampling, sample preparation (sub-sampling, grinding), and C analysis (analytical standards, blind checks).**

The CMS and associated data, programmes and possibly even hardware are vulnerable to the rapid changes being made in information technology. This is a long-term project and the scientists starting now will not be active in 20 or 50 years' time. With this in mind as much of the data and software as possible need to be archived at all stages of development and implementation.

Some concern was expressed about the selection of sites for sampling soil and in particular the search for representative soil profiles. Researchers from Landcare assured the panel that this was done in an objective and reliable fashion but **the procedure to select sites for sampling of soil should be described in full and be subject to quality control and quality assurance measures.**

8.4 Robustness and Credibility of the Monitoring System for Soil Carbon

8.4.1 Scientific and technical merits

The soil C monitoring approach can be characterised as a quasi model-based approach, as compared to the straight survey approach developed for monitoring C changes in forest and scrub vegetation. It conforms to current, accepted concepts about the main factors controlling soil C dynamics and represents a refinement of the current IPCC approach for country-level reporting of soil C stock changes. Much of the data used and approaches adopted have been or are being published in scientific or technical journals.

The estimate of base line stocks is, overall, scientifically and technically sound. It relies on a sample of several hundred soil pedons, which have been screened to only include those with both C concentration and bulk density data. Some cells are at present seriously under-represented, but the ongoing acquisition of new data will continually improve the estimate. A potential weakness is also the uneven geographic distribution of soil pedons, even for “cells” that are well-populated with pedons. The survey as proposed should alleviate these fears when completed but an improvement in credibility could be gained by sampling more extensively throughout the land area of New Zealand. Some concerns were raised about the accuracy of map unit determination of soil type (in other words, are the area of each soil type within a climate zone accurately known from the soil maps). Tests with classification of soil type as determined at the time of measurement versus classification of soil types as mapped at the pedon location showed only small differences in base line estimates (D. Giltrap, pers comm, 1999 and report 31). This suggests that the accuracy of the soil maps is sufficient for the classifications used in the monitoring programme.

Estimates of C stock changes are more challenging and depend on the accuracy of estimates of CoCs and land use change. The potential for an inherent bias involving differential selection of land use as a function of soil properties, suggests that detailed, commonsense scrutiny of all CoCs will be needed. Scientifically, the assumption of a step change between equilibrium states following a land use change is poorly suited for estimating annual change, although it may be suitable for estimating average changes over several years. A further refinement of the CoC approach is proposed in which the change in soil C with time during the transition from one land use change to another is obtained. This has far more scientific merit. Too little detail is given, however, as to how these coefficients will be obtained and it is therefore difficult to comment in detail. It seems likely that a paired site/chronosequence and/or a modelling approach will be adopted and these have the advantage that they address many of the problems inherent in the ANOVA approach as well as providing the rate of change in soils C with time. **Great care must be taken, to ensure that paired sites and chronosequences are representative of the changes they are meant to express. Once calibrated, any model used should be validated against independent data and used without alteration to derive unbiased estimates of the rate of change of C in soil.**

8.4.2 Feasibility

The soil survey as designed and implemented at present is incremental in nature and not yet complete. This seeming disadvantage that is alluded to at length elsewhere carries with it the strength that it is able to give (admittedly less precise) answers immediately. The soil survey has achieved the object of establishing a 1990 base line and will be in a position to monitor changes in soil C. It is the precision of these estimates that demands attention. An expanded role of soil and litter sampling in the forest and scrub plots as well as the establishment and sampling of permanent “benchmark” sites in non-indigenous forest and non-forested (e.g. pasture) lands is technically feasible (and relatively straightforward), but an increased field measurement component for soils is highly dependent on increased funding. Thus the financial feasibility for such a programme needs further evaluation, including potential leveraging through the involvement of other stakeholders.

8.4.3 Ability to meet clients’ needs

Estimates of the base line have been given along with the associated uncertainty. The confidence in this estimate will improve as additional cells are sampled. Priorities for future sampling are given based on the proportion of the error variance each of the unsampled classes contributes. The base line C stock estimates at the national level appear reasonably good and have not been markedly affected with the addition of new data. Estimates of C stock changes, using the CoC approach, have yet to be sufficiently tested and verified. However, for the purposes of greenhouse gas reporting, the available information represents a refinement (and enhancement) of the IPCC default methodology and therefore should be acceptable internationally and meet the needs for New Zealand’s reporting under FCCC.

For the purposes of addressing the issues in articles 3.3 and 3.4 of the Kyoto Protocol that deal with terrestrial C sinks, the CMS for soils requires much additional testing and validation, particularly independent checks on the CoC values using information from paired plot studies, long-term experiments, etc. The availability of an expanded set of soil measurements, particularly in forest and scrub systems where knowledge of C dynamics is poor, is key. Such data, while not available immediately (due to a remeasurement period of at least 10 years), provide an independent validation of the model-based estimates. An expanded set of soil measurements on a national basis, both in terms of a better geographical spread of measurements and also as part of an enhanced forest, scrub and other vegetation survey, may also help meet objectives of a variety of other stakeholders concerned with other aspects of soil monitoring, including soil quality and potentially biodiversity.

9 Integration of Approaches into a Single National Framework for Monitoring of Carbon and Changes in Carbon Over Time

9.1 Importance of Integration of Approaches

The integration of the various parts of the CMS to form a cohesive framework will be essential because:

- there is a need for spatial and temporal consistency in the estimation of C stocks in soils, forests, scrub and other vegetation, particularly where the vegetation is changing
- there is a need for consistency in the precision and accuracy of estimates of C stocks in soils, forests and scrub to satisfy client needs and provide for future verification of the monitoring system
- unless an effective integrating mechanism is introduced, the approaches adopted by the soil and vegetation monitoring researchers could continue to diverge and create a very fragmented system with an uneven ability to monitor carbon changes and would ultimately fail to meet the clients' needs.

9.2 Progress to Date and Issues to be Resolved

The CMS consists of four major parts:

- monitoring of C in forest and scrub
- monitoring of C in soils
- an information system
- a land cover data base.

To date, these four parts have been developed and implemented more or less in isolation from one another. A workable soil CMS and a forest and scrub CMS have been substantively developed. An information system and a LCDB are not yet completed but are well advanced and have undergone some initial testing.

The major issues to be resolved are:

- the independence of the design and implementation of soil C monitoring from the monitoring of forest and scrub C
- the independence of the management of various data bases by different agencies using different data management systems and different software
- the production of an initial 1990 base line estimate of C stocks of uncertain accuracy which is based on information sources such as the VCM and other pre-1990 information sources that will play little or no part in future C monitoring

- the apparent lack of a quality assurance programme or strategy for the soil and vegetation monitoring systems
- the role of the CMP Steering Committee in influencing improved integration of approaches.

The weak integration between parts of the overall CMS is regarded by the panel as a serious failing but one that can be rectified.

9.3 Improving Integration

Improving the integration of the component parts of the CMS is largely dependent on four integrating mechanisms:

- a new resolve by soil and vegetation researchers to link their data collection programmes more closely
- integration of data bases by the developing information management system
- integration of spatial information through the use of the LCDB
- a more active role by the CMP Steering Committee in the harmonising or integration of the approaches adopted by the soil and the vegetation researchers.

The 1998 transect monitoring exercise indicated that soil and vegetation monitoring can be coordinated and linked. However, additional effort is needed to strengthen these links. The collection of soils information on forest and scrub plots would provide much-needed soil C information in areas where very meagre information currently exists thus adding robustness to the soil C stock data base. A potential barrier to the integration of soil and vegetation work is the additional cost of soil and fine litter sampling at each forest/scrub plot. Reducing the cost of soil C monitoring will be an important step to improving integration between soil and vegetation CMPs.

The information system is designed to assemble, analyse, store and integrate the various data bases related to the CMS. The panel was assured that the information system will be able to carry out these functions efficiently and provide the necessary access to the data bases by various people working on the CMS and by clients. However, it is likely that the improvement of integration of the soil and vegetation CMSs will be little affected by the information system.

The development of the LCDB is an important integrating factor. The LCDB should impart an improved consistency to the spatial information used by both the soil and the forest/scrub CMSs. The improved spatial resolution of the LCDB compared to the VCM and the anticipation that the LCDB will, in time, gain improved thematic resolution, will make this data base a powerful integrating tool. **The future development of the LCDB by MfE should be done in close communication with the key researchers driving the CMP so that their needs are taken into consideration by MfE.**

The CMP Steering Committee which oversees the development of the CMS is in a good position to help improve the integration of approaches by providing advice to the soil and vegetation researchers. The possibility of creating a combined soil and vegetation monitoring research team could possibly be one avenue that the Steering Committee could explore. Another possible avenue is the establishment of a network of benchmark sites on which soil and vegetation monitoring would be closely coordinated and integrated. **The CMP Steering Committee should adopt a more active role in improving the integration of approaches within the CMS.**

10 Extent to Which the Needs of Various Stakeholders are Being Met

10.1 Indicators of Biodiversity and Environmental Performance

New Zealand's ratification of the Convention on Biological Diversity in 1993 committed the government to develop a national strategy outlining how New Zealand intends to manage its biodiversity. A draft biodiversity strategy was developed in 1998 which laid out the vision and goals for conserving and sustainably managing New Zealand's biodiversity. Successful management of biodiversity is dependent on reliable and consistent monitoring programmes which can provide an understanding of the extent of and changes in biodiversity. To date, New Zealand's biodiversity monitoring programmes have not been comprehensive. Nor have they been consistent across the agencies responsible for managing indigenous resources.

Monitoring biodiversity and health of ecosystems requires the use of appropriate environmental indicators or environmental performance measures. Under MfE's Environmental Performance Indicator programme a set of proposed indicators for terrestrial and freshwater biodiversity have been developed, primarily for national state of the environment reporting. The proposed indicators are rather broad and many rely on good spatial information. For instance, indicators of biodiversity include:

- change in gross habitat fragmentation of indigenous vegetation cover for each of New Zealand's different environments
- the number of taxa in IUCN and New Zealand threat categories
- change in the distribution of selected invasive weed and pest species.

Other more detailed sets of indicators for reporting on ecosystem biodiversity, weediness, animal browsing impacts and other ecosystem condition and trends are not widely available in New Zealand although some current research aims to accelerate the development of such indicators. DoC is in great need of such indicators and has commissioned a review by Landcare Research of suitable indicators for measuring and reporting on forest condition. DoC now needs to select the indicators which best suit its business requirements and its external reporting requirements. DoC recognises the value to be gained by integration with the CMS. The private owners of production indigenous forests may also be in need of external indicators or measures of sustainable forest management.

National and international reporting concerns, and the CMP have been instrumental in stimulating the development of the LCDB data base. The spatial information provided by the LCDB is crucial for the further development and testing of many of the proposed MfE core environmental indicators. The strengthening and updating of the NVS data base or its replacement of a network of circular nested plots through the implementation of the CMP will help provide improved information about ongoing changes including biodiversity changes within forest and scrub ecosystems. Such information is needed for identifying which species are most useful as indicators of forest and scrub health and which are important for indicating

responses of the ecosystems to animal browsing and other pressures or to changes in pressures. DoC is particularly interested in indicators which are sensitive to changes in animal pressure.

In the absence of a nationwide assessment of biodiversity, the CMS has the potential to provide information on trends in certain indicators of biodiversity and to add significantly to New Zealand's biodiversity monitoring programme. The facts that the CMP is conducted at a national level, involves both vegetation and soil monitoring and utilises some of New Zealand's most qualified vegetation and soil researchers, provide a powerful surveillance system of great potential value to DoC.

Changes in soil characteristics, although they have not been used in New Zealand to any significant extent, offer potential as indicators of ecosystem health. Soil C storage and changes in storage could become an important indicator of ecosystem health as discussed in Sections 10.2 and 10.4.

In summary, the CMS has important implications for the further development of environmental indicators, including indicators of biodiversity. The development of vegetation indicators, soil indicators and spatial indicators are likely to be positively influenced by the implementation of the CMS. **Closer communication and cooperation between the CMP researchers and DoC regarding forest, scrub and soil monitoring could enhance the contribution of the CMP to the development of environmental performance indicators.**

10.2 Forest Condition and Trends

DoC's management of the conservation estate, particularly the indigenous forest and scrub lands which constitute a large part of the estate, depends on careful and regular monitoring. DoC's proposed monitoring programmes are aimed at identifying the condition and trends of indigenous vegetation and habitats. In addition, DoC monitors the performance of the activities and methods the department adopts to protect the estate and maintain environmental values such as biodiversity and health of forest ecosystems. The use of PSPs as proposed in the CMS will be a crucial resource for the monitoring of indigenous vegetation condition and trend.

The CMS will provide a valuable contribution to DoC's monitoring programme. The total vegetation C stock or changes in the C stock have not been used by DoC as indicators of forest and scrub condition. However, the associated measurements made on the vegetation plots provide important information about forest health and changes in composition and structure. The repeated measurement of a national set of indigenous forest and scrub vegetation plots to assess C changes also adds to the indigenous vegetation data base that DoC largely relies on for information about condition and trends. DoC considers that soil C information is, at present, not very useful for monitoring ecosystem condition and trend, mainly because the department has not given much consideration to soil aspects. However, judging by overseas developments, soil C could become an important indicator of soil and ecosystem health on the conservation estate

Close communication between the CMP researchers and DoC about the needs of the department regarding monitoring condition and trends could raise the carbon monitoring project's ability to assist DoC in its monitoring role. DoC should advise MfE of a set of forest condition and biodiversity indicators which best suit its needs with a view to integrating these with the CMS.

10.3 Sustainable Land Management: Forests

Approximately 0.8 million ha of indigenous forest is suitable for production of timber under sustainable forest management systems. With the exception of West Coast forests managed by Timberlands West Coast Limited and forests in Southland which fall under the South Island Landless Native Act (1906) known as the “SILNA forests”, the sustainable management of indigenous production forests is controlled by the 1993 Amendment to the Forests Act (1949) administered by MAF. Private forest owners who wish to manage their forests for timber production have to obtain approval from MAF through a sustainable management plan submission and approval system. Sustainable forest management plans need to contain considerable amounts of information about the nature and condition of the forest and the likely impacts of any future management activity on the composition, health and structure of the forest, forest animals, and soil and water resources within the forest. At present about 50,000 ha of indigenous forests are under sustainable management. Total annual production of wood from indigenous forests amounts to approximately 115,000 m³. This level of wood removal is not likely to impact significantly on the estimate of forest C stocks.

Information provided by the CMP could provide a source of forest and soil information for the preparation of sustainable forest management plans and for their assessment by MAF. However, in reality, it is unlikely that the data bases provided by the CMS will be used to any significant extent by forest owners or by MAF as the critical information required for preparing plans and for assessing plans is usually available from other sources such as local forest maps and local forest specific surveys and inspections. On the other hand, forest owners may be able to provide information about forest changes and estimation of tree volumes that could constitute valuable input information for the CMS.

Up to the present time the ability of indigenous forests to sequester C has not been a major consideration in the sustainable management of indigenous forests but may become important in the future. If and when C sequestration is adopted as a factor for consideration in the approval of sustainable forest management plans, then information provided by the CMS may become very important for the indigenous production forest owners. The CMS could also play an important but as yet undefined role in the development of indicators of sustainable forest management.

10.4 Sustainable Land Management: Soil Quality

A Ministry funded sustainable management project on investigating soil health indicators recently identified soil C as the most significant indicator of soil quality likely to be of national relevance (Stuart Calman, pers comm, 1999).

Compared to the forest survey, the soil inventory approach is model-based and soil measurements taken so far have not been geographically distributed throughout the land area of New Zealand. This probably does not matter from the point of view of estimating soil C or of monitoring soil C; however, it may affect the value of soils information for other purposes. MAF and DoC indicated to the panel that extra information coming from the forest/scrub survey had been helpful to them in a way that they had not anticipated when setting up the survey. The forest research team appears to have hung other projects onto its forest-scrub survey multiplying the utility of the work it is doing to other stakeholders and multiplying the return to all concerned on the science investment in the CMP. Neither MAF nor DoC reported a similar synergy from the results of the soil survey. It is not clear to the panel from the reports presented and from the brief time available for discussion whether this is because of the non-geographical

nature of the soil survey or because the soils team has not attempted to combine projects in the same way that the forest and scrub team reported they have done. **It may be worthwhile considering the additional gain to be made through closer contact between all, including soil, survey work carried out within Landcare and the CMS.**

Many of the questions that this project tries to address cannot really be answered without long-term experiments. It is unfortunate that New Zealand does not have such a resource to interrogate. In a sense the proposed forest sampling grid based on 9 km grid squares represents a diffuse example of such a resource. It is clear that establishing long-term experimental sites is beyond the scope of the CMP but the **stakeholders may wish to consider taking whatever action is needed to facilitate setting up long-term sites.**

Current thinking within New Zealand science policy is to investigate a small number of indicators of soil health and quality which can be implemented within a time frame of one to two years and a second series of indicators for which further investigation is needed but that might become useful to investigate in two to five years' time. The initial set of indicators are simple visual indicators such as the extent of soil erosion. Given the possible relevance of erosion to the soil C survey as a disturbance and the undoubted role that soil C plays in stabilising soil against erosion **it may well make sense to explore the correlation between soil erosion and (lack of) soil C in order to check the assumption in the use of the CoC approach that land use change is the only factor that brings about a change in soil C.**

Other disturbances seem to play a significant role in determining the removal of C from the landscape. Browsers at first stimulate the oxidation of vegetation carbon but if the plants respond by producing less palatable leaves, the whole decomposition cycle may become retarded, although it is unclear if the amount of vegetation produced is decreased by the cost of synthesising unpalatable leaf-compounds. Disturbance as a layer in the GIS in general may be of interest to other stakeholders.

Kyoto Protocol issues regarding C trading are not really addressed. If ratified, the Kyoto Protocol provides for trading of C emission reduction units, including sinks in forests as a result of additional activities. Similar arrangements for soil C are under discussion. C sinks must be legally defensible and the sinks must be given with known precision. Traders are prepared to deal in sinks that have less than 100 percent precision but may discount them accordingly. Precision may thus ultimately equate to dollars. **Stakeholders need to consider to what extent they wish to prepare at this stage for the implications of the Kyoto Protocol.**

10.5 Meeting the Information Needs of the Steering Committee

Having considered the draft of the review report, the Steering Committee posed some questions to the review panel. Taking the time limitations of the review into account, the review team provided the following answers.

- Q1 The monitoring systems for both soils and forests had to be operational by the end of the third year. Has this aim has been achieved, and if not, what is required to achieve this?
- A1 The following fundamental issues raised in the report make the review panel question if the system was operational by the end of the third year: the use of a 9 km grid (the researchers have assured the panel that this is not fixed, but yet alternatives have not been offered); how this will be sampled; lack of explicit consideration of the use of circular nested PSPs, which have been shown to be optimal and more cost efficient for

C monitoring (the panel senses a strong insistence on maintaining the NVS system); how to sample CWD more precisely and cost efficiently; the poor integration between the vegetation and soil efforts; and the lack of real cost estimates to implement. Other more detailed improvements such as allometric relations, improvements in the soil pedon data base and CoC, and updating the LC/LU map are not perceived as barriers to implementation as these could be dealt with while the CMS is ongoing.

For soils, the aim has been only partially achieved. A national base line stock estimate has been achieved. However, estimates of soil *C change* will require a) estimates of land use change over time and b) a full complement of CoCs which have been adequately tested and verified. The later two components of the system are not operational.

If operational is defined as “in operation”, i.e. delivering estimates each year of the C stock changes in New Zealand forest and soils, then we have to answer no for both projects. However, the projects are in the implementation phase; progress has moved beyond the design phase.

Q2 Does the panel wish to recommend a mechanism for improvement of the management of the programme, to avoid the current stop-start situation?

A2 Some ideas from the panel: fund multi-year if this can be done, or at least not to have the researchers prepare extensive annual reports. The availability of multi-year funding or the ability to “roll over” funding from one year to the next would help provide added certainty to the continuity of the programme and enable improved forward planning. Funding for the entire five-year project period would have been the preferred model. Another suggestion: set a timetable and set priorities; agree interim funding (if tick-over funding is needed); present interim results and agree forward funding. For longer time-scale work agree funding for more than one 12-month period.

Q3 What is the rationale behind using the time range 1996-98 for the base map? Why are we attempting to develop data for this time frame? The international agreement requires us to have a base line for 1990 and in the first commitment period to be able to measure the change between 2008 and 2012. At what point in time should we cement our 1990 base line and accept its shortcomings? Or should we continue to update it as improved data on, for example, biomass relationships become available?

A3 The time frame of 1996-98 was suggested based on discussions with Steve Thompson who seemed to indicate that this is where the effort is being focused right now based on recent acquisition of satellite data – a base map for 1990 would be more desirable though it is not clear to the panel that this is the focus of ongoing work. The panel feels that every effort should be made to produce a base map for as close to 1990 as possible. The panel also believes that attempts should be made to improve the base line for C stocks in indigenous forests and scrubs as new data become available.

Q4 Are the NVS plots better suited for purposes other than the CMP? Are they sufficient or inadequate, do they meet other needs (and would the nested radii meet other needs as well as NVS?

A4 The panel believes that circular nested PSPs are a more cost efficient and optimal design for C monitoring – experience by one panel member in sampling a complex tropical forest (with six strata) has shown that 625 such plots (all located with a differential GPS) measuring all trees to a minimum diameter of 5 cm, understorey, litter, and soil to 30 cm depth took less than six months to accomplish. Three teams were employed at an average cost of US \$250/plot including all field support. Teams were led by a crew leader with a BSc degree and used semi-skilled local people. During this six-month period data for

developing local allometric regression equations for some specific species groups were also collected. CWD was not measured at that time but has been added since for about 100 plots which took two weeks to measure using the line intersect method, including collection of wood samples for density determination. The panel also believes that nested circular plots will also meet the needs of other stakeholders just as well as the NVS plots. The panel is not advocating immediate conversion to nested PSPs, but to do replacement over time.

The NVS plots were developed for ecological purposes other than C monitoring. Nevertheless, they do provide adequate sampling for monitoring C. However, there is no doubt that the improvements recommended by the review panel to the design of the plots for future monitoring could result in cost and time efficiency gains.

Q5 Do we need to determine disturbance overlays if, as in forests, we sample what ever we encounter at the sample point, which is in effect sampling representative populations of occurrences in the field. Will the disturbance be not reflected in the average figure for biomass over time changing?

A5 Disturbance effects will be reflected in average values of carbon stock change over time, but attribution to cause may not be discernible. One view is that, in the case of forests and scrub, the remeasurement of the same plots at different points in time will build in the impacts of disturbance thus negating the need for disturbance overlays.

Q6 Why does the base line need improvement? If we have determined reliable areas of land use, we can move on from this point towards determining the changes in the first commitment period. For FCCC we could probably report an average annual change over the period circa 1990 to 2001/02, with annual reports from then on (assuming it is implemented by then) For Kyoto and policy purposes we probably need more focus on having good quality data to be able to determine a 2008 figure and a 2012 figure.

A6 Under the Kyoto Protocol, Article 3.3 states that ARD activities since 1990 shall be used to meet commitments for Annex 1 countries. Article 3.4 states that Annex 1 countries “will provide data to establish its levels of C stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years.” Further, Annex 1 countries may chose to apply a decision by COP regarding additional human-induced activities (including emissions or removals in agricultural soil and land use change and forestry) for its first commitment period, provided that these activities have taken place since 1990. Within the Kyoto Protocol it is clear that 1990 is an important base line, both with respect to land use and C stocks therein.

The soils base line will improve as more data are collected for the unsampled cells. The priority for soil is not yet clear as soils (Article 3.4) do not have the same status as af/re/de/forestation (Article 3.3) under Kyoto.

Q7 Can the review team provide a ranking of the improvements required in the forest monitoring system before the system can operate?

A7 This is taken up in Section 12, where the priorities for improvement are ranked.

Q8 The Steering Committee directed the soils group to explore the use of the LCDB at the end of the 1998/99 financial year. Is there any evidence of this occurring? Should there be a stronger emphasis on its use? Is a hybrid layer feasible?

A8 The review panel strongly endorses the adoption of the LCDB for the CMS, which seems to be universally agreed upon by both projects. It is the only viable option since periodic updates (five-year intervals) are needed and VCM was a one-time effort. For the soil

base line, however, VCM was the only option having the required land-cover types. The critical issue is that a single LC/LU data base, with sufficient thematic resolution for both forest and soils components of the CMS, needs to be developed and carried through in the future. There seems to be progress on that front.

Another view: the soils group has studied the use of the LCDB but not yet implemented a system using it (the LCDB is not yet finished and that factor alone has made reviewing its use difficult). Details are given in Reports 31 (p 18), 38 (p 10), 39 (p 11). There is thus clear evidence of the exploration of the use of the LCDB. The VCM and the LCDB are not compatible, however, neither in scale nor in land use class; hybridisation has been proposed as a solution. On its own, hybridisation may not work but aerial photography or other additional sensing have been proposed where there are conflicts. The soils group acknowledged that changing from VCM to LCDB is not a trivial problem.

- Q9 Is a difference of 0.4 Mt C acceptable between the measured amount of carbon and the modelled amount (in the Benmore study, Section 8.2.2)? It appears to be an over-estimation of 33 percent. Is this acceptable?
- A9 Landcare concluded from the 33 percent error that more data need to be collected for climate classes. This may be true for the Benmore Range. Data collection, while important for all New Zealand and all cells, needs to be concentrated on cells where land use is changing or expected to change. A 33 percent error is not in general acceptable but we do not know how representative Benmore is nor why it was chosen. The system is by admission not yet finished. It is, however, operable. The question cannot be answered without knowledge of the uncertainty of the measured estimates.
- Q10 How can a CoC approach be implemented in the short term when it is clearly identified that we do not have temporal data required to construct the very basis of a CoC?
- A10 The question is incorrectly stated. The CoC approach is based on estimating a “step change” in C levels as land changes from one class to another. In other words, the CoC values are the differences (tonnes/ha) in C between two land use types – they are not a temporal rate coefficient, per se.
- If accurate year-to-year C changes were necessary, the step change could be a major problem. For average changes over a several year period (this will be the only option anyway, since data on land use change will be generated only every five years or so), it is less of a problem.
- Q11 Does the identified bias in the identification of CoC due to land selection offer a problem that should be rectified in some manner?
- A11 As described in Section 8.3.3, there are recommendations to use additional sources of data to double-check the values derived for CoCs to insure they are not biased.
- Q12 The lack of fine litter and soil measurements violates the principle of full C accounting and introduces potential bias in estimating changes in C stocks. Is this a significant problem in the current sampling design?
- A12 It could be for certain land use changes, e.g. pasture to scrub reversion. It could be a significant problem if soil and litter C are changing in forest and scrub plots due to land use change or other factors. The present forest/scrub plot methods do not address this. At present, only coarse litter (>10 cm) is being measured on the plots, while the soil C is being assessed independently (CoC approach). Soil and litter measurements on the forest plots would assure full C accounting and provide a valuable source of validation data for the CoC based soil estimates.

Q13 Are the mapping scales of the soil an issue? And the fact that 1:250,000 scale maps are in use compared with the accuracy required in the vegetation cover maps? What happens with regard to the fact that at some points the soils mapped did not occur on the ground and they had to go looking for soil types?

A13 Since the soils are grouped at a fairly coarse level (three classes comprise over 90 percent of the land area), use of small-scale maps such as 1:250,000 is not necessarily a big problem for national estimates. It all depends on how the soils are distributed. If there are soil types that occur as many small “inclusions” then it could be a problem. Example, small inclusions of organic soils (within a larger surrounding area of mineral soils) is a concern in parts of the midwest of the USA. It was indicated during the review that there is very little area of organic soils converted to crops, pastures or plantation forests. We would recommend that additional testing be done to confirm that the soil map accuracy is not an issue – reports from the soils group suggested that this had been done to some degree, but better documentation of the results is needed. The main issue is whether the area of each soil class, at the national level, is accurate.

This issue should be dealt with under quality control. The procedure for selecting sampling sites should be fully described there.

Q14 Will the CoC approach be acceptable for reporting under Kyoto? What about step-change estimates without a temporal dimension?

A14 The CoC approach as presently implemented (i.e. step change) is functionally equivalent to the IPCC inventory guidelines and is thus designed to meet national reporting needs (under FCCC). In the panel’s view, the step change approach (current CoC approach) will not be appropriate to estimate C sinks/emissions for Kyoto reporting. Estimating soil C changes specifically for the Kyoto commitment period (i.e. changes from 1 January 2008 to 1 January 2012) will require time series of land use distributions, i.e. land use at several times post-1990. This will need to be incorporated in a more dynamic estimation of soil C change.

Q15 CMP Steering Committee should adopt a more active role in improving the integration of approaches within the CMS. How so in practice given that the committee are not scientists in these areas? Should the Steering Committee incorporate more independent scientific advice/peer review into its processes? None of the Committee are truly science experts in the areas under development. Is this a potential research/process management issue that should be addressed?

A15 This is a management issue for the Steering Committee to resolve. As the members of the Committee have a very good overview of the CMP and are probably more knowledgeable than they indicate in their questions about much of the detail of the research, the Committee is in a good position to determine at least broad options to improve integration of approaches. Another suggestion: an external advisory committee of three to five experts, charged with periodic reviews (e.g. once per year) and tasked with facilitating integration between the various researchers, could be of considerable benefit. Such committees are frequently used to help manage large, integrated projects (e.g. US LTER projects).

Some members of the Steering Committee have clear (but admirably held in check during the review) views about what should come out of the process and how it should be achieved. What is required is a vision of what the whole system must do, look like and be capable of; this vision is the responsibility of the client. The current difference in philosophies of the forest and soil surveys is a symptom of the need for such a clearly expressed vision. The way forward is to define this endpoint or else the flexibility that

needs to be built into the CMS for it to be capable of reaching a variety of possible (policy-shaped) endpoints.

Q16 Do we have a problem separating the research aspirations of the groups from the process of developing an operational system? If so, what are the suggestions for moving forward?

A16 There does appear to be resistance from the researchers towards adopting some of the review panel's recommendations. For instance, the vegetation researchers are strongly wedded to the NVS plots and it is likely that they will not easily accept that there would be advantages in adopting other plot designs to improve the efficiency of the monitoring system.

It may not be so much an issue of separating research aspirations from the task of implementing a practical system, but rather a lack of integration due to the managing the CMS R&D as (in effect) two separate projects. An integrated project management team and an external advisory committee could facilitate focusing on the overall needs for the CMS.

Both groups appear to have worked very hard to achieve the aims of the project as they perceive it. The problem is more one of integrating other research aspirations of each group into the programme and ensuring that there is a clear vision of what the system should be capable of, including in its integrated form

Q17 Can this system be utilised for a full C inventory system over the entire country?

A17 For national reporting purposes, a qualified "yes"; however, some modifications may be necessary, depending on the definition of "full C inventory". Information for plantation forests needs to be integrated. The integration of the two surveys may be a problem; the key seems to be the use of the same land cover information. Additional stocks such as buildings and landfills may need to be included.

Both the soil and vegetation monitoring systems have been developed for national-level monitoring. The SI transect study indicated that the systems do work and could be extended to the whole country although the effort required will be considerable if a direct extrapolation of cost and time involved in the transect study is expanded to national coverage.

Q18 What is the quality of samples collected through an e-mail process, and does this lead to a probable bias in the sampling?

A18 The review panel can not speak to the quality of the additional information sent in following the e-mail "appeal"; we did not have it to review. It is a valid point, however, that can be raised. Quality per se may not be the problem, but rather consistency, as well as bias. Samples were taken for other purposes, using different methods, possibly different depths, etc. Thus careful screening is required – much like when one does an analysis using data obtained from a literature search.

Q19 What is the future soil sampling/monitoring process being recommended and to what depth? Do we have any greater clarity on the way forward? How does this reflect the potential integrated sampling approach of sampling forests and soils?

A19 A proposal for sampling soil and litter at all forest/scrub plots is outlined in Section 8.3.4. It would entail sampling all litter and soils to a depth of 30 cm, with soils taken with cores to estimate bulk density on the same material that is analysed for C and other properties. The location of the samples should be precisely georeferenced to avoid sampling those

disturbed areas on subsequent re-sampling occasions. It is not necessary to have a trained pedologist sample the soil – inventory field crews could be adequately trained. These samples should be viewed as part of the forest and scrub inventory procedures, but will provide an independent check of the estimates for soil C generated with the CoC approach.

Q20 What can/should be done in the remainder of this year and next year (i.e. extent of initial development funding)?

A20 Take steps to better integrate the two projects and solidify the design and the implementation of the system for acquiring land use change data (“LCDB II”, mining of land use statistics). Pursue other short-term priorities (12.3.1).

11 Meeting New Zealand's Obligations under International Environmental Agreements

11.1 Reporting Requirements under UNFCCC and Kyoto Protocol

Under the FCCC, the reporting requirements are annual rates of change in C stocks for land use change and for the forestry sector. Specifically, the important changes that result in emissions or removals of C (as carbon dioxide) are:

- changes in forest and other woody biomass C stocks as a result of direct human activity (e.g. forest management for timber and other wood products)
- conversion of forests and grasslands to managed uses
- abandonment of managed lands that will regrow into to their prior natural state
- changes in soil C stocks.

This discussion will focus only on the indigenous forests and scrub lands. Based on the IPCC guidelines for national GHG inventories, there are no reporting requirements for changes in C stocks of indigenous woody vegetation that are not under direct human management or have not been cleared in the past. There is, however, ongoing debate on the definition of managed and unmanaged lands and ongoing discussions for the need for a full terrestrial C accounting system. Because of the uncertainty of the outcomes of these ongoing discussions, New Zealand needs to position itself to be able to respond to any possible outcome of these policy debates. For example, policy makers may have to consider if “managing forests” include actions taken to reduce pest outbreaks, e.g. possums in New Zealand. The changes in C stocks from the relatively small area of indigenous forest presently undergoing harvesting could be estimated from data collected for the C work and from data provided to MAF. As these forests are managed sustainably, one assumes that overall there would be no net change in C stocks.

Reporting changes in biomass C stocks of lands reverting from pasture and agriculture are required under the FCCC, and the panel believes that, with the present state of understanding, this *cannot* be accomplished to acceptable levels of accuracy and precision for the early 1990s without significant revisions to the present programme. However, based on the implementation of many of the suggestions given under Section 7, estimates of future changes in C stocks will be possible. Further, the proposed C monitoring plan for all indigenous lands fulfils the New Zealand need to be able to respond to future reporting requirements that may result from decisions about how to report on all terrestrial C stocks.

In the Kyoto Protocol, Article 3.3 states that ARD activities since 1990 shall be used to meet commitments for Annex 1 countries. Article 3.4 states that Annex 1 countries will provide data to establish its levels of C stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years. Further, Annex 1 countries may chose to apply a decision by COP regarding additional human-induced activities (including emissions or removals in agricultural soil and land use change and forestry) for its first commitment period, provided that these activities have taken place since 1990. Within the Kyoto Protocol it is clear that 1990 is

an important base line, both with respect to land use and C stocks therein. Based on the comments above under Sections 7 and 8, the panel feels that the present status of work on base lines will not enable New Zealand to make this commitment. However, incorporation of the improvements outlined in Sections 7 and 8 will enable New Zealand to meet this commitment.

The proposed plan for monitoring changes in C stocks for soil potentially **can** provide the required reporting needs assuming the technical and scientific issues raised in Section 8.2 are suitably addressed. The system as it stands is adequate for reporting under UNFCCC and current IPCC. The non-temporal CoC system cannot be described as good, Temporal CoCs would be a great improvement. Only temporal CoCs are likely to be adequate for reporting under the Kyoto Protocol.

11.2 Other Reporting Requirements

There are several other reporting requirements under international agreements, including, for example, the Convention of Biodiversity, Ramsar, Montreal Process, and UN/FAO/TBFRA-2000. Here we briefly discuss how the CMP could fill the needs for the TBFRA-2000 and contribute to the needs of the Montreal Process.

The TBFRA-2000 requires information on:

- area, volume of growing stock, net annual increment (m^3/yr), and above and below ground biomass of indigenous forest and scrubland (other wooded lands)
- average annual change in forest and scrubland area and in growing stock.

For forests, further subdivision into broad forest types is required, for New Zealand, at least into broadleaf, coniferous, and mixed forests.

Results from the CMP will be able to fulfil the needs of the TBFRA-2000. Data on area and area change, and above and below ground biomass, by the three broad forest types will be the most reliable. Volume, annual increment, and annual change in growing stock for forests could be produced to different degrees of accuracy and precision depending upon which approach the monitoring plan will use to estimate biomass (either directly to biomass or a series of steps starting with volume from diameter). For the indigenous forests that are commercially harvested, state and change of area and growing stock volume are likely to be provided by the commercial enterprise, particularly data on the volume, growth, and removals of timber. Estimates of volume and change of growing stock for the scrublands will be produced when a significant component of the ecosystem is comprised of trees; otherwise these parameters are somewhat irrelevant descriptors for scrublands.

The Montreal Process requires information on numerous indicators related to the conservation and sustainable management of New Zealand's forests, many of which are included under the reporting requirements for the FCCC and TBFRA-2000. As indicated above, the C monitoring work will fill in many data gaps and thus enable New Zealand to report on more indicators under the Montreal Process.

12 Looking Forward: Suggested Improvements and Approaches; Research Priorities

12.1 Some Soil C Issues for Consideration by the Researchers

In various aspects of the CMP, the issue is often not in the detail but in the accuracy and precision of the results required. During the review team's questioning of the scientists, it became apparent that one of the most important but undetermined factors influencing the amount of C in the soil was depth of soil. The comments made in this section are meant to be illustrate this problem with a view to initiating discussions between stakeholders and scientists.

1. Investigating C at depth and variation with depth in sites with unchanging land use (including disturbance) is probably only worthwhile doing in order to increase the accuracy of the base line.
2. It is probably of little value to include long-term monitoring of deep soil unless some change is expected.
3. Compaction and uplift are important factors. To what extent do they occur?
4. Full-grid monitoring of soils comes up in almost every section. It is clearly an area where the soil scientists could make more effort to explain their ideas. Full-grid monitoring is a far more appropriate system than the ANOVA approach (which can be confusing). Full-grid sampling has been rejected as inefficient. It will probably miss disturbances other than land use change. Even Kyoto, where the reporting requirements appear likely to be more stringent, concerns itself with human-induced changes. As such most disturbances other than land use change would appear to be unimportant but they may be of great interest to other stakeholders. The soil scientists have done what was asked of them but a priority would appear to be the adoption of temporal CoCs. Some wider spread of sampling would appear to have value from the point of view of extending the soil survey and making it relevant to a wider range of domestic issues, not just C reporting to the international community.

Many of the above issues are not relevant to the current reporting requirements or are not important yet. They may become so and, although the soils survey is adequate for the current purposes, it may not be sufficiently future-proofed. This section addresses some of these perceived shortcomings. It is difficult to make concrete recommendations without knowing what the future reporting requirements are likely to be.

12.2 Approaches Not Considered in the Proposed Carbon Monitoring Plan

12.2.1 Forest and scrub

Another approach for the CMS that could be used is a non-systematic grid approach, where the land is stratified into relatively homogeneous vegetation classes and PSPs randomly, or systematically with a random start, established. The number of PSPs in each stratum would be based on the variance in the main C pool in that stratum. This approach would allow for strata expected to be disturbed little to be less intensively monitored and strata undergoing great change to be monitored more intensively.

Another approach not considered is the development of aerial tools for monitoring C, such as a combination of pulse laser profilers, dual camera videography GPS and the like on single engine planes. The only remote sensing means proposed is satellite imagery for LC/LU change but there is a potential for other types of remote sensing using other technologies as mentioned to the scientists – this could be a research development activity related to developing a more cost efficient means for monitoring using remote means.⁴

12.2.2 Soil

Landcare has a current research project investigating the mechanisms by which C is sequestered in soil. Clearly understanding the mechanisms by which C resists decomposition has two main advantages:

- a) it identifies to be made more efficient or precise
- b) it may suggest the likely circumstances under which sequestration is already taking place, in turn allowing monitoring means by which C sequestration can be enhanced or stimulated.

Aspect and slope have not yet been considered to any great extent in the soil survey. A proposal has been made as to how radiation input might correlate with soil C, slope and aspect, however it is important to be sure how the soil is thought of and sampled. Although soil is probably sampled normally to the surface, the influence of radiation (primary production) is at an angle to the soil surface and soil temperature (decomposition, phenology of the vegetation) will depend on aspect. Consideration might also need to be given to the difference between “projected” surface area (as on a map) and actual surface area, which is a function of slope. Given that soil C storage potential is probably proportional to the amount of soil mineral matter (e.g. mass of clay minerals) which can bind with and stabilise organic materials, the *actual* surface area and depth of soil are determining factors. Thus, on a “projected area” (mapped) basis, it may be that sloping land has a higher sink capacity than level land and slope may need to be considered in calculating base lines and C changes.

⁴ Sandra Brown and Dana Slaymaker of the University of Massachusetts have tested such a system in a complex tropical forest in Bolivia and are presently completing the analysis. The system is capable of providing crown area and tree height for all trees in a given area (1 ha or more). This is correlated against estimates of C in forest vegetation from a plot encompassed by the 1 ha.

Soil depth is an important determinant of how much C soil contains. This is clearly a difficult parameter to measure. Trends in known soil depth, slope, site and aspect may help and there are presumably techniques to determine depth to bedrock. However, additional information on rooting depth and organic matter distributions by depth for different vegetation communities would be needed to evaluate the importance of considering soil C to greater depth. Also, soil C stored at depths below 1 m is probably not subject to major changes over decadal time frames, under most kinds of disturbance or land use change.

The panel has discussed at length the need to implement a full or fuller grid-based sampling scheme over the whole of New Zealand. The soil monitoring system specifically rejected this idea as inefficient. It does, however, seem worthwhile raising the suggestion of including extra grid nodes where land use is expected to change in the near future. This might be particularly appropriate in the marginal pasture lands that are expected to be abandoned in the near future.

12.3 Research Priorities for Improvements in the CMS

12.3.1 Short-term priorities

For the indigenous woody vegetation, the review panel has identified many scientific and technical issues that, if implemented, would improve the CMS. Not all of these issues need to be addressed immediately – here we identify those issues that are needed in the short term.

- a) Produce a reliable base line LC/LU map that meets all stakeholders' needs.
- b) Test the feasibility of using a nested grid design with the selection of PSPs made randomly.
- c) Estimate the changes in C stocks for various levels of precision in different LC/LU classes using a nested grid approach and the cost to implement.
- d) Improve the biomass allometric equations based on harvested trees and on possible analogues.
- e) Identify the approach and methodology for measuring change in C stocks directly and the implications for cost of monitoring.

Many priorities for the soil survey have already been identified in Section 8. The following priorities should be addressed as soon as possible:

- f) Sample unrepresented soil/climate/land use cells.
- g) Evaluate the feasibility of integrated sampling of soil and litter components in conjunction with forest and scrub biomass plots; look carefully at the needs of other stakeholders and try to make the survey fulfil their needs too, for example, by integrating work on environmental indicators.
- h) Develop a general linear model to refine estimates of CoCs and verify values with other data sources (e.g. long-term experiments, paired plots).
- i) Scrutinise all CoCs to ensure that their value is in agreement with common sense.
- j) Formally describe and implement quality control measures.

12.3.2 Long-term priorities

Research priorities for long term implementation for indigenous woody vegetation and soil carbon monitoring are given below.

- a) Investigate the utility of coarse resolution imagery such as AVHRR for monitoring areas undergoing change.
- b) Identify the forms of disturbance (including natural and animal and pest induced events) which have a significant impact on C stocks and develop relationships between the disturbance agent and changes in C pools.
- c) Sample dead wood from a variety of plots to develop relationships between field observed decomposition classes and density classes, and test the utility of the line intersect method for accuracy and precision, and for cost and time efficiency for sampling.
- d) Sample the geographical area of New Zealand more fully to augment the pedon data base for climate/soil/land use cell.
- e) Use computer simulation models and appropriate field data to interpolate changes in soil carbon with time and to suggest what measures may be most effective in sequestering C.

13 Main Conclusions and Recommendations for Further Development of the Framework and National Monitoring System

13.1 Main Conclusions

The main conclusions of the review panel were:

1. Good progress has been made towards the development of a working CMS, but a lack of integration between the forest and soils programmes has created potential problems.
2. The conceptual approach for monitoring soil C is a significant improvement on the IPCC methodology, but much work remains to be done to estimate and validate appropriate CoCs for calculating changes in soil carbon stocks.
3. The conceptual approach for monitoring C stocks in vegetation is heading in the right direction. The use of a fixed grid and PSPs to estimate the C in the identified major C pools is sound and according to international practice, but the development of temporal CoCs should be a priority.
4. For forests, the use of limited data for developing allometric relationships, in live and dead vegetation, remains a major problem.
5. The monitoring system needs a good, well-documented QA/QC system to lend it international credibility.
6. Accurate estimates of land use change over time are fundamental to the CMS for both forests and soils. The linkages between future land use change and new sampling and data collection need to be further developed and integrated between the two programmes.
7. The approach in the forests programme appears to be more focused on changes within the existing extent of forests and scrublands, and insufficient attention has been paid to the impact of future changes in land use and cover on the data collection strategy. The conceptual approach for the soils programme focuses more on the effects of changes in land use and insufficient attention has been paid to potential carbon stock changes in existing “stable” soil/climate/land use classes.
8. The overall programme has done a credible job of integrating existing data to arrive at an acceptable circa 1990 estimate of carbon stocks in indigenous vegetation and soils.
9. For a long-term monitoring programme, the retention and maintenance of research capacity is of concern. The programme is currently vulnerable to the loss of individual scientists.
10. The international credibility of the research underpinning the development of the monitoring system would be enhanced by further publication in peer reviewed literature, for both forests and soils.

11. Ongoing and assured funding for the CMP, and especially funding to enhance the programme in the ways recommended by the review panel, are of concern. More coordination among research providers and stakeholders will help to ensure optimum application of scarce resources
12. The national CMS has the potential to provide a foundation for supporting other monitoring and research programmes, from local through to national level.

13.2 List of Recommendations

The review panel's recommendations, taken from earlier chapters of this report, are repeated below. The recommendations have been grouped and prioritised.

Recommendations of highest importance and highest priority for implementation	
Financial aspects	<ol style="list-style-type: none"> 1 The management and funding of the CMP should be adjusted to enable continuity of research effort, and earlier assurance of funding for each financial year. 2 An accurate estimate of all costs (fixed and variable) of the monitoring system options should be made as soon as possible.
Spatial aspects (LCDB etc.)	<ol style="list-style-type: none"> 3 It is critical that the classification developed for the next iteration of LCDB meets the needs of both the soils and the forest and scrub inventories, as well as other stakeholders where possible. Acquisition of a ground receiving facility – which has apparently been discussed repeatedly in the past – should be seriously (re)considered to insure the maximum data availability and timeliness.
Field sampling/monitoring	<ol style="list-style-type: none"> 4 A method for estimating C stocks and their changes at varying levels of desired precision in different LC/LU classes, and the implications for cost, need to be addressed. 5 Explicit evidence should be provided that the researchers have given consideration to monitoring disturbance effects, how important these are to C stocks, how their plan addresses this or what additional data need to be collected to incorporate this into the plan. 6 Researchers should identify areas where active tree harvesting in indigenous forests is taking place and spend time there destructively harvesting and measuring, using standard techniques, a selection of trees to obtain the necessary biomass data for the development of allometric equations. 7 The ongoing monitoring system should address which LU/LC classes and C pools need to be monitored and over what time frames and at what scales.

Recommendations of highest importance and highest priority for implementation	
Field sampling/ monitoring (continued)	<p>8 Opportunities to leverage the additional costs of more widespread soil sampling through collaboration with other programmes such as soil quality investigations, should be pursued. After a full remeasurement period, the data would be invaluable as a validation of the soil C change estimates based on CoC.</p> <p>9 Provisions need to be made, with explicit plans, to account for the recruitment of new forest and scrub areas (e.g. via pasture abandonment) as part of the grid-based forest and scrub monitoring procedures.</p>
Quality assurance aspects	<p>10 A QA/QC plan should be developed for future implementation, and all field, laboratory, and analytical techniques should be coordinated among the various research teams, to add credibility to the CMS.</p> <p>11 QA/QC procedures should be defined and implemented, including field sampling, sample preparation (sub-sampling, grinding), and C analysis (analytical standards, blind checks).</p>
Land use changes	<p>12 Existing land use statistics should be explored as an auxiliary source of information on historical land use change (i.e. land use history) in relation to the soil C monitoring programme.</p> <p>13 Efforts should be made to establish benchmark sites, particularly for land use types which are expected to undergo significant changes, e.g. abandonment of pastures. One option which may be explored is to locate very recently abandoned lands as potential benchmark sites.</p>
Meeting the needs of stakeholders	<p>14 The future monitoring programme needs to find a balance between the needs for C and the needs for other environmental variables – all stakeholders should develop a minimum list of needs.</p> <p>15 Closer communication and cooperation between the CMP researchers and DoC regarding forest, scrub and soil monitoring could enhance the contribution of the CMP to the development of environmental performance indicators.</p>

Important recommendations with a high priority for implementation	
Financial aspects	16 Accurate costing should be made of the additional costs to sample soil as part of the forest/scrub survey including the costs of simply sampling to 10 cm or to 30 cm.
Spatial aspects (LCDB etc.)	<p>17 All the various users and stakeholders of the LCDB must come to an agreement as to the minimum number of LC/LU classes they can live with for the foreseeable future, with some agreement as to how greater resolution may be attained in the future with the launching of new satellite sensors or aerial remote sensing technology.</p> <p>18 The use of coarser satellite products, such as the 1 km² AVHRR data base on a regular basis to screen for relatively large areas potentially undergoing LC/LU changes, should be investigated.</p> <p>19 Effort must be taken to use all available existing data bases, both spatial (LCDB, VCM, digitised products of forest inventory data, DEM, soil, etc.) and point field data, to produce a reliable base line map for a relatively narrow point in time. The present focus seems to be 1996 to 1998, but every attempt should be made to produce a reliable base line map for close to 1990.</p> <p>20 The future development of the LCDB by MAF should be done in close communication with the key researchers driving the CMP so that their needs are taken into consideration by MAF.</p> <p>21 The procedure for relating the current strata to those which will be derived in the future from the LCDB should be made explicit.</p>
Field sampling/ monitoring	<p>22 Tests should be made of how the grid could be resolved into smaller or larger grid sizes, including the application of nested grids, to address the sampling of changes in area and C stocks of the scrub lands and of large areas of forest.</p> <p>23 The pros and cons of selecting plots within a grid cell in a randomised manner should be investigated.</p> <p>24 Circular nested plots of varying radii should be used, and the use of this sampling scheme should be introduced through time by partial replacement in future sampling.</p> <p>25 The line intersect method should be used as this could be a more time and cost efficient method for measuring CWD.</p> <p>26 It is preferable, if possible, to measure the change in C pools directly from the permanent plots, but to apply this method, the processes causing change must be conceptualised correctly.</p>

Important recommendations with a high priority for implementation	
Field sampling/ monitoring (continued)	<p>27 To maintain a high level of precision in the monitoring of change in C pools, the monitoring system should attempt to measure the change directly in aggrading systems in particular.</p> <p>28 Litter samples and underlying soil samples should be taken (using cores to ensure that bulk density can be determined) at all biomass survey plots. Explicit inclusion of a soils component in the forest/scrub surveys will also help to integrate the two parts of the CMS.</p> <p>29 The procedure to select sites for sampling of soil should be described in full and be subject to quality control and quality assurance measures.</p> <p>30 Great care must be taken to ensure that paired sites and chronosequences are representative of the changes they are meant to express. Once calibrated, any model used should be validated against independent data and used without alteration to derive unbiased estimates of the rate of change of C in soil.</p>
Land use changes	<p>31 The interaction between land use change and soil-climate class needs to be investigated for all relevant land use changes.</p>
Meeting the needs of stakeholders	<p>32 Researchers should discuss with the stakeholders what level of precision they require, giving consideration to cost and international reporting needs.</p>
Integration of approaches	<p>33 The CMP Steering Group should adopt a more active role in promoting the integration of approaches with the CMS.</p>
Coefficient of change aspects	<p>34 Alternative approaches to estimating CoC, i.e. long-term experiments, carefully selected paired plots or chronosequences, are strongly encouraged as a check of CoCs derived from the broad-based (e.g. ANOVA, GLM) statistical procedures.</p> <p>35 It is essential that all CoCs are subject to commonsense scrutiny by a scientist to ensure that (a) sufficient data have been used to derive them and (b) the coefficients are sensible in sign and magnitude.</p> <p>36 For the purposes of addressing the issues in Articles 3.3 and 3.4 of the Kyoto Protocol that deal with terrestrial C sinks, the CMS for soils requires much additional testing and validation, particularly independent checks on the CoC values using information from paired plot studies, long term experiments, etc.</p> <p>37 It may make sense to explore the correlation between soil erosion and (lack of) soil C in order to check the assumption in the use of the CoC approach that land use change is the only factor that brings about a change in soil C.</p>

Other recommendations with lower or longer term priority for implementation		
Field sampling/ monitoring	38	All plots should be spatially located using a differentially corrected GPS.
	39	Researchers should seek out data for analogous forests in other parts of the world – e.g. relevant data do exist for <i>Nothofagus</i> forests of southern Chile.
	40	The present approach of estimating the C pool in roots from the literature should be continued.
	41	In future work, sampling various density classes of dead wood should be encouraged.
	42	It might be worthwhile to use uncertainty analysis to quantify error magnitude in a selection of soil classes to check if this error is the same everywhere and to ensure that sampling intensity on the ground reflects the imprecision, i.e. sample more closely where the uncertainty in soil (or other class) is greatest.
Meeting the needs of stakeholders	43	Stakeholders may wish to consider taking whatever action is needed to facilitate setting up long-term sites.
	44	Stakeholders need to consider to what extent they wish to prepare at this stage for the implications of the Kyoto Protocol.
Integration of approaches	45	It may be worthwhile considering the additional gain to be made through closer contact between all survey work carried out within Landcare and the CMS.

Appendix A: New Zealand's CMP: Timetable for the Review Panel's Meeting in Wellington

12 October 1999

Revised 20 October 1999

Review team

Dr Margriet Theron (Chair), Dr Sandra Brown, Dr Colin O'Loughlin, Dr Keith Paustian, Dr Andy Whitmore. Stuart Calman of MfE will be attending all the meetings of the Review Team as an observer, facilitator, and review coordinator. Mr Andrew Wilson, MAF, will attend the presentations on the Monday, Tuesday and Thursday as an observer and as a member of the Steering Group.

Format and ground rules for the presentations

1. The presentations will not run late.
2. Presenters will assume that the review team have read the reports.
3. Forty minutes have been allowed for most sessions. Presentations on aspects of the research programme will take five to ten minutes, and cover key points only. Twenty to 30 minutes will then be available for discussion and questions from the review team. Overview presentations may take up to 20 minutes.
4. Overheads or PowerPoint presentations may be used.
5. The review team would appreciate a one-page, bullet-point summary of each presentation. Include the name of the topic, the name of the presenter(s), and a list of reports (with page references, if necessary) where further information can be found.
6. There will not be an audience during the presentations. The presenters are listed in the timetable. In addition to those listed, there may be one member of the Steering Group at some of the presentations. Having no audience will encourage free and frank discussion, in an informal environment.
7. The members of the review team will feel free to indicate to a presenter that a question has been answered adequately, or the information given, and that we can move on to the next topic. This will ensure optimum use of very valuable time.
8. If the review team would like to add more ground rules, this will be done at the start of each presentation.

Sunday 17 October 1999

When?	Where?	What?
5.00 to 6.30 pm	Meet in lobby of the West Plaza.	Panel introductions; review of terms of reference; ground rules for presentation sessions; framework for the final report; initial allocation of writers to topics; programme for the week; housekeeping. Review team and Stuart.
6.45 pm	Quayside Restaurant, Oriental Parade.	Dinner; further informal discussions on the review. Review team, Stuart, Margaret Lawton, Paul McFarlane.

Monday 18 October 1999

Where? Ernst and Young, Level 24, Majestic Centre, 100 Willis Street

When?	What?	Who?
8.30 am	1 Overview presentation. View from the perspective of potential users of the research on progress to date.	Steering Committee.
9.10 am	2 Identification of main issues in the various projects.	Steering Committee, Margaret Lawton, Paul McFarlane.
9.50 am	Morning tea.	Review team and presenters.
10.10 am	3 International environmental agreements; New Zealand's reporting obligations.	Andrew Dunningham and Paul McFarlane, Forest Research; Stuart Calman, MfE; Andrew Wilson and James Barton, MAF; Rob McColl, DoC.
10.50 am	4 Overview of forest and scrub projects.	Justin Ford-Robertson, Forest Research; Rob Allen, Landcare Research.
11.30 am	5 Inventory methods.	Chris Goulding, Forest Research; Rob Allen, Landcare Research.
12.10 am	Lunch.	Review team and presenters.
1.00 pm	6 Biomass equations, allometric models and tree physiology.	Peter Beets, Forest Research; Rob Allen, Landcare Research.
1.40 pm	7 Plot methodology, carbon and non-carbon.	Rob Allen and David Coomes, Landcare Research; Peter Beets, Forest Research.
2.20 pm	8 Forest extent, remote sensing, LCDB, data models, information system.	Andrew Dunningham, Forest Research; Neal Scott, Landcare Research. Kevin Tate.
3.00 pm	Afternoon tea.	Review team and presenters.

When?	What?	Who?
3.20 pm	9 Base line calculation for 1990, transect, future monitoring.	Rob Allen and David Coomes, Landcare Research; Justin Ford-Robertson, Forest Research.
4.00 pm	10 Review team's questions for clarification and topics from the issues papers. Approach to future carbon monitoring in forests and scrub.	Review team and all of Monday's presenters.
4.45 pm	11 Wrap-up discussion; overview of the day. Comment on the review process.	Review team.
5.00 pm	Informal reception	Review team and presenters..
6.00 pm	End of the working day	
7.00 pm	Dinner; venue to be decided	Review team.

Tuesday 19 October 1999

Where? Ernst & Young, Level 24, Majestic Centre, 100 Willis Street

When?	What?	Who?
8.30 am	12 Overview of soils projects, data layers, framework.	Kevin Tate and Neal Scott, Landcare Research; Murray Davis, Forest Research.
9.10 am	13 Vegetation cover map and land use layer.	Peter Newsome, Landcare Research.
9.50 am	Morning tea.	Review team and presenters.
10.10 am	14 Climate layers and data.	David Giltrap, Small Office Systems.
10.50 am	15 Soil layer and soil C data bases.	Murray Davis, Forest Research; Hugh Wilde, Landcare Research.
11.30 am	16 Defining cells, statistical analysis, soil data models.	David Giltrap, Small Office Systems; Hugh Wilde, Landcare Research.
12.10 pm	Lunch.	Review team and presenters.
1.00 pm	17 Soil sampling, design, site selection, analyses and protocols.	Hugh Wilde, Landcare Research; Murray Davis, Forest Research.
1.40 pm	18 Estimating land use effects on soil C (coefficients of change).	Neal Scott and Kevin Tate, Landcare Research; Justin Ford-Robertson, Forest Research.

When?	What?	Who?
2.20 pm	19 Paired sites for soil C, Long term ecological research sites (benchmarks).	Neal Scott and Kevin Tate, Landcare Research; Peter Beets, Forest Research.
3.00 pm	Afternoon tea.	
3.20 pm	20 Review panel's questions for clarification and topics from the issues papers. Approach to future C monitoring in soil. Integration of the data into an overall system. CoC approach.	Margaret Lawton, Paul McFarlane, all Tuesday's presenters.
4.20 pm	21 Wrap-up discussion; overview of the day; main issues to be addressed in the report; structure of the report. Are there gaps in the information? Other people the review team must see?	Review team. Stuart to follow up on further appointments to be made for Thursday.
5.00 pm	End of the working day.	
7.00 pm	Dinner; venue to be decided.	Review team.

Wednesday 19 October 1999

Where? Cornish Suite, West Plaza Hotel

Who? Review team

When?	What?
8.30 am	Meeting of the review team to get ready for writing the draft report. Housekeeping; facilities.
9.00 am	Report writing.
10.00 am	Morning tea.
10.20 am	Feedback on progress, if required. Report writing.
12.20 pm	Lunch at a nearby café.
1.00 pm	Feedback on progress, if required. Report writing.
3.00 pm	Afternoon tea.
3.20 pm	Feedback on progress. Identify the presenters to whom the review team would like to talk at 1 pm on Thursday. Report writing. Stuart to make arrangements for Thursday's meeting.
5.30 pm	End of the working day. Draft chapters of the report to Margriet and Stuart, to be collated, copied and distributed to members of the review team.
7.00 pm	Dinner; venue to be decided.

Thursday, 20 October 1999

Where? Glenbervie and Cornish Suites, West Plaza Hotel, and Ministry for the Environment

When?	What?
8.30 am	Meeting of the review team to review the draft report (Glenbervie Suite).
10.00 am	Morning tea.
10.20 am	Report writing by review team (Cornish Suite).
12.10 pm	Lunch at a nearby café.
1.00 pm	Meeting at MfE (Room C&D, Level 5) with Margaret Lawton, Paul McFarlane, Rob Allen, Justin Ford-Robertson, Neal Scott, Kevin Tate, members of the Steering Group and other presenters as requested by the review team. Topic and key issue for the review: integration of approaches into a national framework for monitoring carbon, arriving at spatially consistent estimates.
3.00 pm	Afternoon tea.
3.30 pm	Report writing by review team at the West Plaza (Cornish Suite).
4.30 pm	Review of progress. Planning for Friday. Draft chapters of the report to Margriet and Stuart, to be collated, copied and distributed to the review team.
5.30 pm	End of the working day.
7.00 pm	Dinner at a venue to be decided.

Friday 21 October 1999

Where? Cornish Suite, West Plaza Hotel

Who? Review team

When?	What?
8.30 am	Meeting of the review team to review progress with the draft report.
10.00 am	Morning tea.
10.20 am	Completing the first full draft of the review report.
12.10 pm	Lunch in a nearby café.
1.00 pm	Final review team discussion. Who will be doing what by when to produce the final report? Feedback on review process.
3.00 pm	Afternoon tea. Some members of the review team depart.
3.20 pm	Remaining members of the review team continue discussions and working on the draft report.
5.00 pm	End of the working day.

Facilities

1. As the Review Panel will be drafting the report from the Wednesday, laptop computers and a printer will be available in the Cornish Suite, West Plaza Hotel. Photocopying and fax facilities are available on request from Hotel Reception.
2. Review Panel members are requested to bring their own laptop computers to Wellington, if possible.

Appendix B: List of Participants in Review Panel Meetings at Ernst & Young, Majestic Centre, Wellington, on 18 and 19 October 1999, and/or at the Ministry for the Environment on 21 October 1999

Members of the Review Panel	
Dr Margriet Theron (Chair)	Waiariki Institute of Technology, Rotorua
Dr Sandra Brown	Winrock International, Oregon, USA
Dr Keith Paustian	Colorado State University, Colorado, USA
Dr Andy Whitmore	Silsoe Research Institute, UK
Dr Colin O'Loughlin	Forest Consultant, Christchurch
Members of the Steering Committee and Stakeholders	
Stuart Calman, Chair	Ministry for the Environment, Wellington
Andrew Wilson	Ministry of Agriculture and Forestry, Rotorua
Steve Thompson	Ministry of Agriculture and Forestry, Christchurch
Paul Lane	Ministry of Agriculture and Forestry, Wellington
Dr Rob McColl	Department of Conservation, Wellington
James Barton	Ministry of Agriculture and Forestry, Wellington
Dr John Lancashire	Ministry of Research, Science and Technology, Wellington
Project personnel from Forest Research	
Dr Paul McFarlane	Manager, Rotorua
Justin Ford-Robertson	Project Leader, Rotorua
Dr Peter Beets	Rotorua
Dr Murray Davis	Christchurch
Andrew Dunningham	Rotorua
Dr Chris Goulding	Rotorua
Project personnel from Landcare Research	
Dr Maggie Lawton	Manager, Hamilton
Dr Kevin Tate	Project Leader, Palmerston North
Dr Hugh Wilde	Palmerston North
Dr Neal Scott	Palmerston North
Dr Rob Allen	Christchurch
David Coomes	Christchurch
Dr Peter Newsome	Christchurch
Small Office Systems	
Dr David Giltrap	Small Office Systems, Lower Hutt

Appendix C: List of Abbreviations Related to New Zealand's CMP

Abbreviations related to New Zealand's CMP	
3P sampling	Sampling with probability proportional to prediction
ALP	Alpine
ANOVA	Analysis of variance
ANZLIC	Australia and New Zealand Land Information Council
APEC	Asia Pacific Economic Cooperation
ARC	Arable crops
ATO	African Timber Organisation
AVHRR	Advanced very high frequency resolution radiometer
AWC	Available water soil capacity
BGR	Bare ground
C	Carbon
CAPL	Central American Process of Lepaterique
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
cm	Centimetre
CMP	Carbon Monitoring Programme
CMS	Carbon Monitoring System
CNIDR	Clearinghouse for Networked Information Discovery and Retrieval
CO ₂	Carbon dioxide
CoC	Coefficients of change
COP	Conference of Parties (of CBD)
CRI	Crown Research Institute
CSD	United Nations Commission on Sustainable Development
CTE	Committee on Trade and Environment (of the WTO)
CWD	Coarse wood debris
dbh	Diameter at breast height
DCDB	Digital Cadastral Data base
DEM	Digitised Elevation Models
DoC	Department of Conservation
ECWG	Earth Cover Working Group
EPI	Environmental Performance Indicators
EU	European Union
EXF	Exotic forest

Abbreviations related to New Zealand's CMP	
FAO	Food and Agriculture Organisation (of the UN)
FCCC	Framework Convention on Climate Change
FGDC	US Federal Geographic Data Committee
FRA	Forest Resource Assessment
FRI	Forest Research Institute (now Forest Research)
FSC	Forest Stewardship Council
FSMS	Forest Service Mapping Series
FSTM	Forest Service Type Map Series
GATT	General Agreement on Trade and Tariffs
GEP	Group on Environmental Performance (of the OECD)
GHG	Greenhouse gases
GIS	Geographic Information System
GPS	Global Positioning System
ha	Hectare
HAC	High activity clay
HCA soils	High clay activity soils
HOR	Horticulture
ht	Height
IFF	Intergovernmental Forum on Forests
IFS	Indigenous forest – stable
IFU	Indigenous forest – unstable
IFV	Indigenous forest – very stable
IHD	International Hydrological Decade
IPAR	Intercepted Photosynthetically Active Radiation
IPCC	Intergovernmental Panel on Climate Change
IPF	Intergovernmental Panel on Forests
ITE	Institute for Terrestrial Ecology
ITFF	Interagency Task Force on Forests
ITTO	International Tropical Timber Organisation
IUCN	International Union for the Conservation of Nature
JPL	NASA's Jet Propulsion Laboratory
JRC	Joint Research Centre (of the EU)
km	Kilometres
LAC	Low activity clay
LC/LU	Land cover and land use
LCA	Soils with low clay activity
LCDB	Land Cover Data base, based on satellite images
LINZ	Land Information New Zealand

Abbreviations related to New Zealand's CMP

LTER	Long Term Ecological Research
LUCF	pp 3-45, report 26. Land use change and forestry methodology
m	Metre
MAF	Ministry of Agriculture and Forestry
MfE	Ministry for the Environment
Mg	Million grams
MMU	Minimum Mapping Unit
MoRST	Ministry of Research, Science and Technology
Mt	Million tonnes
N	Nitrogen
NDVI	Normalised Difference Vegetation Index
NIVS	National Indigenous Vegetation Survey
NSD	National Soil Data base
NVS	National Vegetation Survey
NZLRI	New Zealand Land Resource Inventory
NZMG	New Zealand Map Grid
NZSC	New Zealand Soil Classification
OECD	Organisation for Economic Cooperation and Development
ORG	Organic soils
PAI	Pasture – improved
PAU	Pasture and tussockland – unimproved
PGSF	Public Good Science Fund
POD	Podzols
PSP	Permanent Sample Plots
PSR	Pressure, State, Response framework
QA/QC	Quality assurance and quality control
RAMSAR	Convention on Wetlands of International Importance as Waterfowl Habitat (signed in Ramsar, Iran)
SAN	Sandy soils
SAR	Synthetic aperture radar
SBI	Subsidiary Body for Implementation
SBSTTA	Subsidiary Body on Scientific, Technical and Technological Advice
SCR	Scrub
SFM	Sustainable forest management
SI	South Island
t	Tonne
TBF	Temperate/Boreal
TBFRA	Temperate Boreal Forestry Resource Assessment

Abbreviations related to New Zealand's CMP	
TF	Tropical zone
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
URB	Urban
USDA	United States Department of Agriculture
VCM	Vegetative Cover Map
VOL	Volcanic derived soils
WAT	Water bodies
WCMC	World Conservation Monitoring Centre
WET	Wetlands
WHL	World Heritage List
WTO	World Trade Organisation
yr	Year

Appendix D: Index of Reports Produced under the MfE CMP

The following reports were provided to the review panel for reference during the course of their work and references in the review panel's report relate to the report numbers given below. Note that some interim progress reports, which were subsequently superseded or incorporated into a final year-end report, are not included in the list below.

Number	Title	Reference
1	Reclassification of New Zealand soil series to IPCC categories	9697/096
3	Project status report including provisional 1990 base line soil carbon estimate	9798/009
10	Land Use/Land Cover Information	9697/103
4	Determining an appropriate carbon monitoring system for New Zealand's indigenous forest and scrub	9798/010
7	Progress report to the Steering Committee on Estimating the extent of indigenous forest and scrub	9798/023
8	Catalogue and evaluation of existing data sets for forest classes and scrub in New Zealand	9798/024
5	Information system for carbon monitoring in indigenous forests, scrub and soils	9798/011
11	Revision of data layers and overlays	9798/085
23	Initial estimates of land use effects on soil carbon: Estimating coefficients of change	9798/148
28	Selected methodologies for updating national soil carbon levels	9798/157
13	Measuring forest biomass using multi-polarisation, multi-wavelength radar imagery in New Zealand: A first assessment	9798/088
16	Progress report on the national functions for carbon accounting purposes, forest and scrub in New Zealand	9798/152
19	Estimating the extent of scrub and indigenous forests	9798/140
24	Estimate of the carbon stored in New Zealand's indigenous forest and scrub vegetation for 1990	9798/147
25	A national system for monitoring change in carbon storage in indigenous forests and scrub: testing plot locations on South Island transect	9798/166
27	Simulating broad scale forest biomass in New Zealand: applications to a national monitoring system	9798/155
18	Specification for metadata elements and metadata entry system for MfE carbon program	9798/098

Number	Title	Reference
20	Implementation specifications for carbon monitoring information system for indigenous forests, scrub, and soils. 1997-98 report to MfE	9798/136
29	Metadata standards and implementation for carbon monitoring information system for indigenous forests, scrub and soils. 1997-1998 report to MfE	9798/154
30	Monitoring carbon in soils, indigenous forests and scrublands: 1997/98 summary report	9798/162
S2 97/98	Work schedule for the 1997/98 year	
31	Design and testing of the national soil system	9899/094
32	Updated 1990 soil carbon base line	9899/146
38	Prototype System for Monitoring Soil Carbon in New Zealand	9899/148
33	Remote estimates of vegetation biomass and extent	9899/105
34	A test of methods and logistics along a South Island transect	9899/124
35	Second draft of prototype field procedures manual	9899/100
36	Data model and linkages to software for South Island transect	9899/125
37	Information System Team Report 1998/99	
39	Framework document	9900/012
S2 98/99	Work schedule for the 1998/99 year	