PENDAHULUAN

Pada dasarnya setiap perusahaan yang melakukan kegiatan produksi wajib memperhatikan efek yang dihasilkan dari kegiatan produksinya agar tidak menganggu dan mencemari lingkungan sekitarnya. Hal ini tertuang dalam Undang-Undang No. 4 Tahun 1984 tentang Ketentuan-Ketentuan Pokok Pengelolaan Hidup Pasal 7 yang menjelaskan bahwa setiap orang yang menjalankan suatu bidang usaha wajib memelihara kelestarian lingkungan hidup yang serasi dan seimbang untuk menunjang pembangunan yang berkesinambungan. Namun yang terjadi belakangan ini justru sebaliknya. Setiap perusahaan yang melakukan kegiatan produksi kebanyakan tidak memperhatikan efek yang dihasilkan dari kegiatan produksinya. Pada akhirnya lingkungan dan masyarakat sekitar yang merasakan efek buruk dari kegiatan produksi tersebut. Efek terburuknya adalah pemanasan global. Pemanasan global menjadi perhatian utama bagi seluruh negara di dunia. Bumi makin panas dan perubahan iklim telah dirasakan akhir-akhir ini. Masalah pemanasan global ini mendorong berbagai pihak untuk lebih bertanggungjawab terhadap lingkungan. Penerapan proteksi lingkungan ini menimbulkan biaya yang lebih dikenal dengan biaya lingkungan. Biaya lingkungan ini terdiri dari biaya pencegahan, biaya pendeteksian, biaya kegagalan internal, dan biaya kegagalan eksternal. Pada akhirnya biaya lingkungan ini perlu diungkapkan, sehingga muncul ilmu akuntansi lingkungan yang mengkaji tentang biaya lingkungan yang dikeluarkan perusahaan untuk mengatasi masalah lingkungan di sekitar perusahaan.

Dalam mengatasi masalah lingkungan ini, akuntansi lingkungan mengalami perkembangan ke arah yang lebih baik. Pada awalnya akuntansi lingkungan merupakan suatu proses pertanggungjawaban perusahaan terhadap lingkungan sekitarnya akibat proses bisnis yang dilakukan perusahaan tersebut. Umumnya bentuk pertanggungjawaban ini dituangkan dalam bentuk biaya lingkungan. Namun adanya akuntansi lingkungan saja dirasa belum cukup, karena belum ada suatu sistem penghitungan yang tepat untuk mengukur dampak negatif yang dirasakan lingkungan sekitar akibat proses bisnis yang dilakukan perusahaan. Dampak negatif ini pun sudah dirasakan oleh dunia, salah satunya adalah pemanasan global. Pemanasan global ini muncul akibat banyaknya emisi yang dikeluarkan perusahaan. Berdasarkan latar belakang itulah lahirlah akuntansi karbon. Akuntansi karbon adalah proses akuntansi yang dilakukan untuk mengukur jumlah karbondioksida yang dilepas ke atmosfer sebagai hasil dari proyek-proyek mekanisme fleksibel dibawah Protokol Kyoto. Meningkatnya tingkat emisi karbon di dunia menyebabkan kadar CO2 di atmosfer tidak stabil. Oleh karena itu, negara-negara berkomitmen untuk mengurangi emisi CO2 sehingga tercetuslah Protokol Kyoto pada 12 Desember 1997. Saat ini Indonesia belum berpatisipasi dalam akuntansi karbon, namun Indonesia masih memiliki peluang untuk ikut dalam perdagangan karbon ini, mengingat Indonesia memiliki kekayaan hutan terbesar yang seharusnya dapat dimanfaatkan sebagai pereduksi emisi karbon.

Makalah ini membahas mengenai pengertian, sejarah, manfaat dan implementasi akuntansi karbon di beberapa negara. Dengan adanya makalah ini diharapkan dapat memperkenalkan akuntansi karbon sebagai salah satu ilmu baru dalam akuntansi, khususnya dalam ranah akuntansi lingkungan.

PEMBAHASAN

1. Teori yang mendasari Akuntansi Karbon (*Carbon Accounting*)

Akuntansi Lingkungan (*Environment Accounting*)

Perusahaan adalah bentuk organisasi yang melakukan aktivitas dengan menggunakan sumber daya yang tersedia untuk mencapai tujuan yang telah ditetapkan. (Murni, 2001) Perusahaan didirikan dengan maksud untuk mencapai tujuan-tujuan tertentu. Dalam mencapai tujuan tersebut, perusahaan selalu berinteraksi dengan lingkungannya sebab lingkungan memberikan andil dan kontribusi bagi perusahaan, akibatnya terjadilah pergeseran tujuan perusahaan (Yuniarti, 1998). Pertama, pandangan konvensional, yaitu menggunakan laba sebagai ukuran kinerja perusahaan. Perusahaan dengan kinerja yang baik adalah perusahaan yang mampu memperoleh laba maksimal untuk kesejahteraan *stockholder*. Kedua, pandangan modern, yaitu tujuan perusahaan tidak hanya mencapai laba maksimal tetapi juga kesejahteraan sosial dan lingkungannya.

Setiap perusahaan yang melakukan kegiatan usahanya pasti menimbulkan efek dari kegiatan usahanya tersebut, misalnya limbah produksi, polusi, dan lain sebagainya. Dampak semacam inilah yang dinamakan *eksternality* (Harahap, 1999). Besarnya dampak *eksternality* ini terhadap kehidupan masyrakat menyebabkan timbulnya keinginan untuk melakukan control agar dampak negatif yang ditimbulkan dari *eksternality* ini tidak semakin besar. Dari latar belakang inilah munculah sebuah pemikiran mengenai ilmu akuntansi yang bertujuan untuk mengontrol tanggungjawab perusahaan. Ilmu akuntansi yang mengatur proses pengukuran, penyajian, pengungkapan, dan pelaporan *eksternality* disebut dengan akuntansi lingkungan.

Pada mulanya akuntansi diartikan hanya sebagai prosedur pemrosesan data keuangan. Pengertian ini tertuang dalam *Accounting Terminology Bulletin* yang diterbitkan oleh AICPA (*American Institute of Certified Public Accounting*). Dalam *Accounting Terminology Bulletin* no.1 dinyatakan sebagai berikut : *"Accounting is the art of recording, classifying and summarizing in a significant manner and in the term of money, transaction and event which are and part, at least of finantial character and interpreting the result there of."* Namun dalam perkembangannya, kini akuntansi tidak hanya sebagai suatu proses pertanggungjawaban atas laporan keuangan saja, melainkan merambah sebagai suatu pertanggungjawaban sosial lingkungan sebagai ilmu akuntansi yang relatif baru. Tujuan utamanya adalah dipatuhinya perundangan perlindungan lingkungan untuk menemukan efisiensi yang mengurangi dampak dan biaya lingkungan. Dalam akuntansi lingkungan lebih cenderung menyoroti masalah aspek sosial atau dampak dari kegiatan secara teknis, Bidang ini amat penting sebab saat ini terlalu banyak perusahaan yang dalam melaksanakan operasi usahanya menimbulkan dampak negatif terhadap lingkungannya.

Akuntansi lingkungan pun mengalami perkembangan seiring dengan meningkatnya tingkat emisi di udara yang merupakan faktor utama penyebab pemanasan global. Untuk mengatasi emisi ini dibutuhkan suatu alat yang dapat mengukur tingkat emisi karbon gas rumah kaca yang dihasilkan di tiap negara. Sedangkan akuntansi lingkungan sendiri belum mampu mengukur tingkat emisi tersebut. Atas dasar itulah akuntansi lingkungan mengembangkan suatu ilmu baru yang disebut dengan akuntansi karbon. Akuntansi karbon ini pada akhirnya dapat membentuk suatu referensi tentang tingkat emisi gas rumah kaca di setiap negara.

2. Sejarah Akuntansi Karbon (*Carbon Accounting*)

Sejarah akuntansi karbon dimulai dengan dibentuknya Protokol Kyoto. Menurut pengertiannya secara umum (http://untreaty.un.org/), protokol adalah seperangkat aturan yang mengatur peserta protokol untuk mencapai tujuan tertentu yang telah disepakati. Dalam sebuah protokol, para anggota jelas terikat secara normatif untuk mengikuti aturan-aturan di dalamnya dan biasanya dibentuk untuk mempertegas sebuah peraturan sebelumnya (misalnya konvensi) menjadi lebih detil dan spesifik. Pada saat pertemuan otoritas tertinggi tahunan dalam *United Nations Framework Convention on Climate Change* (UNFCCC) ke-3 diadakan di Kyoto, Jepang, sebuah perangkat peraturan yang bernama Protokol Kyoto diadopsi sebagai pendekatan untuk mengurangi emisi gas rumah kaca. Kepentingan protokol tersebut adalah mengatur pengurangan emisi gas rumah kaca dari semua negara-negara yang meratifikasi. Protokol Kyoto ditetapkan tanggal 12 Desember 1997, kurang lebih 3 tahun setelah Konvensi Perubahan Iklim mulai menegosiasikan bagaimana negara-negara peratifikasi konvensi harus mulai menurunkan emisi gas rumah kaca mereka. Untuk mengakomodasikan kepentingan antara kedua pihak tersebut, Protokol Kyoto adalah satu-satunya kesepakatan internasional untuk berkomitmen dalam mengurangi emisi gas rumah kaca yang mengatur soal pengurangan emisi tersebut dengan lebih tegas dan terikat secara hukum (*legally binding*).

Dalam Protokol Kyoto disepakati bahwa seluruh negara *Annex I* wajib menurunkan emisi gas rumah kaca mereka rata-rata sebesar 5.2% dari tingkat emisi tersebut di tahun 1990. Tahun 1990 ditetapkan dalam Protokol Kyoto sebagai acuan dasar (*baseline*) untuk menghitung tingkat emisi gas rumah kaca. Bagi negara *Non-Annex I* Protokol Kyoto tidak mewajibkan penurunan emisi gas rumah kaca, tetapi mekanisme partisipasi untuk penurunan emisi tersebut terdapat di dalamnya, prinsip tersebut dikenal dengan istilah "tanggung jawab bersama dengan porsi yang berbeda" (*common but differentiated responsbility*). Protokol Kyoto mengatur semua ketentuan tersebut selama periode komitmen pertama yaitu dari tahun 2008 sampai dengan 2012. Ada dua syarat utama agar Protokol Kyoto berkekuatan hukum, yang pertama adalah sekurang-kurangnya protokol harus diratifikasi oleh 55 negara peratifikasi Konvensi Perubahan Iklim, dan yang kedua adalah jumlah emisi total dari negara-negara *Annex I* peratifikasi protokol minimal 55% dari total emisi mereka di tahun 1990. Pada tanggal 23 Mei 2002, Islandia menandatangani protokol tersebut yang berarti syarat pertama telah dipenuhi. Kemudian pada tanggal 18 November 2004 Rusia akhirnya meratifikasi Protokol Kyoto dan menandai jumlah emisi total dari negara *Annex I* sebesar 61.79%, ini berarti semua syarat telah dipenuhi dan Protokol Kyoto akhirnya berkekuatan hukum 90 hari setelah ratifikasi Rusia, yaitu pada tanggal 16 Februari 2005. Beberapa mekanisme dalam Protokol Kyoto yang mengatur masalah pengurangan emisi gas rumah kaca adalah sebagai berikut:

1. *Joint Implementation* (JI), mekanisme yang memungkinkan negara-negara maju untuk membangun proyek bersama yang dapat menghasilkan kredit penurunan atau penyerapan emisi gas rumah kaca.
2. *Emission Trading (*ET), mekanisme yang memungkinkan sebuah negara maju untuk menjual kredit penurunan emisi gas rumah kaca kepada negara maju lainnya. *Emission trading* (ET) dapat

dimungkinkan ketika negara maju yang menjual kredit penurunan emisi gas rumah kaca memiliki kredit penurunan emisi gas rmah kaca melebihi target negaranya.

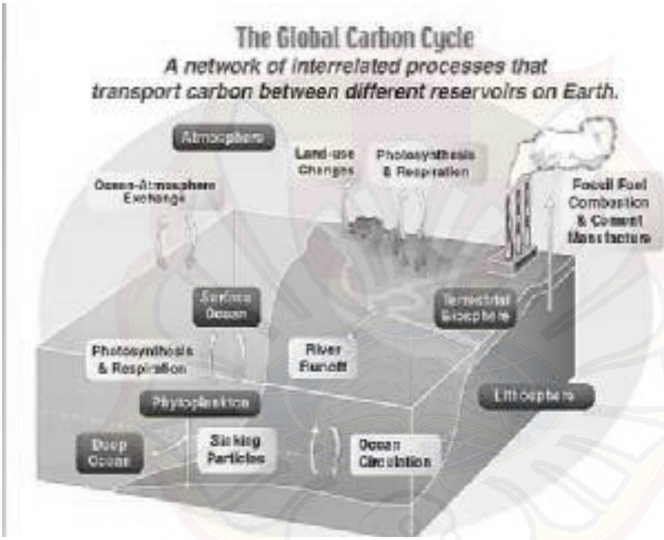
3. *Clean Development Mechanism* (CDM), mekanisme yang memungkinkan negara *Non-Annex I* (negara-negara berkembang) untuk berperan aktif membantu penurunan emisi gas rumah kaca melalui proyek yang diimplementasikan oleh sebuah negara maju. Nantinya kredit penurunan emisi gas rumah kaca yang dihasilkan dari proyek tersebut dapat dimiliki oleh negara maju tersebut. *Clean Development Mechanism* (CDM) juga bertujuan agar negara berkembang dapat mendukung pembangunan berkelanjutan, selain itu *Clean Development Mechanism* (CDM) adalah satu-satunya mekanisme di mana negara berkembang dapat berpartisipasi dalam Protokol Kyoto.

Dari ketiga mekanisme tersebut, hanya *Clean Development Mechanism* (CDM) yang merupakan satu-satunya mekanisme dibawah Protokol Kyoto yang menawarkan *win-win solution* antara negara maju dengan negara berkembang dalam rangka pengurangan emisi gas rumah kaca, dimana negara maju menanamkan modalnya di negara berkembang dalam proyek-proyek yang dapat menghasilkan pengurangan emisi gas rumah kaca, dengan imbalan CER (*Certified Emission Reductions*).

Pada akhirnya Protokol Kyoto menghasilkan suatu kesepakatan yaitu dengan dijalankannya perdagangan karbon bagi setiap negara yang telah meratifikasi Protokol Kyoto. Pengertian perdagangan karbon adalah mekanisme pendanaan yang di berikan oleh negara-negara maju kepada negara yang melestarikan hutannya atau negara yang memberikan jasa lingkungan dengan menjaga hutannya melalui sebuah mekanisme yang telah di atur dalam kesepakatan Protokol Kyoto. (Dewa Gumay, Perdagangan Karbon di Hutan Aceh 2008). Munculnya isu perdagangan karbon dilatarbelakangi adanya pemanasan global sebagai efek gas rumah kaca. Radiasi matahari yang masuk ke bumi, sebagian dipantulkan kembali oleh permukaan bumi, menembus atmosfer ke angkasa. Sebagian radiasi yang dipantulkan tersebut akan diserap oleh gas-gas pemanas yang berada di lapisan atmosfer atau biasa disebut gas rumah kaca, sehingga radiasi tersebut terperangkap di permukaan bumi. Inilah yang disebut efek rumah kaca. Antara tahun 1990 sampai dengan tahun 2004 emisi global gas CO2 meningkat 28 persen. Terjadinya pemanasan global saat ini juga dibenarkan oleh fakta-fakta ilmiah. Badan Meteorologi Dunia (WMO) melaporkan bahwa suhu bumi pada 2006 meningkat 0,420C di atas rata-rata 1961-1990. Suhu di tahun itu merupakan suhu terpanas ke-6 dalam sejarah kehidupan di bumi. Sumber-sumber emisi karbondioksida secara global dihasilkan dari pembakaran bahan bakar fosil (minyak bumi dan batu bara): 36% dari industri energi (pembangkit listrik/kilang minyak, dll), 27% dari sektor transportasi, 21% dari sektor industri, 15% dari sektor rumah tangga & jasa, 1% dari sektor lain -lain. Gas rumah kaca yang berpengaruh langsung adalah CO2 (Karbondioksida), CH4 (Metana), N2O (Nitro Oksida), PFCs (Perfluorocarbons) dan HFCs

(Hydrofluorocarbons). Sedangkan gas rumah kaca yang berpengaruh secara tidak langsung adalah SO2, NOx, CO, dan NMVOC.

ILUSTRASI EFEK RUMAH KACA



(Sumber: *Workshop On Carbon Dioxide Capture & Storage, Proceedings Published By EC Intergovernmental Panel On Climate Change, Nov.2002*.)

Inti dari perdagangan karbon adalah bagaimana semua pihak (negara industri maju) berpartisipasi dalam upaya mengurangi emisi gas rumah kaca (GRK) secara global, dan usaha mereduksi kandungan karbon di atmosfer, sambil mendapatkan manfaat dari penjualan jasa lingkungan penyerapan karbon oleh negara-negara berkembang sebagai sebuah kegiatan tambahan dari kegiatan awal yang sudah berjalan baik. (Upik Rosalina Wasrin, 2005). Perdagangan karbon ini dikelompokkan kedalam dua jenis, yaitu perdagangan emisi (*emission trading*), dan perdagangan kredit berbasis proyek (www.carbontradewatch.org). Namun keduanya disebut sebagai perdagangan karbon. Perdagangan emisi berarti negara penghasil emisi membeli stok karbon dari negara penyerap emisi sesuai dengan jumlah karbon yang disumbangkannya ke udara. Sementara kredit berbasis proyek, bermakna negara penghasil emisi mendanai proyek-proyek ramah lingkungan di negara lain untuk dikreditkan dengan jumlah karbon yang dilepaskannya ke udara. Dalam Protokol Kyoto, pelaku perdagangan karbon adalah pembeli dan penjual karbon. Yang dimaksud dengan pembeli karbon adalah negara-negara yang tergabung dalam *Annex 1* atau negara maju yang mempunyai industry besar dan menghasilkan emisi dalam jumlah besar, namun hutannya telah habis. Sedangkan penjual karbon adalah negara-negara yang masih mempunyai tutupan hutan atau negara ketiga yang berkomitmen untuk mempertahankan tutupan hutannya dari ancaman konversi. (Perdagangan Karbon di Hutan Aceh, 2008). Perdagangan karbon menjadi perbincangan hangat ketika terdapat pihak yang pro dan kontra. Kelompok pendukung ini sebagian besar terdiri dari kelompok organisasi international. Kelompok pendukung ini menyatakan bahwa perdagangan karbon merupakan instrumen untuk mengurangi emisi karbon dioksida (CO2) melalui mekanisme pasar. Contohnya, negara atau daerah yang mempunyai hak untuk konversi hutan, tapi bila tidak melakukan konversi hutan maka negara industri siap untuk mengganti rugi nilai emisi karbon yang dihindari tersebut. Jadi hutan tetap terlindungi dan nilai karbon yang ada di situ bisa dijual di pasar karbon internasional dengan harga cukup bernilai.

Menurut *Carbon Trade Watch* (CTW), yang merupakan bagian dari *Amsterdam Based Transnational Institute* menyatakan bahwa, perdagangan karbon tidak lebih dari mekanisme penebus dosa negara-negara barat yang sudah mengotori udara dunia dengan CO2 (WRM, *issues* 117 April 2007). Maka, ketika mekanisme perdagangan karbon dikenalkan, perdagangan karbon tidak lebih dari sebuah mekanisme imprealis atau penjajahan yang memaksa negara-negara berkembang untuk menjaga hutannya. Mekanisme perdagangan karbon dinilai hanya melancarkan jalan bagi kecurangan negara-negara industri maju. Ada yang menuduh bahwa negara-negara industri maju rela mengeluarkan uangnya untuk mekanisme penyerapan karbon ini di negara berkembang dengan imbalan mereka akan mendapatkan semacam surat ijin untuk tetap mencemari udara tanpa harus menurunkan emisi karbonnya. Timbul rasa ketidakpuasan dan ketidakadilan oleh negara-negara yang masih memiliki hutan namun umumnya miskin dan berkembang yang merasa ditekan untuk tetap menjaga hutannya demi kepentingan internasional tanpa memperoleh kompensasi apapun.. Padahal sekitar 85% emisi karbon yang berada di atmosfir berasal dari negara-negara industry maju. Sebenarnya mereka inilah pihak penyumbang terbesar pemanasan global. Agar negara berkembang tidak hanya bertugas menjaga hutan saja maka disusunlah mekanisme perdagangan karbon yang dimaksudkan sebagai kompensasi atas tugas menjaga hutan tersebut.

3. Implementasi Akuntansi Karbon *(Carbon Accounting)*

Definisi akuntansi karbon menurut keputusan PBB dalam Protokol Kyoto adalah suatu proses akuntansi yang bertujuan untuk mengukur jumlah karbondioksida setara yang akan dilepas ke atmosfer sebagai hasil dari proyek-proyek mekanisme fleksibel dibawah Protokol Kyoto. Akuntansi karbon ini bertujuan untuk mengukur emisi karbon gas rumah kaca, untuk membentuk suatu referensi tentang tingkat emisi gas rumah kaca di setiap negara, dan juga memenuhi persyaratan pelaporan internasional dan kebutuhan pasar. Dikembangkan di Australia, NCAS (*National Carbon Accounting System*) dirancang untuk menyediakan neraca yang dapat menunjukkan tingkat pencemaran atmosfer yang disebabkan oleh kegiatan pengelolaan lahan. Sistem ini dapat menghitung berapa jumlah karbon yang dilepaskan ke atmosfer dengan jumlah karbon yang dapat ditangkap oleh pepohonan misalnya.

Akuntansi karbon telah diterapkan di berbagai negara di dunia dan setiap negara mempunyai pendapat masing-masing atas diterapkannya akuntansi karbon di negaranya. Tentunya tiap negara ini mempunyai tingkat penghasil emisi yang berbeda-beda pula. Duan Maosheng dari China mengatakan bahwa *Clean Development Mechanism* (CDM) merupakan salah satu cara pengurangan emisi, dan tantangan yang dihadapi seperti efisiensi yang rendah, registrasi yang meningkat, permintaan prosedur yang dipersulit, ketidakpastian harga dan kebutuhan pasar. Sementara, kontribusi penyediaan transfer teknologi sangat terbatas. Maka yang lebih diperlukan adalah efisiensi, kelayakan, transparansi dan mekanisme sederhana, seperti halnya transfer teknologi yang lebih besar. Komitmen mitigasi yang lebih besar dari negara maju dapat lebih menciptakan permintaan pasar karbon.

Selandia Baru mengatakan bahwa dengan menggunakan *Clean Development Mechanism* (CDM) tidak mampu merencanakan apapun. *Clean Development Mechanism* (CDM) merupakan pilihan dari sektor swasta, yang tidak mudah diketahui, dan pemerintah pun tidak memiliki kendali. Rusia setuju dengan Selandia Baru dan mengatakan bahwa ekonomi global sedang mengalami krisis, dan baru mulai pulih dari krisis. Hal ini sangat sulit untuk membuat asumsi dan membangun sebuah lintasan pengurangan emisi pada sekarang ini.

Sebaliknya, menurut Uni Eropa, justru dengan adanya *Clean Development Mechanism* (CDM) dapat melengkapi upaya-upaya domestik. Uni Eropa mengatakan bahwa betapa pentingnya untuk mengetahui aturan-aturan sebelum memutuskan pada angka pengurangan emisi. Menurut Uni Eropa jika kita hanya berbicara tentang menutup kesenjangan (antara tingkat ambisi saat ini dan apa yang dibutuhkan oleh ilmu pengetahuan), tanpa menentukan aturan tidak akan membawa kita ke hasil yang akan menyelamatkan bumi ini. Bagaimanapun, investasi pasar karbon belum efektif bagi beberapa sektor, dan perlu dilengkapi dengan instrumen lain. Uni Eropa yakin bahwa mekanisme proyek *Joint Implementation* (JI) dan *Clean Development Mechanism* (CDM) akan berlanjut setelah tahun 2012. Keduanya penting bagi negara *Annex 1* yang berperan dalam pembangunan berkelanjutan dan transfer teknologi ketika menciptakan fleksibilitas berkaitan dengan keberhasilan pengurangan emisi. Bolivia, menanggapi Uni Eropa, mengatakan bahwa jika negara-negara berkembang melakukan peraturan apa pun yang memungkinkan mereka untuk melakukannya, kita akan berada dalam situasi yang sangat buruk, tetapi kita bertanggung jawab dan melakukan yang terbaik. Dikatakan bahwa kita harus mengubah pemikiran kita, demi kemanusiaan dan alam, karena tidak sedikit mereka yang menderita sekarang, sebagai hasil dari emisi sejarah dan tanggung jawab negara-negara maju. Bolivia mengatakan bahwa yang dibutuhkan adalah pengurangan emisi domestik *Annex 1* secara transparan. Janji telah dibuat, tetapi begitu banyak aturan tidak jelas dan kita tidak tahu apa yang kita bicarakan. Bolivia mengatakan acuan bagi pengurangan emisi bersama dari negara-negara maju harus adil sesuai alokasi ruang udara dengan mempertimbangkan anggaran. Berdasarkan berbagai skenario kenaikan suhu (1, 1,5 dan 2 derajat Celsius), kita dapat menghitung anggaran total gas rumah kaca yang dapat dikirim ke atmosfer. Ini akan memungkinkan untuk melihat apa target agregat seharusnya dan yang dipancarkan, dan melihat betapa tidak adil pembagian ruang atmosfer, dengan mempertimbangkan tanggung jawab historis. Dari ini kita dapat sampai pada sasaran yang adil. Bolivia menyimpulkan bahwa yang sebenarnya diperlukan adalah informasi dan analisis mengenai (i) upaya pengurangan emisi domestik yang akan dilakukan oleh para pihak *Annex I*, dan (ii) sejarah emisi dan distribusi ruang atmosfer dengan cara yang adil.

Ethiopia mengingatkan bahwa tujuan *Clean Development Mechanism* (CDM) untuk membantu Negara *Non-Annex 1* (negara berkembang) dalam pembangunan berkelanjutan. Oleh karena itu, perlu mengenal secara komparatif keuntungan negara-negara yang melakukan penghutanan dan reboisasi. Selandia Baru menjawab bahwa *Clean Development Mechanism* (CDM) ditujukan untuk menciptakan efisiensi biaya bagi negara maju, bukan untuk mencapai distribusi regional.

Afrika Selatan menyatakan bahwa ketika mereka setuju dengan pentingnya meningkatkan *Clean Development Mechanism* (CDM) dan proyek distribusi regional yang setara, ini merupakan diskusi tentang mekanisme untuk mencapai pengurangan emisi. Ketika *Clean Development Mechanism* (CDM) harus ditingkatkan, seharusnya ada pembahasan lebih mendalam. (Negara Berkembang Desak Negara Maju Berkomitmen Kurangi Emisi, Ani Purwati, 10 Juni 2010).

NEGARA-NEGARA PENGHASIL EMISI CO2 TERBESAR DUNIA

Emission sources	USA	China	Indonesia	Brazil	Russia	India
Energy	5,752	3,720	275	303	1,527	1,031
Agriculture	442	1,171	141	598	118	442
Forestry	(403)	(47)	2,563	1,372	54	(40)
Waste	213	174	35	43	46	124
Total	6,005	5,017	3,014	2,316	1,745	1,577

(Sumber: *Executive Summary: Indonesia and Climate Change, Working Paper On Current Status and Policies,2007)*

Maraknya isu pemanasan global membuat Pemerintah Indonesia mengambil langkah untuk turut berperan aktif dalam menjaga kelestarian lingkungan hidup dunia dengan meratifikasi Protokol Kyoto. Indonesia menjadi Negara ke 124 yang meratifikasi Protokol Kyoto melalui pengesahan Undang-Undang Nomor 17 Tahun 2004, tanggal 24 Juli 2004 tentang ratifikasi Protokol Kyoto. Proses ratifikasi Protokol Kyoto oleh Pemerintah Indonesia dijalankan oleh Kementrian Lingkungan Hidup (KLH) sebagai national focal point untuk isu perubahan iklim sudah membuat draft undang-undang untuk ratifikasi, dan sudah disampaikan ke DPR dan Presiden.

Beberapa perkembangan yang sudah dilalui Indonesia terkait dengan ratifikasi antara lain :

1. Naskah akademis untuk Ratifikasi Protokol Kyoto sudah dihasilkan. Naskah akademis ini yang memberikan penjelasan mengenai argumentasi bagi Indonesia untuk meratifikasi.
2. Komite Nasional Perubahan Iklim dan tim teknisnya sedang direaktivasi lagi oleh Kementrian Lingkungan Hidup (KLH).
3. Penyusunan rancangan Kepmen untuk pengesahan Komite Nasional Perubahan Iklim yang baru.
4. Proses administratif untuk mendapatkan Persetujuan Presiden untuk Inisiatif (masih diproses di Sekretariat Negara, per 4 Maret 2003).
5. Meningkatkan pemahaman para anggota DPR mengenai isu-isu yang terkait dengan Protokol Kyoto melalui hearing antara Kementrian Lingkungan Hidup (KLH) dengan DPR.
6. Meningkatkan pemahaman public mengenai isu-isu yang terkait dengan Protokol Kyoto melalui pertemuan dengan wartawan dan artikel-artikel atau informasi public lainnya. Kementrian Lingkungan Hidup Indonesia juga masih merencanakan untuk meningkatkan lagi pemahaman public melalui media akan dampak yang terjadi akibat peristiwa iklim yang ekstrim di Indonesia, melakukan kampanye public dan juga lebih meningkatkan lagi pemahaman anggota legislatif untuk isu perubahan iklim.

Dengan meratifikasi Perjanjian Kyoto ini maka Indonesia bersama-sama dengan negara berkembang lainnya harus mempersiapkan diri menyongsong ajakan stakeholder asing untuk bertransaksi dalam proyek perdagangan karbon di sektor energi dan kehutanan sebagai dua sector utama penyokong proyek perdagangan karbon ini.

4. Sistem perhitungan Akuntansi Karbon (*Carbon Accounting*)

A. NCAS *(National Carbon Accounting System*)

UNFCCC (konvensi PBB untuk perubahan iklim) telah mengakui suatu sistem penghitungan karbon nasional di Australia yang lebih dikenal dengan istilah NCAS (*National Carbon Accounting System*). NCAS (*National Carbon Accounting System*) adalah sebuah sistem terdepan yang digunakan untuk menghitung emisi gas rumah kaca berbasis lahan. Emisi-emisi gas rumah kaca yang bersumber pada aktifitas-aktifitas berbasis lahan dan pelepasan gas rumah kaca ke atmosfer membentuk sebagian besar emisi gas rumah kaca di Australia. Sebanyak 27 persen gas rumah kaca di Australia dihasilkan oleh aktifitas masyarakat dalam hal peternakan, penanaman tanaman produksi, pembukaan lahan dan kehutanan.

NCAS (*National Carbon Accounting System*) didirikan pada Tahun 1998 dengan maksud untuk menyediakan sistem akuntansi, prakiraan dan perencanaan mengenai emisi gas rumah kaca yang disebabkan oleh aktifitas-aktifitas masyarakat di Australia dalam penggunaan lahan. NCAS (*National Carbon Accounting System*) telah dikembangkan melalui beberapa tahapan pembangunan dengan penerapan atau pelaksanaannya sebagian besar didorong oleh kebijakan Pemerintah Australia dan isu internasional mengenai perubahan iklim. Sistem NCAS (*National Carbon Accounting System*) pada saat ini telah menjadi referensi dan memiliki kemampuan sebagai berikut :

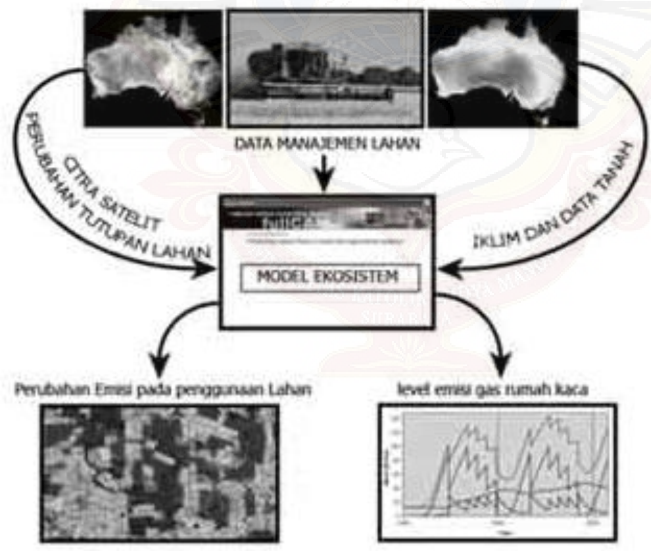
- Baseline untuk Kyoto Protocol dan Inventarisasi Gas Rumah Kaca Nasional pada Konvensi PBB mengenai perubahan iklim (UNFCCC)
- Pelacakan dan penghilangan emisi gas rumah kaca yang berasal dari sektor berbasis lahan
- Proyeksi dan arah tren emisi di masa depan
- Memiliki kapasitas untuk melacak emisi akibat afforestasi (konversi dari areal penggunaan lain menjadi hutan) dan reboisasi.
- Memiliki kemampuan dalam menilai potensi keberhasilan kebijakan dan mengukur pencapaian dalam pengurangan emisi gas rumah kaca
- Pengembangan kerangka program dan data yang kuat yang mendukung kemampuan menghitung gas2 diluar CO_2.

NCAS (*National Carbon Accounting System*) dibangun tidak hanya memperhatikan satu sektor saja, akan tetapi merupakan sistem akuntansi terpadu yang menggabungkan unsur-unsur lahan secara menyeluruh di dalam proses penghitungannya.

Unsur-unsur lahan tersebut adalah sebagai berikut:

- *Remote Sensing* (Penginderaan Jauh) terhadap perubahan tutupan lahan. Data penginderaan jauh di Australia diperoleh dari ribuan citra satelit yang diperoleh sejak tahun 1970, sehingga diperoleh secara lengkap data perubahan tutupan lahan dari tahun dimaksud sampai sekarang.
- Data manajemen penggunaan lahan
- Iklim dan data tentang tanah
- Program penghitungan emisi gas rumah kaca dan
- Model ekosistem sementara dan tata ruang

Berikut adalah diagram alir sistem NCAS (*National Carbon Accounting System*) di Australia :



Program NCAS (*National Carbon Accounting System*) yang ada pada saat ini sebenarnya sudah mengalami beberapa tahap pengembangan. Adapun tahapan proses pengembangan programnya adalah sebagai berikut:

- Tahap awal (Akhir Tahun 1997 - 1999). Pada tahap ini merupakan tahapan pembentukan sistem dan arahan program strategis yang akan dibangun
- Tahap 1 (Pertengahan Tahun 1999 - 2002), meliputi pengembangan penelitian tertarget dan pengembangan kapasitas sistem.
- Tahap transisi (Pertengahan Tahun 2002 – 2003) bertujuan untuk menguatkan persyaratan-persyaratan sistem yang teruji.
- Tahap 2 (dimulai pertengahan Tahun 2003 sampai sekarang), bertujuan untuk menyediakan kemampuan akuntansi secara lengkap yang mendukung Protokol Kyoto, perbaikan-perbaikan dalam penilaian terhadap perubahan tutupan lahan dan pengembangan lebih lanjut dalam peningkatan program NCAS (*National Carbon Accounting System*).

NCAS (*National Carbon Accounting System*) dibangun dengan sistem model pengoperasian pada skala yang kecil (25 m). Model ini dapat menentukan perubahan stok karbon pada tingkat spasial yang baik. Pada akhirnya unit spasial 25 meter ini akan membentuk inventori gas rumah kaca skala nasional. NCAS (*National Carbon Accounting System*) merupakan kumpulan program-program yang secara pararel menginformasikan sekumpulan model terintegrasi membentuk model FullCAM (*Full Carbon Accounting Model*). Model FullCAM (*Full Carbon Accounting Model*) tersebut bisa digunakan untuk mengestimasi emisi dari perubahan penggunaan lahan secara menyeluruh. Program-program pararel terintegraris tersebut meliputi: perubahan tutupan lahan, manajemen tata guna lahan, input iklim, parameter pertumbuhan tanaman dan pohon, kenaikan pertumbuhan dan stok biomasa, parameter pohon, parameter hutan, karbon tanah dan kerangka model.

Dalam melakukan penghitungannya, program NCAS (*National Carbon Accounting System)* menggunakan layer-layer data. Layer-layer datanya adalah sebagai berikut:

1. Layer perubahan tutupan lahan (Diperoleh dari citra satelit dengan resolusi piksel 25 meter (terdapat 16 piksel per hektar). Australia menggunakan data citra bulanan dari Tahun 1972 sampai sekarang).
2. Layer perubahan peruntukan lahan (Berisi data-data penyebab terjadinya perubahan tutupan lahan dan mencakup aktifitas-aktifitas perubahan lahan).
3. Layer tipe tanah (Merupakan karakteristik-karakteristik tanah dalam satu unit lahan).
4. Layer tipe hutan (Merupakan tipe hutan dalam suatu unit lahan, diidentifikasi dari layer peta).

5. Layer manajemen (merupakan rentang waktu terjadinya perubahan tutupan lahan, lokasi, tipe tanah dan lain-lain dalam suatu unit lahan).
6. Layer iklim (data iklim bulanan untuk suatu unit lahan, diperoleh dari peta iklim).
7. Layer pertumbuhan biomasa (penghitungan biomasa saat panen, pertumbuhan pohon, regenerasi pohon).
8. Layer input sampah (sampah-sampah yang terdapat di dasar hutan, sampah sisa panen, pergantian alam dan unsur manajemen).
9. Layer pemodelan (laporan karbon bulanan meliputi stok karbon, proses pembentukan dan proses emisi karbon terhitung).

Tingkat perubahan level karbon berbasis lahan setelah terjadinya perubahan penggunaan lahan bervariasi tergantung pada variasi penggunaan lahan, manajemen penggunaan lahan dan sifat alami tanah. Program manajemen dan penggunaan lahan pada NCAS (*National Carbon Accounting System*) menjelaskan tentang penggunaan lahan dan sistem manajemen yang dipakai, hal ini mempengaruhi level karbon tanah setelah terjadinya deforestasi. Tipe tanah informasinya dikumpulkan dari masing-masing daerah, termasuk didalamnya tipe tanaman dan tipe pengelolaan berdasarkan waktu. Hasil kajian diperoleh bahwa di Australia terdapat 141 perbedaan dalam hal sistem tanam dan sistem penggembalaan. Informasi yang diperoleh dikumpulkan selama rentang waktu yang direncanakan, hasilnya dijadikan sebuah model FullCAM (*Full*

Carbon Accounting Model) berupa database relasional. Laju perubahan stok karbon dari waktu ke waktu juga dipengaruhi oleh iklim yang berlaku pada masing-masing unit lahan. Pada program *climate input* (salah satu program tentang iklim yang terintegrasi pada NCAS (*National Carbon Accounting System*), curah hujan minimum, curah hujan maksimum, rata-rata temperatur, penguapan air dan tingkat kekeringan harian selama periode waktu tertentu diperoleh dari Biro Meteorology Australia. Data stasiun meteorologi ini memberikan prakiraan cuaca yang mencerminkan pengaruh cuaca pada suatu tempat dan menghasilkan peta iklim bulanan dengan resolusi 1 kilometer.

Karbon yang tersimpan dalam biomasa tanaman perlu dilakukan penghitungan sebagai stok karbon. Karbon biomasa akan mempengaruhi tingkat perubahan dalam karbon di dalam tanah, tanaman dan sistem tanaman untuk peternakan. Pada program parameter pertumbuhan tanaman dan pohon memberikan data relevan mengenai hasil panen, alokasi variasi pertumbuhan dari masing-masing komponen tanaman, pengguguran material pohon secara alami dan proses pembusukan, semuanya berpengaruh pada kedua hal yaitu stok karbon tanah dan stok karbon sampah. Data yang telah dikumpulkan untuk masing-masing daerah biogeografis berdasarkan tipe tanah, tipe tanaman dan sistem penanaman dari waktu ke waktu, dimasukan ke dalam database relasional yang mendukung model FullCAM (*Full Carbon Accounting Model*).

B. NCAT (*National Carbon Accounting Toolbox*)

Program NCAS (*National Carbon Accounting System*) yang telah dibangun saat ini telah memenuhi standar untuk menghitung emisi karbon berbasis lahan untuk tingkat nasional dan tingkat internasional. Program NCAS (*National Carbon Accounting System*) juga dapat digunakan untuk penghitungan karbon pada tingkat proyek atau wilayah kecil, yaitu dengan menggunakan program turunannya yang dikenal dengan program NCAT (*National Carbon Accounting Toolbox*). Program ini memungkinkan untuk melakukan penghitungan karbon dari aktifitas-aktifitas penggunaan lahan pada tingkat lebih rendah, seperti halnya tingkat desa, tingkat kecamatan, tingkat kabupaten ataupun wilayah tertentu. Program NCAT (*National Carbon Accounting Toolbox*) sendiri disediakan secara gratis di Australia dan dapat digunakan oleh pengguna untuk menghitung dan menghilangkan emisi karbon dioksida menggunakan data dan model yang sama dengan yang digunakan untuk skala nasional. Sebenarnya untuk kepentingan pembelajaran di Indonesia, program NCAS (*National Carbon Accounting System*) dan program NCAT (*National Carbon Accounting Toolbox*) beserta contoh-contoh datanya dapat diperoleh dengan meminta secara resmi ke pemerintah Australia. NCAT (*National Carbon Accounting Toolbox*) dalam CD programnya berisi hal berikut ini :

1. Satu set alat untuk melakukan pelacakan emisi gas rumah kaca dan perubahan stok karbon akibat pengaturan dan penggunaan lahan.

2. Model FullCAM (*Full Carbon Accounting Model)* yang berasal dari NCAS (*National Carbon Accounting System*).
3. Dokumentasi atau referensi teknis yang mudah diakses.

Persyaratan teknis komputer untuk dapat menggunakan program NCAS (*National Carbon Accounting System*) maupun NCAT (*National Carbon Accounting Toolbox*) adalah sebagai berikut :

- Sistem operasi Win2000/NT4SP6/XP sp2
- CPU-Pentium 233MHz atau lebih cepat
- Memori minimal 256MB
- Hard Disk 120MB
- Resolusi tampilan minimal 800x600 dengan true colour
- CD Room
- Program browser Internet eksplorer 5 atau diatasny

Program NCAS (*National Carbon Accounting System*) maupun NCAT (*National Carbon Accounting Toolbox*) juga disediakan data satelit dalam bentuk DVD dan dikenal dengan istilah Data Viewer. Data Viewer tersebut berisi panduan penggunaan dan image satelit. Data image satelit yang ada diberikan yaitu selama 30 tahun terakhir. Dengan menggunakan snapshot, dari data satelit tersebut kita dapat melihat suatu wilayah dan dilakukan perbesaran, membandingkan perubahan suatu wilayah dari tahun ke tahun, membandingkan data iklim dan statistik tutupan lahan. Data viewer juga dengan fasilitas *property* atau *regional scale* dapat menilai hal berikut ini :

- Tempat dimana tutupan atau tajuk pohon berubah
- Daerah mana saja yang paling efektif dalam penanaman pohon
- Daerah mana saja yang menjadi target reboisasi
- Daerah mana saja yang mengalami kekeringan

Program NCAS (*National Carbon Accounting System*) dan NCAT (*National Carbon Accounting Toolbox*) secara berkesinambungan terus dilakukan pengembangan dan peningkatan kemampuan dan kegunaan sistem. Hal ini dilakukan agar kedua program tersebut dapat digunakan untuk menghitung emisi berbasis lahan dari gas-gas rumah kaca lainnya disamping gas karbon dioksida (CO_2), seperti halnya gas CH_4 (metana) dan N_2O (nitro oksida). Pengembangan program juga dilakukan dalam rangka memberikan biaya lebih rendah pada penggunaan penghitungan gas rumah kaca di tingkat proyek atau skala kecil. Keberadaan sistem NCAS (*National Carbon Accounting System*) dalam lingkup internasional diantaranya yaitu digunakan dalam pendekatan kolaborasi oleh *Clinton Climate Initiative*. Pada proyek *Clinton Climate Initiative* program NCAS (*National Carbon Accounting System*) digunakan sebagai dasar untuk mengembangkan sistem pemantauan karbon global yang dapat membantu dalam pembangunan kehutanan berkelanjutan dan reboisasi dalam pasar karbon global.

SIMPULAN

Pada dasarnya kehidupan di bumi ini ada karena adanya efek gas rumah kaca. Namun masalah timbul ketika terjadi peningkatan konsentrasi gas rumah kaca pada atmosfer bumi. Penambahan tersebut mengakibatkan bumi pun semakin panas. Untuk mengatasi hal ini dibentuklah Protokol Kyoto yang merupakan suatu perjanjian internasional mengenai pengurangan gas karbondioksida, dimana Indonesia sendiri telah meratifikasinya melalui pengesahan Undang-Undang Nomor 17 Tahun 2004, pada tanggal 28 Juli 2004. Pada akhirnya Protokol Kyoto ini menghasilkan suatu kesepakatan yaitu dengan dijalankannya perdagangan karbon bagi setiap negara yang telah meratifikasi Protokol Kyoto.

Dalam melaksanakan perdagangan karbon dibutuhkan suatu alat yaitu akuntansi karbon. Akuntansi karbon yang merupakan perkembangan dari akuntansi lingkungan ini lahir sebagai suatu alat yang dapat mengukur dan membuat suatu referensi mengenai tingkat emisi di berbagai negara, sehingga akuntansi karbon dapat dijadikan sebagai alat penunjang dalam pelaksanaan perdagangan karbon. Alat yang digunakan dalam akuntansi karbon adalah NCAS (*National Carbon Accounting System*) dan NCAT (*National Carbon Accounting Toolbox*). NCAS (*National Carbon Accounting System*) yang merupakan kumpulan program-program ini mampu menginformasikan secara paralel sekumpulan model terintegrasi dengan menggunakan layer-layer data dalam proses penghitungannya. Layer-layer data ini merupakan sumber informasi mengenai tipe tanah, tipe hutan, iklim, dan lain-lain dari tiap daerah biogeografis. Kemudian data-data yang telah terkumpul dari layer data tersebut dimasukkan ke dalam database relasional yang dapat mendukung model FullCAM (*Full Carbon Accounting Model*). Model FullCAM (*Full Carbon Accounting Model*) berguna untuk mengestimasi emisi dari perubahan penggunaan lahan secara menyeluruh. Sedangkan untuk menghitung karbon dari aktivitas-aktivitas penggunaan lahan pada tingkat yang lebih rendah dapat menggunakan program turunan dari NCAS, yang disebut dengan NCAT (*National Carbon Accounting Toolbox*) dan saat ini program ini telah disediakan secara gratis di Australia.

Penerapan akuntansi karbon di berbagai dunia masih terus menimbulkan silang pendapat dan perdebatan. Terdapat pihak yang mendukung pelaksanaan perdagangan karbon ini, tetapi tidak sedikit pula yang menolak pelaksanaan perdagangan karbon dengan berbagai alasannya masing-masing. Sejatinya, wacana perdagangan karbon ini lebih dapat dilakukan pada kondisi ekonomi yang stabil, dimana kondisi masyarakat secara umum telah sejahtera sehingga mereka memiliki modal untuk merawat hutannya, dan tentunya ditunjang oleh sumber daya manusia yang baik pula.

DAFTAR PUSTAKA

Hutan dan Lingkungan Aceh, diakses 23 Agustus, 2010, http://dewagumay.wordpress.com/2008/07/20/perdagangan-karbon-di-hutan-aceh/

Mengenal NCAS-Perhitungan Karbon Nasional di Australia, diakses 10 September, 2010, http://www.baligreen.org/mengenal-ncas-perhitungan-karbonnasional-di-australia/Proses-Emisi-Karbon.html

Richards, G.P., 2001, The Fullcam Carbon Accounting Model : Development, Calibration and Implementation, diakses 10 September 2010, http://joanneum.at/ieabioenergytask38/workshop/canberradata/richards.ppt

Ngili Yohanis, Peran Penting Indonesia Dalam Protokol Kyoto, sumber: Harian Pikiran Rakyat, Rabu 22 April 2009

Risnandar, ST, Bisakah Kredit Karbon mengurangi emisi CO2, diakses 12 September, 2010, http://www.baligreen.org/bisakah-kredit-karbon mengurangiemisi-co2.html

Full Carbon Accounting and the Kyoto Protocol : A Systems-Analytical View, diakses 3 Oktober, 2010, http://www.iiasa.ac.at/Publications/Documents/IR-99-025.pdf

Harkin Zoe and Bull Gary, An International Forest Carbon Accounting Framework A System for Managing, Measuring, Reporting and Trading Forest Carbon From An Operational To An International Scale, diakses 11 ktober 2010 http://www.uach.cl/procarbono/pdf/simposio_carbono/04_Harkin.PDF

Rohim Abdul, Peran Serta Masyarakat dalam Pengendalian Lahan Kritis, diakses 14 Oktober, 2010, http://www.kabarindonesia.com/berita.php?pil=4&jd=Peran+Serta+Masyarakat+dalam+Pengendalian+Lahan+Kritis&dn=20081031213830

Kadarmo Yuliadi, Menelisik Potensi Perdagangan Karbon di Sektor Kelautan, diakses 21 Oktober, 2010, http://lepmida.com/column.php?id=236&awal=20

Anielski, M., 1998, In Search of the Carbonic Truth: Carbon Accounting. *Paper disajikan tanggal 14 November 1998 pada Konferensi Institut Parkland, Canada.*

AN INTERNATIONAL FOREST CARBON ACCOUNTING FRAMEWORK
A SYSTEM FOR MANAGING, MEASURING, REPORTING AND TRADING FOREST CARBON FROM AN OPERATIONAL TO AN INTERNATIONAL SCALE

Zoe Harkin[1] and Gary Bull[2]

University of British Columbia
Forest Resources Management
Forest Sciences Centre
2424 Main Mall
Vancouver, BC. V6T 1Z4
Phone:+1 (604) 822 0161 Fax: +1 (604) 822 8645
[1]zharkin@netscape.net
[2]garybull@interchange.ubc.ca

ABSTRACT

The 'Kyoto Protocol', signed by the parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 1997, allows countries to use carbon sequestered in forests as a means to meet internationally binding Greenhouse Gas reduction quotas.

To provide a transparent and verifiable means of measuring and reporting forest carbon, an international forest carbon accounting framework is required. This report outlines and describes a forest carbon accounting framework that is designed to meet the reporting requirements of the Kyoto Protocol. It also provides step-by-step guidance on defining, measuring, managing and reporting carbon stocks while maintaining a link between the operational, national and international levels of reporting. The framework is designed to adapt to the dynamic nature of climate change negotiations, promote emissions trading, interface with existing vegetation inventories, and be useful to all countries interested in establishing carbon markets.

Keywords: Forest carbon accounting, Kyoto Protocol, emissions trade

LIST OF TERMS

- **Kyoto forest =** Forests that are eligible to achieve emission offsets under Articles 3.3, 3.4, 6 or 12 of the Kyoto Protocol.
- **Kyoto-credible carbon =** Forest carbon storage that is eligible to achieve emission offsets under Articles 3.3, 3.4, 6 or 12.
- **Forest Carbon Project (FCP) =** The collective activities undertaken to design, implement and manage a Kyoto Forest.
- **Forest Carbon Project (FCP) Owner =** The entity or entities with the legal, contractual right to management of a Kyoto forest, and/or ownership of carbon stored in a given Kyoto forest.
- **Emission Offset =** A one ton equivalent of CO_2 stored as forest carbon. Can be used to meet allocated emission reduction quotas. Excess emission offsets can potentially be sold in an emissions trading market.
- **Carbon Credit =** An emission offset that has been sold or bought, or is intended for sale or purchase in an emissions trading market.
- **Reference year =** A performance benchmark against which to determine the amount of 'Kyoto credible' carbon that is stored for a given accounting period.
- **Emission reduction quota =** A specified level of GHG emissions below which an entity must reduce their emissions by the conclusion of a specified compliance period.
- **Project boundaries =** The geographic location within which direct and indirect GHG emissions and storage are affected by FCP activities.

INTRODUCTION

In an effort to combat the effects of climate change, a pioneering agreement know as the 'Kyoto Protocol' was signed in 1997 by many of the developed (Annex I[1]) nations of the world, committing them to implementing measures in order to meet legally binding GHG reduction quotas. One way that Annex I countries can help meet their quota is by promoting sustainable forest management practices through forest carbon sequestration, conservation and substitution. Interest in such Forest Carbon Projects (FCP's) is growing, as companies are discovering that planting and conservation of forests represents a cost-effective and environmentally sensitive solution to the climate change problem.

To provide a transparent and verifiable means of measuring, reporting and trading forest carbon, an international forest carbon accounting framework is essential. This report describes a forest carbon accounting framework that is designed to meet the reporting requirements of the Kyoto Protocol. It provides step-by-step guidance on defining and measuring carbon stocks at the operational level, while maintaining a link between the operational, national and international levels of reporting. The framework is designed in order to adapt to the dynamic nature of international climate change treaties, promote emissions trading, interface with existing vegetation inventories, and be useful to all countries interested in establishing carbon markets.

The framework has three main phases and eleven steps. The first phase, 'Design and Evaluation', outlines the preliminary planning considerations and actions that must be taken prior to project implementation. In phase two, 'Implementation – Inventory and Management', describes the operational level forest management and inventory practices that should be undertaken in order to efficiently run a FCP. It also explains the methodology for scaling up operational level forest inventory to a regional, national and international level. Finally, phase three, 'Emissions Trade', outlines the procedures needed to commence trade of forest carbon.

1 Annex I countries refer to the countries that are listed in Annex I of the UN Framework Convention document. This is a list of 24 developed countries belonging to the Organisation for Economic Cooperation and Development (OECD) as well as 12 countries classified as 'economies in transition' (UNFCCC 1994).

PHASE ONE: DESIGN AND EVALUATION OF A FOREST CARBON PROJECT

1 DEVELOP PROJECT PROPOSAL

The planning stages of the FCP are critical to ensure that land, labour and capital resources are allocated to maximum efficiency and climate change benefit. This section provides details on some of the factors that must be considered for inclusion in an operational level project proposal.

1.1 IDENTIFY MANAGEMENT OBJECTIVES

The goals of the FCP owner should be clearly stated at the beginning of the project proposal. Operational level management objectives should be devised to describe short-term goals. It is also advised that a section of the project proposal should contain a strategic level plan; describing long-term objectives. Some of the principal management objectives for FCP owners might be to: Maximize climate change mitigation; maximize wood production; maximize profit from the sale of forest carbon credits; increase biomass production; and broaden the range of forest values considered in management. Through careful design, an optimal solution can be achieved for the FCP owner both in terms of revenue flow and positive environmental impacts.

1.2 OUTLINE ACCOUNTING OBJECTIVES

The ultimate objective of a Kyoto credible forest carbon accounting system would be to provide an accurate description of the changes in forest carbon stocks, in full compliance with the guidelines, methodologies and reporting requirements as specified by the UNFCCC. This implies that a forest carbon accounting system should be consistent, complete, accurate and verifiable (GHG Protocol Initiative 2000).

1.3 DETAILS OF THE PROJECT

The project proposal should include a concise description of the nature of the FCP, including details on the relevant sections of the Kyoto Protocol and how the project actually mitigates climate change.

1.3.1 RELEVANT ARTICLES OF THE KYOTO PROTOCOL

Within the Kyoto Protocol, there are potentially four articles that allow forest owners a means to obtain emission offsets from a FCP. Article 3.3 of the Kyoto protocol allows an Annex I country to receive 'credit' to a country's emission reduction quota for carbon sequestration due to afforestation[2] and

[2] 'Afforestation' is defined as the "direct human-induced conversion of land that has not been forested for a period of at least 50 years to forest land through planting or seedling" (SBSTA 2000).

reforestation[3] activities; and a 'debit' for deforestation[4] activities. This is restricted, however, to afforestation, reforestation or deforestation [ARD] activities that have occurred since 1990. The full text of Article 3.3 is presented in Appendix 1.

Article 3.4 of the Kyoto protocol expands upon Article 3.3, by suggesting that a set of 'additional human-induced' forest management activities may be used towards meeting Kyoto commitments. Article 6 of the Kyoto Protocol defines 'Joint Implementation' [JI], which allows Annex I parties to supplement their domestic GHG reduction activities, with emission reduction or sink enhancement activities conducted in other Annex I countries.

Article 12 of the Kyoto Protocol defines the 'Clean Development Mechanism' [CDM]. The CDM provides a means for Annex I countries to fund and implement GHG reduction projects in non-Annex I [developing] countries. This is under the proviso that the Annex I country must contribute to the sustainable development of the developing country. [Eg: By training forest managers in developing countries in advanced silvicultural practices]. At present, it is uncertain whether sink projects will be eligible for inclusion in the CDM. This issue is due for resolution at the COP6 meeting in Bonn, Germany [July, 2001].

1.3.2 CARBON SEQUESTRATION, CONSERVATION OR SUBSTITUTION?

There are three main ways in which FCPs can mitigate climate change (Vine et al. 1999): Through carbon sequestration; conservation or substitution. Forest carbon sequestration projects aim to create new areas of forest, or increase the rate and amount of carbon uptake by existing forests. This has the overall effect of increasing the amount of carbon removed from the atmosphere by storing it in the tree biomass.

Forest conservation projects aim to prevent the release of carbon emissions from a forest. This is can be achieved by a variety of means such as preventing deforestation; placing forests in parks and reserves; modification of forest management practices [eg: shelterwood harvesting and utilization of wood protection technologies]; and increased control of fires, insects and disease (Vine et al. 1999).

Forest carbon substitution projects aim to promote the utilization of sustainably produced forest biomass as a direct energy source, or by replacing products that are fossil-fuel intensive to produce. When forests are managed sustainably, forest biomass energy is classified as 'carbon neutral'. [ie:

[3] 'Reforestation' is defined as the "direct human-induced conversion of non-forest land to forest land through planting or seeding, on land that was forested but that has been converted to non-forest land" (SBSTA 2000).
[4] 'Deforestation' is defined as the "direct human-induced conversion of forest land to non-forest land" (SBSTA 2000).

neither a carbon emission nor sequestration]. Thus, if carbon neutral forest biomass is used to replace fossil fuels that are traditionally used for heat and power production, then total carbon emissions are reduced (IEA Bioenergy 2001).

1.4 ADDRESS LEAKAGE CONCERNS

Leakage is defined as the unexpected loss of GHG reduction benefits when activities or markets are displaced, resulting in emissions elsewhere (Schlamadinger & Marland 2000). All potential sources of leakage should be identified, and can be addressed by measuring all carbon pools that are a source of carbon emissions, and by carefully considering the temporal lifetime and company and project boundaries.

1.4.1 MEASURE ALL SOURCES OF CARBON EMISSIONS

Leakage becomes problematic when emissions are transferred to a carbon pool that is not measured [see Box 1 for the forest carbon pools that are measured under the Kyoto Protocol]. Therefore, leakage can be addressed by measuring all carbon pools that are a source of carbon emissions.

- Forest carbon pool components that must be measured*:
  - Aboveground Biomass
  - Belowground Biomass
  - Litter
  - Dead Wood
  - Soil Organic Carbon
- Greenhouse Gases that must be measured (expressed as CO_2 equivalents)**
  - CO2
  - All non-CO2 greenhouse gas emissions
- Forest carbon pools that are a source of GHG emissions <u>must</u> be measured***

*At present, carbon storage in forest wood products is not measured in the Kyoto Protocol. However, future COP meetings may decide to include carbon storage in wood products.
**An equivalent of CO_2 may include any of the greenhouse gases (Carbon Dioxide, Methane, Nitrous Oxide, Hydrofluorocarbons, Perfluorocarbons or Sulphur Hexafluoride), weighted according to their global warming potential, to give the amount of global warming equivalent to one ton of CO_2 (Environment Canada 2000).
*** Forest carbon pools that are not a source of GHG emissions do not have to be measured if sufficient proof is provided that the pool is not a source.

Box 1: Forest carbon pools that must be measured to ensure Kyoto compliance.

1.4.2 DETERMINE TEMPORAL LIFETIME OF THE PROJECT

One of the key sources of debate in recent climate change negotiations, has been the issue of temporal leakage, or 'permanence' of emission offsets from FCPs. There is some concern that forest carbon sinks may undermine the integrity of the protocol, since it is possible that carbon sequestered in forests may be released back into the atmosphere [by harvesting or natural disturbance] at a later date (Schlamadinger & Marland 2000)[5].

Carbon should be stored in forests for a sufficient duration such that the warming effect of carbon in the atmosphere is offset (Moura Costa & Wilson 1999). Given that one ton of CO_2 stored as forest carbon for 55 years is sufficient to counteract the effects of a one ton pulse emission of CO_2, it could be argued that FCPs should have a carbon storage lifetime of at least 55 years (Moura Costa & Wilson 1999). This carbon storage is then is equivalent to a permanent removal of CO_2 from the atmosphere. A similar method of solving the permanence issue is the 'ton-year' approach, explained in Section 5.2.3.

1.4.3 DEFINE COMPANY AND PROJECT BOUNDARIES

To avoid leakage via geographic displacement of GHG emissions, the company and project boundaries of the project should be carefully defined. 'Company boundaries' include all GHG emissions and abatement activities for which the FCP owner is directly responsible for (AGO 1998). 'Project boundaries' could be defined as the geographic location within which direct[6] and indirect[7] forest carbon emissions and sequestration are affected by FCP activities.

In the event of shared ownership of a FCP, or if some of the project activities are to be carried out by outside contractors, the responsibility for carbon emissions and sequestration should be specified in a contract (GHG Protocol Initiative 2000). Concise specification of company and project boundaries is also crucial in FCPs where 'carbon rights'[8] are established (Blair 1999).

[5] Special mention should be made regarding the permanence of FCPs under the CDM. Permanence in CDM projects is especially concerning, since the CDM results in the creation of new 'Certified Emission Reductions' [CER's] in Annex I countries, without subtraction from the assigned GHG amounts in a developing country [since developing countries do not have GHG reduction quotas]. At present, the Kyoto Protocol contains no provisions for the Annex I country to account for potential carbon losses after the project activities lifetime. COP negotiators must be careful to define the accounting lifetime of forest carbon CDM projects, to ensure the integrity of the Kyoto Protocol is not undermined (Schlamadinger & Marland 2000).

[6] Direct emissions or sequestration are due to activities within the company boundaries that occur on the FCP site.

[7] Indirect emissions or sequestration are due to activities within the company boundaries that occur on lands not managed by the FCP owner.

[8] 'Carbon rights' involves the legal separation of carbon ownership from the land and trees.

1.5 INVESTIGATE MANAGEMENT ALTERNATIVES

The management implications of the three types of FCP's are described in the sections below.

1.5.1 MANAGING CARBON SEQUESTRATION AND TIMBER PRODUCTION

One of the challenges in managing a FCP, is to allow for the dual pursuance of the goals of sustainable timber production and climate change mitigation. The following management strategies can be adopted to maximize timber volume and carbon storage:

- Maintain a range of forest age classes such that the amount of carbon sequestered in actively growing stands is equal to or greater than the amount of carbon being emitted due to harvesting (AGO 1999a).
- Harvest at a frequency that emulates the natural rate of disturbance (Kurz et al 1998),
- Thin regularly and at a light to moderate intensity [between 5 to 25% of total biomass] (Thornley and Cannell 2000)
- Consider the price of timber and carbon when prescribing rotation length (van Kooten *et al*. 1997).

1.5.2 MANAGING CARBON SEQUESTRATION AND/OR CONSERVATION

In addition to consideration of harvesting frequency, age-class distribution and rotation length of forests, there are a number of other forest management activities that are suitable for achieving the goals of carbon sequestration, conservation and protection of non-timber values. These activities [listed below] may or may not prove to be eligible under Article 3.4. This issue is due for resolution at the COP 6 [Part II] meeting in Bonn, July 2001.

- Increase intensity of insect and disease protection activities. This is estimated to be one of the cheapest ways to increase forest carbon storage (NCCS 1999).
- Implement activities that increase the site index of the forest, such as fertilization.
- Increase the use of a genetic improvement program to allow planting of species that are faster growing, disease-resistant species, contain more carbon, or are capable of producing greater quantities of biomass (NCCS 1999).
- Implement density management and commercial thinning regimes to prevent carbon loss due to mortality, promote increment on the fastest growing species, shorten rotation lengths and allow greater carbon storage in wood products[9]. Commercial thinning may also extend wood supply, and therefore may result in reduced harvest activities elsewhere (NCCS 1999).
- Conduct enrichment planting to improve stocking of existing stands

[9] Carbon storage in wood products is not recognized in the Kyoto Protocol at this time.

- More careful consideration of matching appropriate species to site and micro-site, thereby maximizing productivity of the stand
- Plant frost-resistant species
- Increase intensity of fire prevention activities.
- Develop wood preservation technology, allowing carbon to be stored in wood products for a longer time[9]
- Remove introduced grazing animals from the forest, thereby allowing greater biomass accumulation in the understory
- Investigate low soil disturbance planting and reduced impact logging techniques.
- Restore degraded forest land [e.g.: management to alleviate the effects of erosion or restoration of salt-affected and polluted lands]
- Investigate use of biowastes to increase forest productivity and soil carbon storage.
- Implement natural wildlife conservation schemes, thereby increasing overall ecological productivity and carbon content of the entire forest system.
- Consider implementation of urban tree planting schemes. Planting trees in city centres has the dual purpose of increased tree carbon storage, and also for the value of urban trees in breaking up 'urban heat-islands', thereby reducing energy requirements and demand for fossil fuels (IPCC 2000).
- Consider disposing of harvesting and mill residues and timber waste, by burying in landfills. This limits the rate of carbon decomposition in wood products to less than 3% per annum (Meil 2000).
- Conduct research and development into improving the efficiency of timber recovery, re-use and recycling processes, thereby increasing the wood product use-life (NCCS 1999).

1.5.2.1 FOREST PROTECTION PROJECTS

Forest protection projects may prove to yield the maximum carbon benefit at least cost on some sites. Forest protection projects are particularly suitable to old growth forests, which typically have a high initial level of carbon storage. Forest sites that are low in productivity, sensitive to disturbance, aesthetically or socially significant, or have a high ecological importance are also be well suited to forest protection projects.

One problem is that forest protection projects are particularly susceptible to leakage. Protection projects that do not address the principal causes for harvesting, may simply shift the harvesting to another forest elsewhere. It is crucial that these leakage issues are identified and addressed.

1.5.3 CARBON SUBSTITUTION PROJECTS

Once a forest is harvested, the biomass can be used as an energy source instead of fossil fuels. This can result in significant *avoided* GHG emissions. This is because biomass energy produced from sustainable forests is classified as 'carbon neutral'. This means that the amount of carbon released when the wood is burned for energy, is equivalent to the amount of carbon sequestered when the forest was planted. There is thus no net carbon effect on the atmosphere. Emissions avoided from carbon sequestration projects will not be re-emitted. Carbon substitution projects can also mitigate climate change though using sustainably produced wood products in place of products which are fossil fuel intensive to produce, such as aluminium or concrete (IEA Bioenergy 1998).

A FCP owner should manage carefully to ensure other forest values are not compromised when undertaking a carbon substitution project[10]. A FCP owner should avoid locating biomass plantations on sites of high aesthetic and ecological significance. Visual buffer zones around biomass plantations can also make the forest more aesthetically pleasing.

1.6 PUBLISH THE PROJECT PROPOSAL

Each of the factors outlined from section 1.1 to 1.6 should be addressed in the project proposal, and published as a clear, well-written document to be distributed to all relevant parties.

2 PRELIMINARY CARBON YIELD PROJECTIONS

To determine an appropriate FCP design for the site, preliminary estimates of future forest carbon yields from each of the potential management regimes [Section 1.5] should be produced. Carbon and timber volume estimates produced at this stage will be based on the data which are already available and are therefore intended for use only as a rough indication of expected yields. Preliminary carbon yield projections can be obtained either by using rough estimates from literature (Birdsey & Heath 1995; Bonnor 1985; Lowe 1996; Penner et al 1997; Rombold 1996; TBFRA 2000;), IPCC default values[11], rough inventory estimates and/or using computer modeling software packages. A number of forest volume, biomass and carbon projection models are currently available (CCRS 1999; Ecosecurities 1999; Harmon et al. 1996; IEA Bioenergy 2001; Kurz et al 1992; Mohren et al. 1990; Mohren et al. 1999, Richards & Evans 2000; West 1997;). These can be divided into three types:

[10] Forest biomass plantations are generally single-age, single species, short-rotation stands. These stands are generally regarded as being of low ecological and aesthetic value.

[11] The Revised *1996 IPCC Guidelines for National Greenhouse Gas Inventories* published a set of default carbon conversion factors, specific to forest type and country. These conversion factors can be used to convert merchantable biomass to estimates of belowground biomass. The IPCC Guidelines are available for download from the IPCC website: http://www.ipcc.ch/pub/guide.htm

Simple allometric models, Growth and yield models, and physiological-based models (Spittlehouse 2000). Simple allometric models[12] are generally used to predict carbon on an individual tree basis using a biomass or volume equation specific to the species, then converting to carbon using a range of expansion and conversion factors, [Section 6.1.1]. Growth and yield models use stand-level biomass tables to calculate carbon yield for a number of trees. Physiological based models use equations to simulate the processes such as photosynthesis, respiration, decomposition, Net Ecosystem Productivity and Net Primary Productivity.

Unfortunately, most of the allometric, growth and yield, and physiological models outlined above do not consider the influence of market demand on future forest carbon levels. Market effects can be taken into account by incorporation of a demand-driven model, which are capable of simulating the effect of social, economic and other demand-side factors on future carbon storage. A forest carbon sink owner would be also well advised to incorporate predictions of plant growth response to climate change in their carbon modeling procedures. A range of climate change simulation models are discussed in Bortoluzzi (2000).

3 DEFINE AND MEASURE BASELINE

In order to quantify the amount of carbon that has been sequestered [or emitted] due to a FCP, changes in carbon should be measured in relation to some baseline or reference (Schlamadinger & Marland 2000). The 'baseline' or 'business-as-usual' [BAU] carbon balance is defined as "the pattern of greenhouse gas emissions and carbon sequestration that would have been expected to take place on a project site over time, without implementation of the new project." (AGO 1998). Comparison of expected carbon benefits of the project [Section 2] to the baseline is useful to ensure that all GHG reductions are real and verifiable. Determination and measurement of the baseline is also necessary for projects registered under the JI or CDM mechanisms, to comply with the 'additionality' specification[13].

3.1 DEFINING THE BASELINE

A baseline can be defined in either of two ways: A fixed path of emissions, or a dynamic forecast of projected emissions (Pape & Rich 1998). A fixed baseline assumes the rate of emissions remains constant, relative to emissions in a benchmark year (Pape & Rich 1998). A fixed baseline should be

[12] Allometric equations provide a means of estimating tree biomass from readily measurable tree parameters such as diameter and height.
[13] The requirement for 'additionality' of JI and CDM projects implies that the carbon storage achieved from the FCP must be in excess of the carbon storage that would have occurred under the BAU scenario.

calculated based on analysis of historical forest growth trends, rates of land use change, and causes for land use change (Brown et al. 1997).

A dynamic forecast of projected emissions takes into account a range of assumptions about future patterns of emissions, and is continually adjusted as new information and technology becomes available. Defining a dynamic forecast of baseline emissions involves analysis of historical data [as for the fixed baseline]. The baseline is then adjusted over time to reflect anticipated future emissions [or storage] (Pape & Rich 1998). Dynamic baseline projections should be regularly adjusted to reflect changes in laws, regulations, population dynamics, economic growth, market trends and future land use patterns (Vine *et al.* 1999)

3.2 MEASURING THE BASELINE

There are four ways a FCP can measure or estimate the baseline carbon balance: Direct measurement, computer modeling, use of default values or retrospective measurement. In order to directly measure the baseline carbon stocks, , a series of sample plots can be located and measured using a statistically sound sampling method. Regardless of the BAU land-use, carbon pools should be measured according to the regulations specified is Box 1. If the project site is forested, the methodology specified in Section 6.1 should be used. If the BAU land-use is non-forested, then the methodology for the appropriate land use in the *Revised 1996 Guidelines for National Greenhouse Gas Inventories* (IPCC 1996) should be used.

For larger or more complex stands, one of the three types of computer models [Section 2] can be also be used to model baseline carbon balance. Default values can also be used to give a rough estimate of baseline carbon storage. Preferably, regionally specific default values, suitable to the BAU land use should be used. As a last resort, the IPCC Guidelines (IPCC 1996) give approximate carbon storage values for a range of soil types, geographic locations and land uses.

'Retrospective measurement' is necessary if project activities have commenced before the baseline was measured. Retrospective measurement requires the FCP owner to estimate the carbon balance of the former land use. If historical carbon inventory data is available, this can be used. Where no data is available, baseline carbon balance can be estimated by measuring the carbon storage of neighboring lands that are subject to the BAU land use. As a last resort, default values can be used.

4 PROJECT EVALUATION AND REGISTRATION

4.1 FINAL PROJECT APPRAISAL – EVALUATION OF PROJECT DESIGN

Prior to implementation of project activities, it is useful to evaluate the project according to a number of project eligibility criteria. This is advisable to ensure that the project is Kyoto compatible, economically feasible and does not negatively impact other forest values.

4.1.1 'KYOTO COMPATIBILITY' OF THE PROJECT

Moura Costa et al. (2000) suggests that there are four elements that should be assessed in determining the 'Kyoto compatibility' of a project: acceptability, additionality, leakage and capacity.

'Acceptability' implies that the FCP must be approved by all countries and parties directly involved with the project, and acceptable in terms of goals such as biodiversity, promotion of technology transfer and aesthetics. 'Additionality' implies that all carbon benefits must be "additional to any that would otherwise occur". The requirement for additionality is only specified for JI and CDM projects (Articles 6 and 12). However, establishing additionality of a project is also useful in context with Article 3, to ensure that the project is consistent with the goals of the UNFCCC[15] and the Kyoto Protocol. In practical terms, additionality is most easily demonstrated by comparing the carbon stock of the baseline scenario [Section 3], with the expected carbon yields accumulated due to the FCP [Section 2]. If the net carbon stock of the project exceeds that of the baseline, then project carbon benefits are said to be 'additional'.

As described in Section 1.4, all sources of leakage minimized, then quantified and subtracted from the total expected carbon stock of the FCP. The final aspect of Kyoto compatibility is to assess the 'capacity' of the project to fulfil expectations. This can be evaluated by appraising the skills of the FCP management team, technology and equipment, as well as considering the ecological, political and economic environment in which the project is undertaken.

4.1.2 ECONOMIC ASSESSMENT OF THE PROJECT

Using the preliminary estimates of carbon yield [Section 2], a FCP owner should conduct an economic analysis of each of the proposed forest carbon management alternatives. Economic analysis should attempt to factor in a range of possible forest products and forest uses. A number of computer models can be used to conduct economic analysis of the project (Stone et al. 1996). Alternatively, a simple

[15] The overall aim of the UNFCCC is the "*…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system…*" (UNFCCC 1992).

cost-benefit analysis, and plotting the NPV of each of the alternative management regimes against the BAU scenario would suffice.

4.1.3 IMPACT ON OTHER FOREST VALUES

Prior to implementation of a forest carbon sequestration project, a FCP owner should carefully consider other forest objectives, such as recreation, aesthetics, aboriginal land rights and water supply. This is necessary to comply with other objectives of the Kyoto Protocol, as well as achieve public support for the project and therefore ensure temporal continuity (Brown *et al.* 1997).

4.2 PROJECT REGISTRATION

Having decided upon which forest management regime to implement, and determined that the project is indeed Kyoto credible and economically viable, a FCP owner can now proceed to 'register' their FCP with a central carbon registry [Section 9.5.3]. Although most countries have yet to establish a national carbon registry, it is likely that a registry will be crucial to the development of an efficient national carbon accounting system. Some countries are also beginning to trial national registries on a voluntary basis[16].

The central carbon registry is managed by a national agency that maintains records of Kyoto-credible forest carbon. FCP owners wishing to obtain official national recognition of Kyoto-credible forest carbon would be required to register and report to the central carbon registry using a national standardized format. Registration will encourage uniformity in carbon inventory methodologies, eliminate confusion regarding interpretation of data, facilitate exchange of information between operational and national level carbon inventory and increase data accuracy, transparency and verifiability. Most importantly, registration provides encouragement for a united, coordinated effort towards greenhouse gas abatement, thereby helping to avoid leakage due to market effects where demand is simply shifted to emitters (AGO 1999b).

The use of web-technology would greatly increase efficiency of data transfer between operational and national level carbon inventory (AGO 1999b). A web-based registry could also provide FCP owners with advice on how to conduct forest inventory, as well as providing default carbon yield curves for region and species.

[16] In 1997, the Voluntary Challenge and Registry [VCR] was established in Canada. http://www.vcr-mvr.ca/home_e.cfm. In October 2000, the Pacific Rim Regional Association of RC&D's launched the 'Carbon Technology Transfer Center' for registration and trade of carbon: http://www.pacrimrc-d.com/Aggregator/carbon_technology_transfer_cente.htm. The Environmental Resources Trust (ERT) has setup a GHG Registry for quantifying, registering, and tracking GHG emissions and/or reductions http://www.ecoregistry.org/.

Once a FCP has been officially registered, the FCP owner can proceed to implement the project.

PHASE TWO: PROJECT IMPLEMENTATION – INVENTORY AND MANAGEMENT

5 DESIGN SAMPLING SYSTEM

5.1 CONSIDER SAMPLING AND ACCOUNTING OBJECTIVES

In designing a forest carbon sampling system, it is necessary to define either the *specified* level of precision to be achieved by the forest inventory, or the *maximum* level of precision that can be achieved, given fixed inventory costs (MacDicken 1997). Different levels of precision may be required for each forest carbon pool [i.e.: aboveground biomass, belowground biomass, soils, litter, etc] (AGO 1998). Thus, sample size allocated for each forest carbon pool should reflect the required precision.

5.2 ALTERNATIVE ACCOUNTING METHODS

It is assumed that the 'stock change' method will be used to account for changes in forest carbon for projects eligible under Articles 3.3 and 3.4[17]. This method is discussed below. There are, however, a number of alternatives to the stock change method that have been proposed to account for forest carbon sequestered in JI and CDM projects. Three methods are discussed briefly below.

5.2.1 STOCK CHANGE METHOD

The stock change method of accounting involves calculating the difference between forest carbon storage at two different points in time. The total change in carbon stock is calculated by subtracting the carbon stock at the start of the commitment period, from that at the end of the commitment period. Figure 1 shows an example of how to calculate 'Kyoto credible' carbon for ARD activities over the first commitment period.

[17] The stock change method of carbon accounting [over the commitment period] is the methodology specified to be used to account for carbon storage under Article 3.3: "…measured as verifiable changes in carbon stocks in each commitment period.." (UNFCCC 1997). It is unclear at this stage whether the stock change method is required for Article 3.4. The IPCC *Special Report on LULUCF* (2000) identified at least four ways that additional activities could be temporally accounted for: Using 1990 as a baseline; Stock change over the first and subsequent commitment periods (provided activities were implemented after 1990); Using a BAU baseline; and stock change over the second and subsequent commitment periods (IPCC 2000). For the purposes of this document, it is assumed that the stock change method will be adopted for Article 3.4.

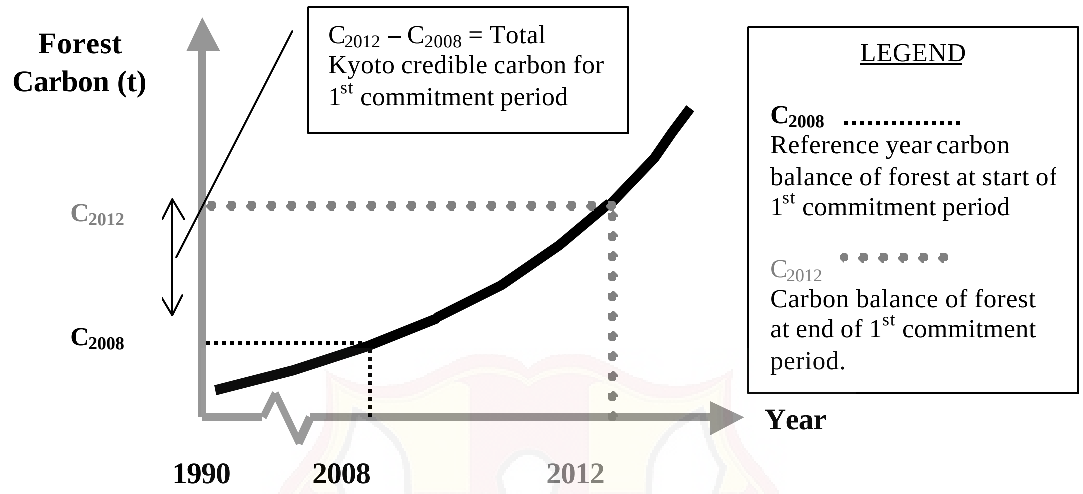


Figure 1: Calculation of Kyoto credible forest over the first commitment period (2008 – 2012)

A disadvantage of the stock change approach is that it may provide disincentive for long-term sustainable forest management practices. This is because the stock change method detects short-term fluctuations in carbon storage. Practices such as juvenile spacing, thinning, and planting of slow-growing species may result in short-term carbon emissions [or slower rates of carbon sequestration]. In the long term, however, these practices result in greater forest carbon storage. In order to address this issue, the 'average forest carbon storage' accounting method has been proposed.

5.2.2 AVERAGE CARBON STORAGE ACCOUNTING METHOD

Under the 'average carbon storage' accounting methodology, the amount of Kyoto-credible carbon is calculated as the average forest carbon storage over successive rotations (Moura Costa & Wilson 1999). By calculating the average forest carbon storage, the long-term trend in forest carbon storage is captured, as opposed to the fluctuations [Figure 2].

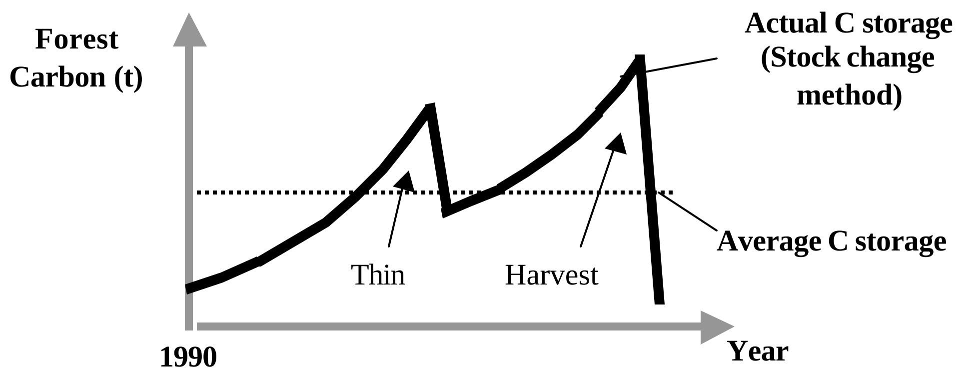


Figure 2: Comparison of average carbon storage accounting method with stock change method.

Figure 2 depicts the carbon storage of a forest that has been thinned once, then harvested. The solid black line indicates the change in carbon stocks to be reported, using the stock change method. The dashed black line shows change in carbon stocks using the average carbon storage method. This implies that carbon losses due to harvesting [or thinning or spacing] are not debited [providing the forest was immediately replanted] (Moura Costa 2000).

5.2.3 THE TON-YEAR METHOD

The ton-year method has been proposed to address the issue of permanence of forest carbon storage. The method gives a FCP credit for each year of storage, relative to the rate of carbon decay in the atmosphere. It has been determined that storage of one ton of carbon for one year is equivalent to preventing the emission of 0.0182 tons of carbon, regardless of whether it is released again at the end of this year (Moura Costa & Wilson 1999). Therefore, one year of forest carbon storage could generate 0.0182 carbon credits. According to the CO_2 decay curve, storing one ton of forest carbon for 55 years could generate one carbon credit.

6 CONDUCT FOREST CARBON INVENTORY

Forest carbon inventory can potentially be conducted using three main methodologies: Field measurement, modeling and remote sensing techniques, or some combination of the three.

6.1 ESTIMATION USING ALLOMETRIC EQUATIONS

For small FCP owners, it may be most practical and cost effective to use simple allometric equations to estimate forest biomass. Using this approach carbon estimates can be derived from current forest inventory data and data redundancy and high inventory costs can be avoided. The following sections describe how forest carbon can be estimated using field measurements.

6.1.1 CARBON STORAGE IN ABOVEGROUND BIOMASS

Tree carbon estimates can be derived from volume. Tree volume is estimated based on height and diameter at breast height, and by applying the appropriate allometric equation[18]. Volume estimates are then multiplied by a species-specific expansion ratio to estimate the total aboveground biomass. The expansion ratio accounts for the volume of the branches, leaves, twigs and other aboveground non-merchantable tree components[19]. For greater accuracy, expansion ratios should be specific to the region and species. Where these expansion ratios are not available, they can be developed by plotting a regression of non-merchantable biomass against merchantable volume and statistically determining the appropriate regression equation. This requires the use of destructive sampling techniques. As a last resort, country specific default expansion ratios can be obtained from the *1996 Revised IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 1996).

To calculate aboveground biomass on a dry weight basis, the total aboveground biomass is then multiplied by the appropriate biomass conversion ratio. This is a ratio to exclude the weight due to moisture in the tree. Biomass conversion ratios again should be species and regionally specific. However, default values are generally available in literature.

To convert biomass to carbon, the proportion of carbon contained in the biomass must then be multiplied by the dry weight of biomass. In general, the carbon content varies very little between species, and the IPCC default carbon content is 0.5 (IPCC 1996). However, species specific carbon contents for most forest species are generally available in literature. This estimate can then be scaled up to produce estimates of aboveground biomass carbon uptake on a per hectare or stand-level basis, by averaging the total carbon storage from a number of statistically significant plots across the stand, and multiplying by the stand area.

To express the total aboveground biomass carbon as CO_2 equivalents, stand level aboveground biomass carbon is simply multiplied by the stochiometric ratio of CO_2, which is $^{44}/_{12}$.

---

[18] An example of an allometric equation specific to coastal Douglas fir in British Columbia, Canada is:
$$\mathbf{V = [4.796550265*10^{-5}]*[D^{1.813820}]*[H^{1.042420}]}$$
Where: V = Total merchantable volume of the tree [m^3], D = Diameter at breast height [cm], and H = Tree height [m]. In cases where allometric equations are not available, these can be developed using regression analysis of measurements taken from destructive sampling techniques.

[19] Many of the expansion ratios available may also account for below ground biomass. If this is the case, aboveground biomass and belowground biomass should simply be accounted for together.

For multi-species stands, stratification may reduce sampling error. In this case, carbon storage for each species can be sampled independently, and summed to give total stand-level carbon storage.

6.1.2 CARBON STORAGE IN OTHER CARBON POOLS

Sources of carbon emissions must be reported from the belowground biomass, litter, dead wood and soil unless the FCP owner can prove that the pools are *not* net sources of carbon emissions. If the carbon pool is a sink, the FCP owner has the option of including the pool in their forest carbon inventory. Therefore, it is useful for a FCP owner to have a general knowledge of the processes involved in measurement of other carbon pools. A description of the carbon measurement procedures for each of these carbon pools can be found in MacDicken (1997).

6.2 ESTIMATION USING MODELS

Where the stand size becomes too large or the forest too complex in structure, measurement of forest carbon on an individual tree basis may no longer be practical. In this case, the FCP owner may prefer to use a software-based model to estimate forest carbon[20].

To calculate current year carbon storage, the model will utilize simple forest inventory data input. These data are then substituted into a series of equations inherent within the model. Usually, a model will determine the carbon balance in the above and belowground biomass, however models can often also determine the amount of carbon in soils, litter and dead wood (Vine et al. 1999).

6.3 INTEGRATION OF REMOTE SENSING TECHNIQUES

Remote sensing can be used in forest carbon inventory for three purposes: Direct measurement of carbon, stratification and/or to provide estimates of forest area. Direct measurements of forest carbon can be obtained via SAR [Synthetic Aperture Radar] scanners. SAR scanners are capable of examining the patterns and strength of spectral reflectance of vegetation (Baker & Luckman 2001). Data from the scanner can then be input into a computer model, which can then produce estimates of Net Ecosystem Productivity [NEP] and forest carbon storage. A range of these computer models are available: InTEC, Integrated Terestrial Ecosystem Carbon Cycle Model (Canadian Centre for Remote Sensing CCRS 2000); BEPS, Boreal Ecosystem Productivity Simulator (Liu 1997) and Forest-BGC (Running & Coughlan 1998, Running & Gower 1991);

[20] A summary of a range of software-based forest carbon models is available at the following address: http://www.joanneum.ac.at/iea-bioenergy-task38/model/fmodel.htm

Remote sensing can also prove useful for stratification of land use and/or forest type prior to field sampling. By examining the crown formation characteristics of forests from aerial photographs or spectral reflectance from satellite images, it is possible to identify forest and non-forest areas, and classify forest according to forest type or species (Avery & Burkhart 1983). Stratification can enhance efficiency of forest inventory by reducing variation between grouped sample plots. Another way remote sensing can significantly enhance the accuracy of a forest carbon inventory, is to provide more precise estimates of forest area. This is beneficial since inaccuracy in forest area estimates has been identified as being one of the major sources of error in forest inventory estimates (NGGIC 1998).

One problem with the use of remote sensing at the operational level, is that the cost can prove prohibitive for a single forest owner. This problem can be overcome by cooperating with other land holders nearby, organizing to have remote sensing conducted at the same time on a larger area of land. Costs are then shared amongst a number of individuals.

7 DETAILED MODELING OF FUTURE CARBON YIELD

Once the FCP has been implemented and forest inventory has been conducted, more detailed estimates of carbon yield can be produced, using the carbon yield prediction models as described in Section 2. The FCP owner will have gained some experience and insight into the limitations associated with the project. This experience should give FCP owner a more realistic idea of the assumptions, constraints and growth trends for input into the carbon and timber yield projection models. More reliable estimates of future carbon yield are especially important if the FCP owner intends to conduct forward trades of forest carbon [Section 11.1].

8 MONITORING, VERIFICATION AND CERTIFICATION

The Kyoto protocol specifies that carbon estimates should be…“ reported in a transparent and verifiable manner…” (UNFCC 1997); therefore a well-designed system for monitoring, verification and certification is essential. Monitoring can be defined as the “periodic inspection or measurement of project carbon against reported or estimated values” (State Forests NSW 2000). Verification can be defined as the act of checking the validity of the claims of a project (Moura Costa et. al. 2000). Certification occurs when the verification agency officially confirms that the FCP conforms with specified verification criteria.

8.1 MONITORING

A forest carbon monitoring system involves an analysis of reported values to estimates obtained from the re-measurement of a certain proportion of forest inventory plots. If reported and re-measured estimates differ significantly, this suggests incorrect inventory design or technique, or invalid assumptions. To reduce the costs of monitoring, a combination of ground-based and remote sensing techniques can be adopted. Monitoring and verification costs for small landholders could be minimized through groups of forest owners forming a 'carbon pool' of plantations, thereby sharing costs among a number of individuals.

8.2 VERIFICATION AND CERTIFICATION

There are three components that are required for a successful verification/certification system (Moura Costa et al. 2000),: a published standard, an accreditation body and verification/certification agencies that are accredited to use the standard.

A forest carbon verification standard is defined as a set of generally accepted principles, procedures and methodologies for recording the level of forest carbon sequestration and emissions (Meridian Institute 2000). This would allow forest owners to conduct their own forest carbon inventory suitable to their own forest type, geography and technological capabilities. In order to ensure that the standard is unbiased and suitable to all parties, the international standard would be developed by an independent standard setting authority, comprised of representatives from all parties to the UNFCCC. More detailed national guidelines may also be developed for each country. The guidelines should provide standards for each the field measurement, remote sensing and modeling components of the inventory system.

In addition to an independent standard setting authority, an accreditation body is also required. The accreditation body would attest to the integrity and competence of the verification/certification agency, and oversee the performance of the verification agencies to ensure that the published verification standards were being used appropriately. At present, there is no established accreditation body for this purpose. However the Meridian Institute is currently proposing to establish an international standard setting, accreditation and certification system (Meridian Institute 2000). Under a National Carbon Network [NCN] scheme [Section 9.5.5], it is likely that government for each of the parties to the Kyoto Protocol will play a major role as an accreditation body.HIPERVÍNCULO

Upon official certification by the accreditation body, the verification/certification agency would then be licensed to undertake the actual verification procedure. In order to verify the existence of Kyoto credible forest carbon, three main aspects of the project should be examined. First, the project baseline should be assessed in terms of validity of assumptions. Next, the verifier should confirm that the actual project activities have occurred. Finally, the forest carbon inventory system itself is verified. The verifier would then compare their own estimates of forest carbon data to those reported by the project owners. Based on this comparison, uncertainty of forest carbon data could be calculated.

Certification occurs if the verification agency can attest that the carbon accounting data is true as represented, and meets the carbon verification standard (Meridian Institute 2000). This will normally involve the fully accredited verification agency issuing a certificate, giving formal recognition of a specified quantity of forest carbon storage. Certification of forest carbon storage has the benefit of encouraging investor and buyer confidence, and also avoids the possibility of trading of poor quality, non-verifiable carbon credits (Obersteiner et al. 2000).

9 REPORTING OF FOREST CARBON DATA

Reporting of forest carbon estimates should be accompanied by an assessment of uncertainty, assumptions and excluded carbon pools. For verification purposes, it is also prudent to supply adequate documentation and explanation of project activities and inventory methodology. In addition, this section defines a formal methodology for reporting of carbon data to a 'National Carbon Network' (NCN) to facilitate efficiency in data collection; and to provide a means of scaling up of operational level carbon inventory to interface with national level GHG reporting.

9.1 REPORTING OF UNCERTAINTY

There are two main types of uncertainty associated with forest carbon data: measurement uncertainty, and counterfactual uncertainty (Moura Costa et al. 2000). Measurement uncertainty is due to limited data availability, and limited resources available to capture this data. There are four types of measurement uncertainty: Uncertainty due to averaging and use of approximated values [such as a root to shoot ratio]; Uncertainty associated with the science of forest carbon sequestration; the uncertainty associated with attempting to measure parameters that cannot be directly measured [eg: Using diameter and height to approximate biomass] (Vine et al. 1999). The final type of measurement error arises due to mistakes, systematic biases and accidental errors occurring during the actual forest inventory (Brack & Wood 1998). Measurement uncertainty, is readily quantifiable and should be stated when reporting forest carbon estimates.

Counterfactual uncertainty generally refers to the inability to predict 'what might have been' (Tetlock and Belkin 1996). Counterfactual uncertainty arises due to assumptions that are made in estimating baselines, future forest management regimes and occurrence of risk events. Counterfactual uncertainty is difficult to quantify, and is best dealt with conducting extensive risk management assessment, and using a reputable software package to produce reliable estimates of future carbon yield [Section 2].

Uncertainty can be reported in either of two ways (Vine et al. 1999): Statistically, as the standard error of the mean, or confidence limits around the mean; or qualitatively, where a precision of level of high, medium or low, for example, is assigned to the estimate.

9.2 DOCUMENTATION OF PROJECT ACTIVITIES

To facilitate verification and certification, each stage of the forest carbon inventory and accounting system should be documented. An 'audit trail' allows an independent third party to verify that the forest carbon inventory is carried out according to a specified standard, and that the claimed amount of carbon storage is a good approximation of actual carbon storage. Given the uncertain and dynamic nature of the Kyoto protocol, extensive documentation will also be useful in ensuring that early FCP emission reductions are officially recognized, ahead of finalization of climate change negotiations (CO2e.com 2000).

-

9.3 REPORTING OF ASSUMPTIONS AND EXCLUDED CARBON POOLS

If a forest carbon pool is not accounted for, "transparent and verifiable proof" must be provided to prove that the unaccounted pool is not a source (SBSTA 2000). It follows that a report on unaccounted pools must accompany all inventory estimates. A list of all assumptions made during the inventory, modeling and calculation stages should also be prepared.

9.4 POST-REPORTING FEEDBACK

Review and feedback mechanisms are useful to facilitate flexibility and improvement of a forest carbon accounting system. To facilitate public input and feedback, annual carbon progress reports could be released, both internally and publicly. Sampling systems should be reviewed by experienced forest inventory specialists and statisticians, and verification reports should be noted and adjustments made accordingly. Formulation of a special review board, to assess, recommend and implement the required changes would be advisable for larger FCP owners.

9.5 THE CONCEPT OF THE NATIONAL CARBON NETWORK

The National Carbon Network [NCN] presented in this section is a proposed model to facilitate efficiency in data collection; and to provide a means of scaling up of operational level carbon inventory to interface with national level GHG reporting. The proposed NCN model is divided into six main sectors:

1. Public relations and consultancy
2. Inventory
3. Recording, reporting and tracking of forest carbon [National Carbon Registry]
4. Risk management
5. Accreditation of verification agencies
6. Supervision of emissions trade/brokerage services

Each of these sectors is inter-related as shown in Figure A1 in the Appendix. The role and basic operations of each sector are described in the following sections.

9.5.1 PUBLIC RELATIONS AND CONSULTANCY SERVICES

The primary means of communication between the NCN and individual forest growers, would be via a web-based national carbon registry [Section 9.5.3]. Forest growers could also communicate with the NCN via a series of regional representatives [Section 9.5.1.4]. The public services sector could be divided into four departments: project evaluation; management advice; legislative services, and public relations. Each of these departments is outlined below.

9.5.1.1 PROJECT EVALUATION

In order to assess the Kyoto compatibility and economic feasibility of a forest carbon project [Section 4.1], the NCN could provide an evaluation service to forest growers. Using a number of specified guidelines, the NCN could advise forest owners as to whether their proposed project is Kyoto-eligible.

The NCN could provide either basic, web-based evaluations, or conduct in-depth project evaluations. Basic project evaluations could occur via the public-services module in the web-based registry [Section 9.6.3]. Alternatively, the forest grower could elect to have an in-depth project evaluation carried out in person by one of the regional NCN representatives. This would involve a site visit by the regional representative, who would conduct soil and site productivity test, and conduct a personal interview regarding management intentions of the owner, commitment and expected outcomes of the project.

9.5.1.2 INVENTORY AND MANAGEMENT ADVICE

FCP owners are likely to benefit significantly from a well-written manual, providing detailed information on how to conduct forest inventory, and advice on how best to manage a forest carbon project (BRS 2000). The NCN could publish an inventory and management manual via the public services module in the web-based registry. It is essential that the manual be easy to read, and provide detailed illustrations on how to conduct forest inventory. In addition, the regional NCN representative would be available for individual consultations and guidance regarding inventory and management advice.

9.5.1.3 LEGISLATIVE SERVICES

The legislation regarding ownership of carbon is, at this stage, highly uncertain. Prior to commencing trade of forest carbon, it is essential to legally establish separate ownership of the trees, land and carbon (Blair 1999). This will allow trade of forest carbon as a separate commodity, regardless of whether the ownership of the trees or land changes hands. Pending the finalization of appropriate legislation, a forest grower would be prudent to seek legislative advice regarding the formulation of legally binding contracts, to establish carbon rights. The NCN could offer this service, by providing a legally binding on-line carbon rights contract. The contract could also be accompanied by simple explanations of the implications of the carbon rights contract. NCN regional legislative representatives would also be available for personal consultation in legislative services.

9.5.1.4 PUBLIC RELATIONS

It is crucial to maintain well-established lines of communication between the forest grower and the NCN to overcome distrust of a government agency; to facilitate interest in establishing a forest carbon project, and to inform forest growers about how to manage and maintain a forest carbon project (BRS 2000). The public relations program of the NCN could comprise a number of initiatives, such as:

- A web-based promotional and informational package
- A series of regional seminars and conferences
- A network of regional contact persons, preferably employment of individuals who are local, approachable and well established in the community.
- Informational booklets and pamphlets distributed to secondary and tertiary education institutions.

9.5.2 INVENTORY

The challenge of any national forest carbon inventory program, is to provide a means of scaling up operational, stand-level forest inventory to interface with the national level GHG inventory, allowing participation of both small and large scale forest growers. In an attempt to meet these requirements, the national forest inventory proposed under the NCN provides a system of incentives to encourage small forest growers to submit detailed inventory information to supplement broad scale forest inventory. This system, described below, would be conducted on two levels: broad scale forest inventory, and detailed operational level forest inventory.

9.5.2.1 BROAD SCALE FOREST INVENTORY

Broad-scale forest inventory would be conducted by the NCN on all forest land within the country. This would be done using a combination of remote sensing and ground sampling techniques. Benefits of the NCN conducting a broad scale forest carbon inventory are numerous: The per unit cost of inventory is minimized. Carbon data could be obtained for Kyoto forests where the FCP owner is unable to conduct inventory themselves. Utilization of remote sensing data enables carbon data to be reported in a manner that is both timely and consistent (Natural Resources Canada 2001). Inventory data could be used for a range of purposes. However, a major limitation of conducting such broad-scale forest inventory, is that areas of less than approximately 20 metres cannot be measured or mapped accurately (Weir pers. Comm. 2000). Therefore, there is also a need to conduct a more detailed, operational level forest inventory.

9.5.2.2 OPERATIONAL LEVEL FOREST INVENTORY – THE CARBON 'REFUND SCHEME'

In order to increase the precision of the national forest inventory and enable mapping and measurement of small areas of forest, more detailed, ground-based forest sampling techniques must be implemented. Via a 'carbon refund scheme', individual forest owners are encouraged to cooperate with the NCN and conduct their own detailed forest inventory. This refund scheme could work as follows: In order to claim rights to the carbon ownership of their forest, the forest owner would be required to electronically register their forest on a national web-based carbon registry [Section 9.6.3][21]. By officially registering their forest, a forest owner would effectively enter into an agreement with the NCN. Under this agreement, the forest owner would be required to make a 'payment' to the NCN for conducting the broad scale forest carbon inventory [in much the same way that one might pay taxes to the government]. This 'payment' would obligate the forest carbon owner to forfeit a proportion of their forest carbon ownership to the NCN. If the forest owner decided to conduct their own forest carbon inventory to supplement the broad forest inventory carried out by the NCN, they would be entitled to a 'carbon refund' of a certain proportion of their carbon ownership. The more detailed forest inventory information submitted by the forest grower, the greater amount of carbon that would be refunded by the NCN. In this way, the number of carbon credits obtained by the forest owner would be in proportion to the precision of the forest carbon inventory. Thus, additional costs of inventory are offset by the increase in carbon that is eligible for trade. The concept of a 'variable precision carbon accounting system' is derived from the carbon accounting standard developed by the State Forests of NSW (2000).

9.5.3 MAINTAIN A NATIONAL CARBON REGISTRY

As described in Section 4.2, forest owners would be required to register their forest on the web-based national carbon registry. A national carbon registry is also needed to meet the requirements of Articles

[21] If a FCP owner decided not to register their forest, they would not be eligible to claim carbon offsets. The NCN would obtain rights to claim ownership of the forest carbon. The NCN could then decide whether to conduct their own detailed forest carbon inventory, or simply use data from the broad scale forest inventory [Section 9.5.2.1].

6 and 12[22]. The national carbon registry would essentially be a user-friendly, multi-purpose, web-based computer program. The carbon registry could be divided into a number of separate modules, each to perform a separate role. Some ideas for modules in the national carbon registry might be:

- Land Tenure module: Linked with national tenure records, register ownership
- Inventory module: Contains all historical and current forest inventory data
- Public accounts module: Tracks ownership of carbon for each forest owner, tracks emissions record for each forest owner
- Public Services module: Contains general information, references, links and contact details [Section 9.5.1.4]
- Carbon accounting module: Spreadsheet-based statistical module, to combine all forest inventory data to calculate forest carbon on an operational, regional and national level
- Risk management module: Contains a record of carbon contributions of each forest grower towards a carbon risk management buffer. Primarily maintained by independent risk management agencies [Section 9.5.4]
- Verification/Certification module: Documents verification and certification of the forest by an independent verification/certification agency [Section 9.5.5].
- Emissions trading module: Details of purchase and sale of forest carbon credits, interfacing with the public accounts module. Primarily run by the independent clearing house.
- GIS component: All data within the national carbon registry would be spatially referenced and linked to a GIS system (AGOa 2000).

9.5.4 RISK MANAGEMENT

As described in Section 9.5.2.2, the 'carbon refund scheme' requires the forest owner to forfeit a certain proportion of carbon ownership to the NCN as 'payment' for forest inventory. A proportion of this carbon is automatically contributed to a national carbon risk management pool. The NCN could act as a risk manager for the forest owner, by using a proportion of these retained carbon credits to form a 'risk mitigation buffer' against disturbance events (State Forests NSW 1998). Thus, in the event that the forest was destroyed by fire or insect attack, the losses would be covered by the reserve pool of carbon credits. The buffer of carbon credits would also balance the temporary carbon loss occurring during the harvest/regeneration cycle across the entire carbon pool.

[22] A decision was made at COP 4 to facilitate the development of web-based national carbon registries. This decision specified that:*"Each party in Annex B shall establish and maintain a national registry to ensure the accurate accounting of the issuance… holding, transfer, acquisition, cancellation and retirement of (one-ton equivalents of CO_2)"* (FCCC/SB 2000). A copy of these guidelines is available at the following address: http://www.unfccc.int/resource/docs/2000/sb/crp22.pdf

To perform this role, the NCN could oversee the license and performance of a number of risk management agencies. Each of the risk management agencies would compete for the right to manage the carbon pool of forest growers. In the same way that tax payers are required to fill out a tax-return, forest owners could fill out a 'carbon-return'. Level of risk could be assessed in terms of potential for natural disturbances, anthropogenic interventions and socio-political and economic risk (Moura Costa et al. 2000). Under this risk assessment, each forest carbon project could be assigned a 'permanence rating', or likelihood of achieving permanent carbon storage. Based on this permanence rating, the carbon pool manager could then negotiate the amount of carbon ownership forfeited to the national carbon pool [and thus, the level of risk protection required]. In this way, the amount of carbon that is eligible for trade is in proportion to level of risk associated with the project.

The NCN could also provide advice on other means of reducing risk associated with forest carbon projects, such as portfolio diversification or strengthening of insect and fire protection activities. The NCN may also function as a simple insurance agency, whereby a forest grower may choose to make financial payments to insure against risk, rather than setting aside a proportion of their carbon credits towards a carbon pool.

9.5.5 ACCREDITATION OF VERIFICATION AGENCIES

As described in Section 8.2, there is a need for an international accreditation body, to attest to the competence of independent verification agencies. The NCN could perform this role, as well as overseeing the performance of verification agencies by allowing them access to appropriate records the national carbon registry. The agent could then check their own estimates of forest parameters against the forest inventory data recorded by the NCN and the forest owner in the carbon registry. The agent would then be required to write up a verification report, stating the precision of forest carbon inventory estimates. The verification agent would then file the report in the verification module of the national carbon registry. Upon receiving the verification report, the NCN could then certify the amount of forest carbon that is tradable, according to the precision of the inventory.

9.5.6 OVERSEE EMISSIONS TRADE/BROKERAGE SERVICES

An 'emissions clearing house' is essentially a mechanism for trading of CO_2 equivalents. An emissions clearing house should be run by an entity that is independent of the NCN kept separate from the NCN. Otherwise, there is potential for fraudulent activities such as inflated forest carbon inventory estimates to create additional carbon credits (Beil 1999). The NCN could act as the central governing body of the emissions clearing house, described further in Section 11.3.

PHASE THREE: EMISSIONS TRADE

Having measured, monitored and reported the amount of 'Kyoto eligible' forest carbon, a FCP owner may wish to participate in an emissions trading market. To do so, the FCP owner must determine the amount of forest carbon that they should make available for trade, and then proceed to enter the emissions trading market.

10 DETERMINE NUMBER OF CARBON CREDITS

Emissions trading will involve buying and selling of one-ton equivalent of CO_2 known as 'carbon credits'. Described below is the process by which a FCP owner can determine the amount of carbon that is eligible for trade as carbon credits, or 'Trade Eligible Carbon', TEC.

10.1 DETERMINE AMOUNT OF TRADE ELIGIBLE CARBON

There are four steps involved in calculating the amount of TEC. First, the FCP owner must determine the net amount of forest carbon for the first accounting period. This can be done using the stock change methodology, as explained in Section 5.2.1. The second step required to calculate TEC, is subtract stock of carbon to account for counterfactual[23] and measurement uncertainty of carbon estimates. This conservative approach will instill market confidence by ensuring that all carbon credits represent real and verifiable carbon storage. The third step in calculating the amount of TEC, is to subtract a buffer stock of carbon to account for risk of unexpected carbon loss[24]. To quantify risk, it is suggested that a FCP owner should undertake a qualitative risk assessment. The forest owner should retain a pool of forest carbon in reserve in proportion to the severity and frequency of risk events over the project lifetime. Another way of dealing with risk is to insure forest plantations. Then, in the event of a risk event occurring, the forest owner would be compensated for lost carbon credits and timber value. Another risk management strategy suited particularly to small forest owners, is the formulation of carbon 'pools', whereby a number of forest owners agree to spread the risk of carbon loss due to disturbance amongst a number of individuals. Responsibility for carbon credit acquittal in the event of

[23] Since counterfactual uncertainty is difficult to quantify, the FCP owner should undertake a risk assessment and estimate the uncertainty associated with yield forecasts to calculate the probable error of counterfactual assumptions.

[24] Note that in the event that a NCN has been established and the FCP owner contributes to a national risk management buffer via the 'carbon refund scheme' [Section 9.5.4], subtraction of carbon due to risk will not be required. Until a NCN has been established, a FCP owner would be prudent to voluntarily contribute to their own risk management buffer.

carbon loss would then become the shared responsibility of each of the carbon pool members. A similar principle can be applied to a single forest owner, whereby risk is spread across a “diverse portfolio of carbon sequestration projects” (Brown *et al*. 1997). Finally, a FCP owner should account for their own emission reduction quota before selling their carbon to another party. At present, it is uncertain as to how a country might proportion their allocated emission reduction quotas. In the event that individual sectors and companies are allocated an assigned amount of emissions, it would be wise for a FCP owner to meet their own emission reduction quota before selling their carbon.

11 EMISSIONS TRADE

The Kyoto Protocol allows carbon to be traded internationally via three mechanisms: Joint Implementation [JI], the Clean Development Mechanism [CDM] and International Emissions Trading [IET]. JI allows Emission Reduction Units [ERU’s] to be traded between Annex I countries [via linkage to a specific project, to the approval of both parties]. The CDM allows transferal of Certified Emission Reductions [CER’s] to an Annex I country from a non-Annex I country. International Emissions Trading [IET] has been included as a mechanism under Article 17 of the Kyoto protocol, and allows carbon to be traded at market value between Annex I countries.

Essentially, emissions trade enables a party to purchase or sell the right to emit a specified amount of GHG’s from another party (CO2e.com 2000). It is proposed that by allowing trade of emissions, parties will be able to meet their allocated emission quotas at least cost[25]. Emissions trade is particularly suitable to FCP’s, since the substantial initial establishment costs of a FCP can be financed through profit from the forward sale of forest carbon. The Sections below define the units of emissions trade, how these trading units will be allocated, and proposes a trading mechanism within the NCN.

11.1 DEFINING THE TRADING UNIT AND TRADING MECHANSIM

The primary unit of international emissions trade is likely to be one-ton CO_2 equivalent, or carbon credit. In selling of a carbon credit, a FCP owner promises to sequester a one ton equivalent of CO_2 in a specified year, and that this carbon should remain stored in the forest for a specified amount of time. A carbon credit cannot be used to meet Kyoto targets until the carbon is actually sequestered (State Forests NSW 2000). Depending upon the time of sale and storage of the forest carbon, there are three different types of trading mechanisms (CO2e.com 2000): A ‘forward sale’ of carbon credits occurs when a buyer agrees to purchase a carbon credit from the seller at a specified date in the future. A

[25] It has also been found that by allowing full trade of emissions, global GDP is expected to decline by 0.2% in 2010. This is compared to the expected decline of 0.5% in 2010 without emissions trading (Reuters News Services 2001).

'futures contract' is similar to a forward sale, but is tradable in it's own right, and is facilitated by a 'futures exchange' trading platform (CO2e.com 2000). Finally, carbon credits can be sold as 'options', which is entitles a buyer the right, but not the obligation to purchase carbon credits in the future.

11.2 ALLOCATION OF PERMITS

Although a formal international emissions trading market is yet to be established, it is expected that companies will be allocated a set number of 'emission allowances', the total of which will reflect the Kyoto target of the particular country. There are two main options for the initial allocation of emission allowances (AGO 1999b): administrative allocation, and auctioning. Administrative allocation (sometimes referred to as the 'grandfathering' approach) would involve distribution of emission permits to companies by the government. The number of emission permits allocated to each company might depend on level of historical emissions and/or the extent to which the industry would be adversely affected by greenhouse gas abatement (AGO 1999b). The administrative allocation of permits should also contain provisions for recognition of early emission abatement action. The alternative approach to administrative allocation, is auctioning. This would involve a system whereby a company would gain emission permits by purchasing them on an open market.

11.3 EMISSIONS TRADING WITHIN THE NATIONAL CARBON NETWORK

As described in Section 9.5.6, the NCN could act as the central governing body of the emissions clearing house. In order to gain a license to provide emissions trade/carbon brokerage services, a party would need to apply to the NCN. The applicant would need to provide adequate documentation to ensure they had a well-designed system in place that is capable of tracking all transactions in an efficient manner. The NCN would then oversee the performance of the clearing house, to ensure all transactions were accountable and legal. To assist the clearing house in providing an efficient, fully verifiable means of trading carbon, the NCN would provide the clearing house with direct access to the public accounts module of the carbon registry. The national clearing house would calculate the number of carbon credits for each forest grower wishing to participate in the market, and assign each carbon credit with it's own unique serial number, linked with the public accounts module of the national carbon registry. In this way, the national clearing house would keep track of carbon credits bought and sold via a simple double-entry accounting system (Lamb 1998). It is anticipated that individuals could actually trade 'on-line' via an electronic clearing house, which would also interface with the national carbon registry [Section 9.5.3]. This would enable prospective buyers instant access to information about the origin and nature of carbon credits on the market.

11.4 EXISTING EXCHANGES AND TRADING SYSTEMS

A large number of trades in forest carbon have occurred already. Initially, trades were largely project-specific [eg: In July, 1999, Tokyo Electric Power company agreed to purchase the carbon sequestered from planting 1000 hectares of forest from the State Forests of NSW]. As the emissions trading market progresses, however a greater number of trades will be facilitated by the ever-increasing number of emissions trading platforms. For example, GERT, A Greenhouse Gas Emissions Trading Pilot http://www.gert.org/; and Climate Partners http://www.climatepartners.com/index.cfm in Canada. In Australia, the . Queensland emissions trading platform, http://www.qetf.org/, and The Carbon Trader http://www.thecarbontrader.com/bottom.htm have been established. In the US, CO2e.com http://www.co2e.com/strategies/default.asp; and Trexler and Associates http://www.climateservices.com/ are large emissions trading platforms. To date, most exchanges occurring through trading platforms involve the buying and selling of options (CO_2e.com 2000). Most of these trading platforms encourage on-line trading, whereby a buyer or seller is required to register on the global trading platform. Once registered, the user can gain access to pricing information, and can proceed to place a bid to purchase carbon, or offer carbon for sale. An example of one of the worlds first on-line emissions clearing houses is CO2e.com, founded by Cantor Fitzgerald in association with Price Waterhouse Coopers. As an indicator of the success of on-line trading of carbon, between 60 to 100 trades had already occurred within weeks of launching the site, trading approximately 160 million tonnes of carbon (CO2e.com 2000).

CONCLUSIONS

The 'Kyoto Protocol', signed by the parties to the United Nations Framework Convention on Climate Change (UNFCCC) in 1997, allows countries to use carbon sequestered in forests as a means to meet internationally binding Greenhouse Gas reduction quotas. An international forest carbon accounting framework for measuring, reporting and trading of forest carbon is therefore required. This framework must provide incentive for sustainable forest management practices without compromising the integrity of the protocol, as well as providing a means of 'scaling up' carbon inventory.

An eleven step forest carbon accounting framework, designed to meet the reporting requirements of the Kyoto Protocol, is described in this paper. The process by which an operational-level forest carbon project owner can assess their need for a forest carbon project was discussed, and a range of forest management schemes were suggested. The report described how and why baselines should be measured, and discussed how field measurements, software packages and/or remote sensing can be used to conduct forest carbon inventory. The need for a monitoring, verification and certification system was highlighted. A National Carbon Network was proposed to act as a central carbon manager, to conduct a variety of forest carbon accounting and management roles, and facilitate efficiency in forest inventory and risk management. In order to commence trade of forest carbon, it was advised that risk, uncertainty and emission reduction targets should be taken into account when determining the amount of Trade Eligible Carbon. The unit of emissions trade was defined, and the variety of trading mechanisms and platforms were listed.

REFERENCES

AGO(a), 2000. National Carbon Accounting System, Available at www address <http://www.greenhouse.gov.au/ncas/files/consultancies/tool.html>, Accessed on 17th November.

AGO(b), 2000. System Design, 21, Australian Greenhouse Office, Canberra, ACT, pp. 21.

AGO, 1998. Greenhouse Challenge Vegetation Sinks Workbook - Quantifying Carbon Sequestration in Vegetation Management Projects, Australian Greenhouse Office, Canberra, ACT, pp. 20.

Avery, T. E. and H.E. Burkhart, 1983. *Forest measurements.* McGraw-Hill Book Company, New York, pp. 331.

Baker, J. and A. Luckman, 2001. Radar remote sensing of forests, Available at www address <http://www.soc.soton.ac.uk/RSADU/forests.html>

Beil, S., 1999. Evolution and Design of an Emissions Trading Market for Greenhouse Gases. Presented at the *2nd Annual Emissions Trading Forum,* Sydney, Australia.

Birdsey, R. A., and L.S. Heath, 1995. Carbon changes in U.S. forests. IN: Joyce, L. A., ed. Productivity of America's forests and climate change., RM-271, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO, pp. 70.

Birdsey, R. A., 1992. Carbon Storage and Accumulation in U.S. Forest Ecosystems. General Technical Report, WO-59, U.S. Department of Agriculture.

Blair, R., 1999. Carbon Trading in Australia, Available at www address <http://www.mckeanpark.com.au/>, Accessed on 17th November.

Bonnor, G. M., 1985. Inventory of Forest Biomass in Canada, Canadian Forest Service, Petawawa National Forestry Institute, Hull, PQ.

Bortoluzzi, B, 2000. Review of recent forest research projects on climate change and CO2 concentrations in Europe, European Forest Institute, Joensuu, Finland, pp. 52.

Boscolo, M., M. Powell, M. Delaney, S. Brown and R. Faris, 2000. The cost of Inventorying and Monitoring Carbon. *Journal of Forestry,* **98,** 24-31.

Brack, C. L. and G.B. Wood, 1998. Forest Mensuration - Measuring trees, stands and forests for effective forest management., Available at www address <http://www.anu.edu.au/Forestry/mensuration/BrackandWood1998/MENSHOME.HTM>, Accessed on 25th February.

Brown, P., B. Cabarle and R. Livernash, 1997. *Carbon Counts - Estimating Climate Change Mitigation in Forestry Projects.* US: World Resources Institute, pp. 32.

BRS, 2000. A pilot study to identify appropriate ways of conducting a national farm forest inventory in Australia, Bureau of Rural Sciences. Available at www address <http://www.brs.gov.au/nfi/nffi/ausfor.html>, Accessed on 30th November.

Cairns, M. A., S. Brown, E.H. Helmer and G.A. Baumgardner, 1997. Root biomass allocation in the world's upland forests. *Oecologia,* **,** 1-11.

Calman, S., 1998. Technical Design Issues for a Domestic Emissions Trading Regime for Greenhouse Gases: A working paper, New Zealand Ministry of Environment, Wellington, pp. 62.

Cathcart, J. F., 2000. Carbon Sequestration. *Journal of Forestry,* **9,** 32 - 37.

CCRS, 2000. Net Carbon Absorption/Release by Plants and Soils: Net Ecosystem Productivity (NEP), Canadian Centre for Remote Sensing. Available at www address <http://www.ccrs.nrcan.gc.ca/ccrs/tekrd/rd/apps/em/beps/bepse.html>, Accessed on March 2001.

CCRS, 1999. The Boreal Ecosystem Productivity Simulator, Canadian Centre for Remote Sensing. Available at www address <http://www.ccrs.nrcan.gc.ca/ccrs/tekrd/rd/apps/em/beps/bepse.html>, Accessed on April 20th.

Chomitz, K. M., 2000. Evaluating carbon offsets from forestry and energy projects: How do they compare?, Development Research Group, World Bank,, pp. 25.

CO2e.com, 2000. CO2e.com website, Available at www address <http://www.co2e.com/>, Accessed on 27th November.

Ecosecurities Ltd., 1999. The ECO2 Model for Forest Carbon Quantification, Available at www address <http://www.ecosecurities.com/>, Accessed on March.

Ewel, C. W. P. Jnr. And K.C. Ewel, 1984. Carbon Storage Patterns in Douglas-Fir Ecosystems. *Canadian Journal of Forest Research,* **14,** 855-859.

FCCC/SB, 2000. Mechanisms Pursuant to Articles 6, 12 and 17 of the Kyoto Protocol - Registries, Presented in *Conference of the Parties 6* Framework Convention on Climate Change/ Subsidiary Body for Scientific and Technological Advice and Subsidiary Body for Implementation, The Hauge, Netherlands, pp. 10.

GHG Protocol Initiative, 2000. Corporate Greenhouse Gas Inventories: Proposed Reporting Standard, Guidance and Estimation Tools, Greenhouse Gas Protocol Initiative, pp. 45. Available at: http://www.ghgprotocol.org/

Greenfield Resource Options, 2000. Bush For Greenhouse - Field Measurement Procedures for Carbon Accounting, Australian Greenhouse Office, Canberra, pp. 28.

Harkin, Z. and G. Bull, 2000. Towards Developing a Comprehensive Carbon Accounting Framework for Forests in British Columbia. International Institute for Applied Systems Analysis, Laxenburg, Austria. Available at: http://www.iiasa.ac.at/Publications/Documents/IR-00-046.pdf

Harmon, M. E., B. Marks and N.R. Hejeebu, 1996. A Users Guide to STANDCARB. Version 1.0. A Model Used to Simulate the Carbon Stores in Forest Stands, Oregon State University, Oregon.

Haynes, B. E. and S.T. GowerS, 1995. Belowground Carbon Allocation in Unfertilized and Fertilized Red Pine Plantations in Northern Wisconsin. *Tree Physiology,* **15,** 317-325.

Hopp and Associates, 1999. The Noel Kempff Mercado Climate Action Project Bolivia, Available at www address <http://www.ecolaw.com/projnoel.html>, Accessed on 7th December.

IEA Bioenergy, 1998. The Role of Bioenergy in Greenhouse Gas Mitigation, IEA Bioenergy Task 25. Position Paper. November 1998 Available at: http://www.joanneum.ac.at/iea-bioenergy-task38/publication/fpubl.htm.

IEA Bioenergy, 2001. Models developed and applied by Task participants for work relevant to Task 25. IEA Bioenergy website. Available at: http://www.joanneum.ac.at/iea-bioenergy-task38/model/fmodel.htm

IISD, 2000. Earth Negotiations Bulletin - Summary of the sixth conference of the parties to the framework convention on climate change, Vol. 12, No. 163, International Institute for Sustainable Development, The Hauge, pp. 38.

IPCC, 1996. Revised 1996 Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change.

Jerkman, P. a. J. Remrod, 1999. *Forests and the Climate.* Elanders Gummerssons, Falkoping, pp. 19. Available at: http://www.forestindustries.se/pdf/forests_and_the_climate.pdf

Kurz, W. A., S.J. Beukema and M.J. Apps, 1998. Carbon Budget Implications of the transition from natural to managed disturbance regimes in forest landscapes. *Mitigation and Adaptation Strategies for Global Change,* **2,** 405-421.Kurz, W. A., M.J. Apps, T.M. Webb and P.J. McNamee, 1992. The Carbon Budget of the Canadian Forest Sector: Phase 1, NOR-X-326, Forestry Canada Northwest Region, Edmonton AB.

Lamb, K., 1998. Carbon Sequestration Program. The State Forests of NSW Integrated Carbon Accounting, Available at www address <http://www.forest.nsw.gov.au/Frames/f_carbon.htm>, Accessed on 1st December, 1999.

Lempriere, T., 2000. Email to Zoe Harkin, 14th December 2000.

Liu, J., J.M. Chen, J. Cihlar and B. Park, 1997. A Process-Based Boreal Ecosystem Productivity Simulator Using Remote Sensing Inputs. *Remote Sensing of Environment*,**,** 158-175.

Lowe, H., G. Seufert and F. Raes, 2000. Comparison of methods used within Member States for estimating CO2 emissions and sinks according to UNFCCC and EU Monitoring Mechanim: forest and other wooded land. *Biotechnologie, Agronomie, Société et Environnement,* **4,** 315-319.

Lowe, J. J., Power, K., and S.L. Gray, 1996. Canada's Forest Inventory 1991: The 1994 Version, Canadian Forest Service, Pacific Forestry Centre, Victoria BC, pp. 22pp.

Obersteiner, M. Y.M. Ermoliev, M. Gluck, M. Jonas, S. Nilsson, A. Shvidenko, 2000. Avoiding a Lemons Market by Including Uncertainty in the Kyoto Protocol: Same Mechanism - Improved Rules., IR-00-043, International Institute for Applied Systems Analysis, Laxenburg, Austria, pp. 20. Available at: http://www.iiasa.ac.at/Publications/Documents/IR-00-043.pdf

MacDicken, K. G., 1997. A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects. Winrock International Institute for Agricultural Development. Forest Carbon Monitoring Program,, pp. 87. Available at: http://www.winrock.org/REEP/PDF_Pubs/carbon.pdf

Meil, J., 2000. In *Letter to the Globe and Mail.* 11th May, 2000. Canada.

Meridian Institute, 2000a. Proposal for a global dialouge on an independent carbon accounting standard setting and certification system, Meridian Institute, Washington, pp. 9.

Micro-Tek (1999) GERT - Offer to sell. Application No. S5(Ed, Kean, M.), pp. 6 Available at: http://www.gert.org/listings/documents/PDF/s5.pdf.

Mohren, G. M. J., J.F. Garza Caligaris, O. Masera, M. Kanninen, T. Karjalainen and G.J. Nabuurs, 1999. CO2FIX for windows: a dynamic model of the CO2 fixation in forest stands, Institute for Forestry and Nature Research. European Forest Institute, Joensuu Finland, pp. 27pp.

Mohren, G.M.J. & C.G.M. Klein Goldewijk, 1990. CO2FIX: A dynamic model of the CO2-fixation in forest stands., Research Institute for Forestry and Urban Ecology, Wageningen, The Netherlands, pp. 35pp.

Moura Costa, P. 2000. Project duration and accounting methods, Available at www address <http://www.ecosecurities.com/download/PMC_Carbon_Accounting_methods_and_Project_Duration_2000.pdf>, Accessed on 22nd January.

Moura Costa, P., M. Stuart, M. Pinard and G. Phillips, 2000. Elements of a certification system for forestry-based carbon offset projects, Ecosecurities Ltd., pp. 18.

Moura Costa, P. and. C. Wilson, 1999. An equivalence factor between CO2 avoided emissions and sequestration - description and applications in forestry. Ecosecurities Ltd., Oxford, UK, pp. 11.

Natsource 2000. Greenhouse Gas Emissions Trading: Case Studies, Available at www address <http://www.natsource.com/environmental/ghg/case.html>, Accessed on 12th December 2000.

Natural Resources Canada, 2001. National Forest Information System, Earth Observation for Sustainable Development of Forests, Available at www address <http://nfis.cfs.nrcan.gc.ca/eosd.html>, Accessed on March 2001.

NGGIC 1998. Land Use Change and Forestry Workbook for Carbon Dioxide from the Biosphere, Workbook 4.2 (with supplements), National Greenhouse Gas Inventory Committee, Australian Greenhouse Office, Canberra, ACT.

Pape, A. and J. Rich., 1998. Options For Guiding Greenhouse Gas Emission Baseline Determination, CERI Alberta Offset Development Workshop, pp. 21.

Pelangio Mines, 2000. Carbon Offset Credits, Available at www address <http://www.pelangio.com./Ctrade/2ctrade.htm>, Accessed on 6th December, 2000.

Penner, M., K. Power, C. Muhairwe, R. Tellier and Y. Wang, 1997. Canada's Forest Biomass Resources: Deriving Estimates from Canada's Forest Inventory, BC-X-370, Natural Resources Canada.

Reuters News Service, 2001. Emissions trading cuts Kyoto economy impact – study. Amsterdam, Netherlands. 11th April. Available at: http://www.planetark.org/dailynewsstory.cfm?newsid=10483

Richards, G. and D. Evans, 2000. Carbon Accounting Model for Forests (CAMFor) User Manual. Version 1.0, Australian Greenhouse Office, Canberra, Australia, pp. 17pp.

Rombold, J., 1996. A Bibliography on Carbon Sequestration and Biomass Estimation, Winrock International Institute for Agricultural Development, Washington, pp. 35.

Rotter, J. and K. Danish, 2000. Forest Carbon and the Kyoto Protocol's Clean Development Mechanism. *Journal of Forestry,* **98,** 38-47.

Running, S. W. and J. C. Couglhan, 1998. A general model of ecosystem processes for regional applications., I. Hydrologic balance, canopy gas exchange and primary production processes. *Ecol. Model.,* **,** 125-154.

Running, S. W. and S. T. Gower, 1991. Forest-BGC, A general forest model for forest ecosystem processes, II. Dynamic carbon allocation and nitrogen budgets. *Tree Physiology,* 147-160.

SBSTA, 2000. Methodological Issues - Land Use, Land Use Change and Forestry, Presented in *Sixth Conference of the Parties* Subsidiary Body for Scientific and Technological Advice, The Hauge, Netherlands, 18th November 2000, pp. 12. Available at: http://www.unfccc.int/resource/docs/2000/sbsta/crp11.pdf

Schlamadinger, B. and G. Marland, 2000. Land Use and Global Climate Change - Forests, Land Management and the Kyoto Protocol., Pew Centre on Global Climate Change, pp. 54. Available at: http://www.pewclimate.org/projects/land_use.cfm

State Forests of NSW 2000. Draft Carbon Accounting Standard for Planted Forests, Version 1.4, State Forests of NSW,, pp. 22.

State Forests of NSW, 1998. Carbon Sequestration Program. The State Forests of NSW Integrated Carbon Accounting Program., Available at www address <http://www.forest.nsw.gov.au/Frames/f_carbon.htm@gems4.gov>, Accessed on February.

TBFRA, 2000. Forest Resources of Europe, CIS, North America, Australia, Japan and New Zealand, United Nations Economic Commission for Europe. Food and Agriculture Organization of the United Nations. Timber Section., Geneva. Available at: http://www.unece.org/trade/timber/fra/pdf/contents.htm

Tetlock, P. E. and A. Belkin, 1996. Counterfactual Thought Experiments in World Politics. *Social Science Research Council,* **50** (4) Available at: http://www.ssrc.org/decemitems1.htm

The Nature Conservancy, 2000. Climate Action: Noel Kempff Mercado National Park, Available at www address <http://www.tnc.org/climatechange/noel1.html>, Accessed on 7th December.

Thornley, J.H.M. and M.G.R. Cannell, 2000. Managing forests for wood yield and carbon storage: a theoretical study. *Tree Physiology*. **20**, 477-484.

UNFCCC, 1997. The Kyoto Protocol. United Nations Framework Convention on Climate Change. FCCC/CP/L.7/Add.1. 10 December, 1997.

UNFCCC, 1994. Understanding Climate Change: A Beginner's Guide to the UN Framework Convention. United Nations Framework Convention on Climate Change Available at: http://www.unfccc.de/resource/beginner.html

UNFCCC, 1992. United Nations Framework Convention on Climate Change. Available at: http://www.unfccc.de/resource/conv/index.html

UNIDO, 2000. Determining Baselines and Additionality for Clean Development Mechanism/Joint Implementation Projects, United Nations Industrial Development Organization. Available at www address <http://www.unido.org/doc/331158.htmls>, Accessed on 15th February.

van Kooten, G. C., C.S. Binkley and G. Delcourt, 1997. Effects of Carbon Taxes on Optimal Forest Rotation Age and Supply of Carbon Services, 210, Forest Economics and Policy Analysis Research Unit, Vancouver.

Vanderborght, B., 2000. From GHG Measurement to Management - Holderbank's experience with the CO2 issue, Presented in *WBCSD/WRI*, 4th October 2000.

VCR, 2000. Voluntary Challenge Registry - Client Detail, Available at www address <http://www.vcr-mvr.ca/ClientDetail.cfm?No=2355>, Accessed on 9th January, 2001.

Vine, E., J. Sathaye and W. Makundi, 1999. Guidelines for the Monitoring, Evaluation, Reporting, Verification and Certification of Forestry Projects for Climate Change Mitigation., LBNL-41543, Ernest Orlando Lawrence Berkeley National Laboratory. Environmental Energy Technologies Division., Berkeley, CA, pp. 146.

Watson, R. T., I.R. Noble, B. Bolin, N.H. Ravindranath, D. J. Verardo, D.J. Dokken (2000). IPCC Special Report on Land Use, Land-Use Change and Forestry, Intergovernmental Panel on Climate Change. Available at: http://www.grida.no/climate/ipcc/land_use/index.htm

Weir, G., 2000. Email to Zoe Harkin. 14th November, 2000. Victoria, BC.

West, G. G., 1997. STANDPAK Evaluation of the Effects of Site, Silviculture and Genetics on Mean Log Age and the Proportion of Juvenile Wood. *New Zealand Journal of Forestry Science,* **27,** 324-342.

Winrock, 2000. Practical Experience from Pilot Projects: The Noel Kempff Climate Action Project, Bolivia, Available at www address <http://www.winrock.org/REEP/BoliviaNK.htm>, Accessed on 7th December.

ACKNOWLEDGEMENTS

The authors would like to thank Forest Research BC, the BC Ministry of Forests and the University of British Columbia for funding this research. Utmost appreciation to all at the IEA Bioenergy Taskforce 25/38, the forestry project at the International Institute for Applied Systems Analysis and The University of Melbourne. Thank-you to Charley for Gary for encouragement and tolerance of geographical disparities.

APPENDIX

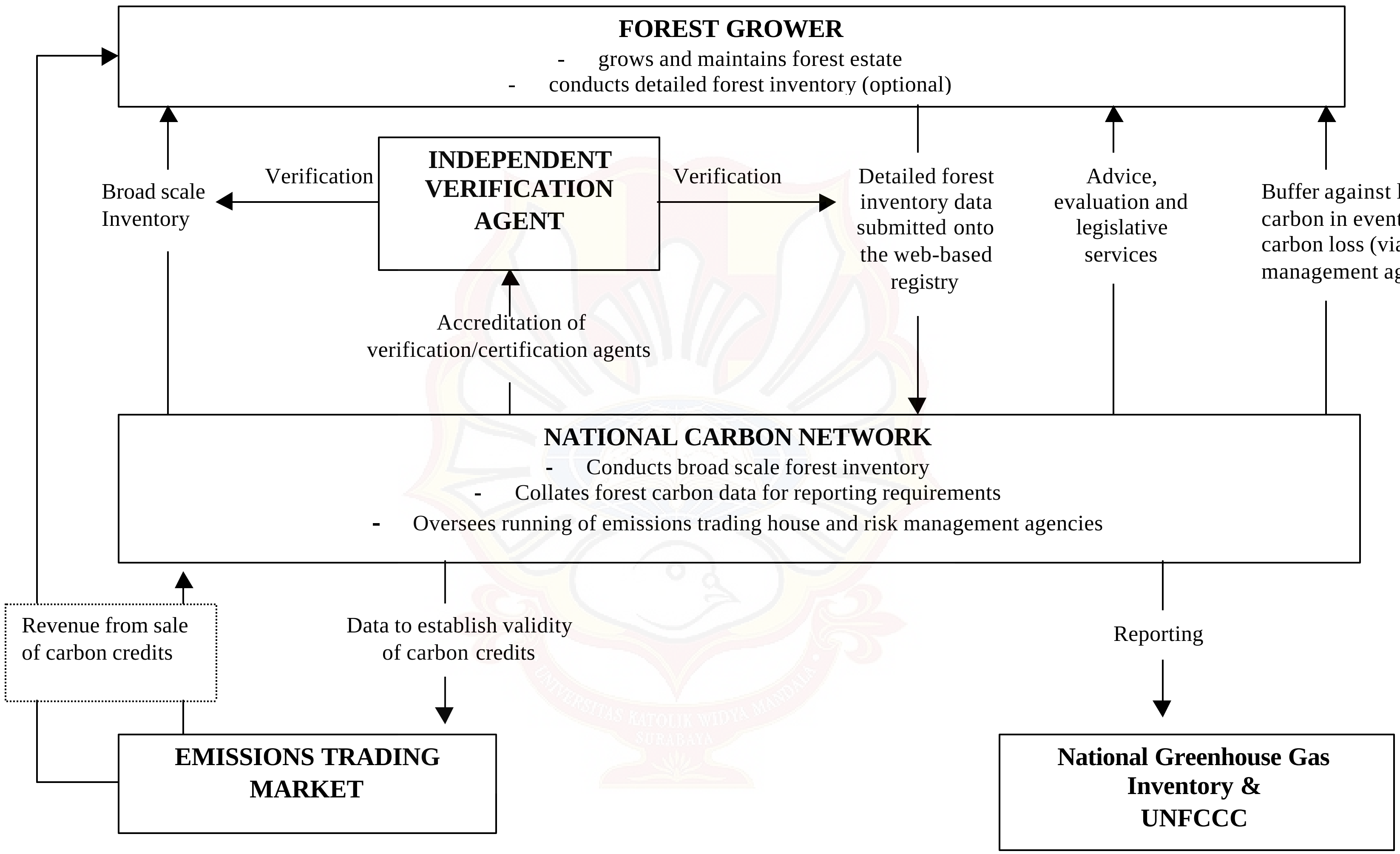


Figure A1: Relationship between the forest grower, the National Carbon Network and the UNFCCC, showing how operational level inventory is scaled up to a national and international level.

In Search of the Carbonic Truth:

Carbon Accounting

Prepared by:

Mark Anielski
Senior Fellow
Redefining Progress
San Francisco/Washington D.C.

&

President, Anielski Management Inc.

AMI

….accounting for a sustainable future…
Edmonton, Alberta, Canada

Presented at the Parkland Institute Conference *Global Village or Global Pillage: Rethinking Citizenship in a Corporate World*, November 14, 1998 session titled "Beyond Kyoto: Natural Resource Policy and the Environment."

In Search of the Carbonic Truth — Carbon Accounting

"*We admit there is a problem, but we argue that the Kyoto accord is unachievable and would have very serious impacts on Alberta*." (Premier Ralph Klein, Edmonton Journal)

Introduction

Premier Klein's statement that the Kyoto protocol is both "unachievable" and "would have serious impacts on Alberta" remains largely unchallenged by concrete evidence or full account of Alberta's carbon balance sheet and income statement. In the absence of such an accounting, political rhetoric tends to precede strategic analysis and physically practical and economically pragmatic action. There is little doubt that the liability of Kyoto challenge, if born mostly by Alberta's energy sector, would be both onerous and indeed one could argue, unfair. Without a provincial and national carbon account or inventory, both physical and monetary, it will be impossible to know how onerous or unfair that expectation might be.

Both the pre-Kyoto preparations and the current response to the Kyoto Protocol lacks a strategic assessment and full accounting of the current stock, flow and monetary value of carbon as an environmental service in our natural environment and economy. Every enterprise, whether business or government, requires a plan and a budget that articulates a desired performance outcome, based in part on a retrospective accounting of the past and a sobering reflection on current knowledge and on what is considerable pragmatically achievable. I would argue that such a practical approach to the greenhouse gas emission reduction challenge is still missing in the post-Kyoto dialogue.

To date, no practical set of carbon accounts have been established for either Alberta or Canada, although carbon budgets have been under development for several years. Undoubtedly, accounting for carbon stocks and fluxes is a complex issue as it relates to forest ecosystems that requires careful scientific analysis. Despite efforts by the Canadian Forest Service since at least 1991 in development of a national carbon budget for forests, "the results are not yet complete."[1] Apps and Kurz (1997) have studied carbon stocks and fluxes in the Boreal-Cordellian forest of Alberta with some important preliminary findings, upon which we will reflect. However, we still lack a plain-language account of the current stock and annual sequestration rates of Alberta's forests that are so vital to the Kyoto challenge. In the absence of national and provincial carbon account of stocks, flows, and economic values, all discussions and strategies for carbon management, carbon credits, carbon sinks, voluntary reductions and other policy responses to the Kyoto Protocol are being made in an information and knowledge

[1] Canadian Council of Forest Ministers. 1998. Criteria and Indicators of Sustainable Forest Management in Canada : Technical Report 1997. P. 58.

vacuum. Such accounting is fundamental to establishing a realistic and economically feasible plan of action

The carbon accounts would provide a reality check on the physical and economic opportunities for carbon management. How large is Alberta's net carbon deficit? What role do forests and peatlands currently play in the carbon cycle and in sequestering anthropogenic emissions? Are they net sources or sinks of carbon? What are the economic value of the services of forests and peatlands in sequestering carbon? What are the economics of carbon management options, including planting of hybrid poplar, aforestation and reforestation and how do these compare with others? How important is fire and forest management to managing carbon? These are just some of the questions to which a full carbon capital account could provide answers.

These accounts would enlighten Premier Klein's lament that the "Kyoto accord is unachievable and would have serious impacts on Alberta."

We are then empowered to devise a realistic game plan, one which is economically and physically achievable. We would be better prepared to manage our carbon deficit and net carbon debt, if we had a "carbon business plan and budget."

My concern is that we may be naively optimistic about both the physical and economic carbon benefits from some carbon management strategies, particularly in intensive management of our forests and agricultural soils. I have openly hypothesized whether or not attempts to increase the sequestration capacity of forests through ecosystem management would make a measurable dent in Alberta's carbon deficit. Undoubtedly, some of these options buy us time while searching for technological solutions that reduce absolute carbon emissions in combination with a shift to renewable energy resources.

More importantly, is that many of the carbon management investment options, which may already exceed the current market value of carbon, face the ongoing risk from random catastrophic natural disturbances, such as the 1998 fire season (the second largest area burned on record). These "acts of God" pose enormous threats in our efforts to manage our ecosystems for maximum carbon storage. Indeed, I wonder whether we can actually improve upon a carbon cycle that, governed by the laws of thermodynamics, tends towards a steady state.

In the end, if our consumption of low-entropy non-renewable energy resources is out of balance with the natural carrying capacity and indeed the laws of physics, it is the absolute throughput of carbon from anthropogenic sources that we must ultimately reduce. Agreement that the second law of thermodynamics and the principles of the entropy hourglass of Goergescu-Roegen (1971) actually rules and bounds our economic existence (our oikos or household) is itself a theological "Everest", as environmental economist Dr. Herman Daly discovered while at the World Bank. As Daly (1994; 13)) in *For the Common Good* the ideology of our post-industrial age remains one which "rely heavily on non-renewable resources and tend to exploit renewable resources and waste absorption capacities at nonsustainable rates." It is the rate at which the absorptive capacity of our renewable natural capital base which is of interest to me since if we are to achieve Goergescu-Roegen's vision of ensuring the conversion of low-entropy matter-energy is reduced to a level that does not tip the entropy balance and that we ultimately move to a society that lives sustainably off renewable natural capital income flows, ultimately off solar income. Of course the economic implications that such a physics constraint would imply are simply anathema to most who view the economic system as capable of infinite exponential growth defying even the laws of physics.

There is little doubt that the challenge of climate change is one of the most important and complex challenges in human history. Most would agree that "climate change is emerging as one of the central policy concerns of our time" (Decanio, 1997). Indeed 2,500 economists, including eight Nobel Laureates in economics, from the United States recently signed a public statement stating unequivocally that "as economists, we believe that global climate change carries with it significant environmental, social, and geopolitical risks, and that preventive steps are justified" to deal with the risks (economic) of global climate change. Indeed the high degree of consensus amongst economists is remarkable for an issue that is largely a non-market and intangible issue that resides outside the traditional scope of economic and national income accounting, such as GDP.

The signing of the Kyoto Protocol and Canada's own commitment to reduce carbon emissions was a endorsement that climate change is perceived to be real, at least the economic consequences of a change in climate, regardless of whether there is a definitive scientific link between the consumption of non-renewable high-carbon energy and changes in climate. Indeed, one of the most tangible pieces of market evidence of the costs of climate change are the soaring insurance payouts and economic losses to property and persons as a result of environmental calamities, some of which might yet be linked to our unsustainable use of non-renewable energy.[2]

The Need for Natural Capital Accounts

In my view it is imperative that provinces and the federal government develop policy on the basis of the best historical performance evidence. In the case of management of natural capital resources, prudent management necessitates a full set of integrated natural capital accounts, including a full stock, flow and monetary account for carbon. While such accounts cannot, in themselves, provide answers to the policy challenges we face, they at least form the basis for a more enlightened discussion of what is realistically possible in the stewardship of our natural capital wealth we inherited.

---

[2] One aspect that is not accounted for is the increasing rate of depletion of our natural resource capital (both renewable (timber) and non-renewable (fossil fuels) to rebuilt and refurbish property and produced assets that have been destroyed or damaged due to environmental calamities and climate change.

Preliminary natural capital accounts were attempted in 1992 for Alberta's forests (Anielski, 1992), carbon (Anielski, 1992), oil and gas (Smith, 1992), and agricultural soils (Lerohl, 1992). The carbon account I presented in 1992 at the second meeting of the International Society for Ecological Economics in Stockholm, Sweden, along with the first Canadian timber capital account. This first back-of-the envelope carbon account, while crude, provided a plain language assessment of Alberta's carbon balance sheet and income statement with respect to forests and peatlands. It was my hope that such natural capital accounts would provide a tool for more prudent natural resource management for Alberta's vitally important natural capital stocks: oil, gas, coal, forests, and productive agricultural soils. This work was based on the resource accounting work of Robert Repetto of World Resources Institute, Washington, D.C. in 1991 in the case of natural resource accounts for Indonesia. The United Nations Statistical Office and the World Bank have since made considerable progress in advancing the framework and tools for natural capital accounting as part of the existing System of National Accounts used by virtually every nation in accounting for GDP and national income.

Unfortunately, while resource accounting has made important inroads it has not yet been fully adopted in Canada, the U.S. or other OECD nations, as part of an integrated set of ecological and economic national accounts. In the U.S. attempts at constructing natural capital accounts by the Department of Commerce met with resounding opposition from the Kentucky coal industry which successfully lobbied for a "stop work" order on the development of mineral resource accounts. The basis for the coal industry's anxiety remains a mystery to those of us who advocate environmental accounting.

Despite these apparent setbacks, I am continually surprised by the positive feedback I receive when presenting the forest (timber), carbon, and energy accounts for Alberta, regardless of the audience. The accounts are apparently relevant to a plain-language discussion of how to account for sustainable resource development. I believe in the need for natural capital accounts at the national and provincial level simply because it makes good policy sense. The accounts provide an important inventory and account of the sustainable development and sustainable income stream from Alberta's natural capital.

Complex Carbon Budgets Emerge at Glacial Speed

Kurz and Apps (1992) and Price et.al. 1997) have been developing complex carbon budgets for Canada that estimate the exchange of carbon in forest ecosystems. They attempt to track the flow of carbon both amongst and between forest biomass, forest soils, forest products, and peatlands. These are complex carbon input-output models of the flows of carbon between trees, atmosphere, soils and timber products as well as the flow of carbon released from fires and other natural disturbances to the atmosphere and forest soils. These models are under continuous refinement as scientist learn more about the complexity of where these molecules of carbon end up. Our particular carbon accounting focus is on the potential carbon sequestering capacity of the growing forest biomass and peatlands in terms of net carbon income from the net growth of the forests and peatlands.

These complex carbon budgets are still under development and are subject to the normal caveats of incomplete knowledge and data. The bottom line is that we simply do not have complete knowledge of the carbon budget for Alberta or Canada at this stage.ue nature of stocks and flows in the case of Canada's forest. Much scientific evidence needs to be gathered and discerned before a more definitive full carbon account emerges.

On a global scale, the Canadian Forest Service carbon budget for 1985-1989 (Canadian Council of Forest Ministers (CCME), 1998) estimates that roughly 100,000 million tonnes of carbon per year (roughly half of the total annual carbon dioxide exchange) is attributed to global forest ecosystems which represent vast carbon pools of some 1,500,000 million tonnes of carbon in soils and 650,000 tonnes in forest biomass.

These same studies estimate that in Canada, roughly 221,000 million tonnes of carbon are stored in our forest ecosystems. Apps and Kurz (1992) estimated that for 1986 Canada's entire forest ecosystem served as a net sink sequestering an estimated 76.858 million tonnes of carbon. In the most recent estimates covering 1985-1989 the Canadian Forest Service (CCME, 1998) estimates the following net flows of carbon:

• Forest biomass pool	- 79 million tonnes
• Forest products pool	+ 23 million tonnes
• Forest soils pool	+ 19 million tonnes
• Peatlands pool	+ 26 million tonnes
Total Net Sink/Surplus (Source/Deficit)	- 11 million tonnes
Including	
• Fossil fuel used by forest industry	– 4.8 million tonnes
Total Net Surplus/Sink (Deficit/Source)	-15.8 million tonnes

Thus the most recent evidence suggests that Canada's forest have actually been a net source or in net deficit of some 11 million tonnes of carbon (or a 15.8 million tonne deficit when including fossil fuel used by the forest industry). This represents a significant departure from estimates for 1920-1975 which estimated that the forest biomass and soil pools were massive net sinks. In fact the amount of carbon stored in the total forest ecosystem biomass declined by 18% from 1970 to 1989 (CCME, 1998) with a loss not so much to the atmosphere but rather to the soil pool. However since 1985 the soil pool and the standing forest biomass pool have lost carbon as the figures indicate. This apparently due to the increase in fire and insect disturbances that have increased in the 1980s and 1990s.

The Kurz and Apps (1992) carbon budget for Canada estimated Canada's total Boreal West ecoregion carbon balance as a net sink of 14.189 million tonnes of carbon in 1986 (based on estimates of carbon fluxes from net forest growth, natural disturbance releases to the atmosphere, sequestration by soils and transfers to forest products). For the Cordellian forest ecoregion (which constitutes much of the Eastern Slopes forests of

Alberta) Kurz and Apps (1992) estimated a net sink of 7.0 million tonnes of carbon. These balances will change dramatically due to the influence of forest fires on the carbon budget.

In addition, they have recently develop a comprehensive assessment of carbon stocks and fluxes in the Boreal-Cordellian ecoregions, namely the Foothills forest region of Weldwood of Canada's FMA. These accounts provide more precise estimates of the complex input and output flows of carbon from forest growth, fires, insect, harvesting, soils, peatlands, forest products, and the atmosphere. Their initial 1986 carbon budget suggested that the Boreal-Cordellian forests of Alberta were net sinks of carbon. However, there is considerable debate as to whether forests are net sinks or sources of carbon, particularly given the importance of catastrophic forest fires which can release massive tonnes of carbon to the atmosphere and which then destroy carbon sequestering trees, in the short term. Indeed, the Canadian Forest Service notes that Canada's' forests may have become net sources of carbon beginning in 1985 due to fires (Canadian Forest Service, 1998).

Exactly how and where anthroprogenic emissions find a sink sustains a scientific debate. Indeed, the methodologies and science for quantifying carbon dioxide removal from the atmosphere are still poorly developed (Hormug, 1998). This may be one of the reasons that scientist studying the carbon budget model have been reluctant to present a definitive carbon budget model, to date. However, under the circumstances, even crude estimates become relevant to framing our policies and strategies.

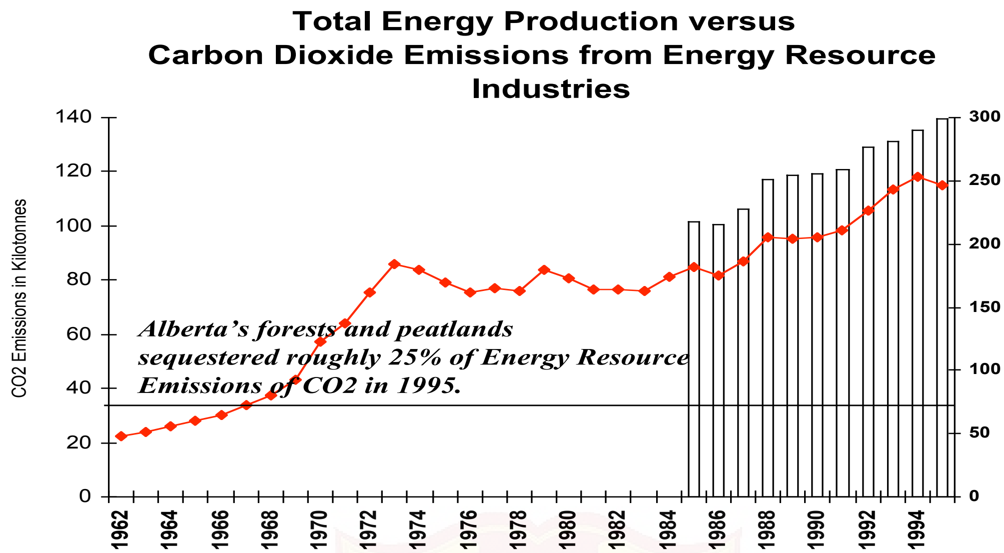
These question are fundamental however to our inquiry and determining whether the investments we are now considering in terms of biophysical carbon management make economic or financial sense, let alone carbonic sense. It may be that in the end our solution to carbon management must come from the absolute reduction of emissions from their anthropogenic source while ensuring maximum natural system sequestration capacity.

Alberta's Contribution to the Greenhouse Problem

The main greenhouse gases include CO_2, methane, nitrous oxides, and chlorofluorocarbons (CFCs). Of these gases CO_2 is the most important greenhouse gas. Total Alberta CO_2 in 1995 were estimated at 152 million tonnes of carbon dioxide or 41.523 million tonnes of carbon C equivalent. Compared to global CO_2 emissions of 5,650 million tonnes of C equivalent per annum, Canada contributed roughly 2.7 percent to the total global emissions in 1988 (Jaques 1990, p.4). Alberta's CO_2 emissions in 1988 were roughly 124 million tonnes or 33.9 million tonnes[3] of C equivalent; 23.3 percent of the national total emission.

[3] Carbon, by weight, constitutes 27.3% of a carbon dioxide molecule.

Chart 52



Source: Canadian Association of Petroleum Producers..
AUEB: Energy Conservation Board (1994). Energy Requirements for Alberta: Supplemental Report 1994-2008.
Environment Canada, Canadian Emissions Inventory of Common Air Contaminants
Note: IncludesC02 emissions from coal electric generation which made up 30% of total emissions in 1995.

The above chart shows the increase in carbon dioxide emissions (bar chart) in Alberta 1988-1995 compared with the long term production of non-renewable energy resources (oil, gas, and natural gas by-products, the line chart). Generally, CO_2 emissions have tracked total energy production. Between 1990 and 1995 Canada's emissions of total greenhouse gases (GHG) grew by 9.5 percent (Environment Canada, 1998). Canada's carbon dioxide emissions from fossil fuel use increased 9% from 1990 to 1995 while Alberta's emissions of carbon dioxide grew by 8.2% between 1990 and 1995 (Environment Canada, 1998, www2.ec.gc.ca/climate/fact and Alberta Environmental Protection, 1996, personal communication).

Where is the excess carbon going?

According to Environment Canada (1998) and scientists, global atmospheric carbon dioxide concentrations have increased by 4% in the decade between 1987 and 1996 and are believed to be the highest concentrations (360 ppm) in the last 220,000 years, based on glacial ice core analysis. As these scientists note, the growth in global atmospheric carbon dioxide emissions follows the trend in global emissions of carbon dioxide.

It is this increased concentration of carbon dioxide in the atmosphere which is being attributed to global warming and climate change.

If much of the increase in carbon dioxide output is finding itself in increasing concentrations in the atmosphere, including water and ice (as many such as Mike Apps and others suspect might be the missing sink), then what role at all might forests and peatlands play in the sequestration of anthropogenic emissions? Common sense would suggest that based on the global carbon account that our forests and peatlands of Alberta may already be in a steady state and thus play little role in sequestering increasing amounts of anthropogenic sources of carbon. Ironically, as noted earlier, Canada's forests and peatlands might already be in a net deficit as a net source of carbon as evidenced by estimates of increased net carbon flux to the atmosphere as per the Canadian carbon budget 1985-1989 (Kurz and Apps), even before we consider the anthropogenic emissions issue. This would imply that our net carbon deficit for Alberta might actually be significantly higher when considering the net source of carbon from Boreal-Cordellian ecoregions and the tonnes of carbon released through fossil fuel production and use in the province.

If so why are we spending time and money tinkering with what may amount to be rather insignificant adjustments at the margin of a giant net deficit elephant? What are the relative economic and physical economies of scale that can be achieved by investing in the intensive management of our forests and agricultural soils for increased sequestration capacity?

First and foremost, our efforts should be focused on a) reducing absolute emissions from anthropogenic sources, b) dealing with the net carbon deficit of our forests by dealing with the tremendous influence of fires on our carbon deficit and c) investing in land management options that make economic and carbon sense in terms of maximum carbon sequestration benefits.

A carbon accounting framework would allow us to assess both the current stock and low of carbon in Alberta but also help to measure and track the impact of carbon management on our existing carbon deficit.

A Back-of-the-Envelope Carbon Capital Account

My preliminary account for carbon was intended to satisfy a curiosity as to exactly how much carbon Alberta's vast forests and peatlands sequester per annum and how does this capacity compares to annual anthropogenic emissions from fossil fuel use, industrial production and households.

This preliminary inquiry into the development of a carbon account for Alberta was motivated by the work of Dr. Casey Van Kooten of UBC who in 1991 estimated the economic values of carbon fixation by B.C's forests. Based on these preliminary estimates and early carbon budget work by Gorham (1991) and Kurz and Apps (1992). I was able to construct back-of-the envelope accounts of Alberta's carbon account related to forests and peatlands. The 1992 carbon account revealed some startling results.

My original estimates for forest biomass and peatlands showed an annual carbon sequestration capacity equivalent to only 24.2 percent of Alberta's total anthropogenic (industrial and household) carbon dioxide emissions in 1990. These were based on conservative assumptions of the annual growth rates of the forest biomass (trees) and the annual net carbon uptake by peatlands. The 1992 estimates were based on the work of Gorham (1991).

Since those first estimates, other studies have been produced notably by Kurz and Apps (1992, 1997) that revealed higher peatland sequestration levels.[4] In addition, new and higher average forest growth rate estimates for Alberta's forests were revealed (from an MAI (mean annual increment) of 1.70 cubic meters/hectare/year in 1990 to 2.00 m3/ha/yr in 1995, according to a Alberta Land and Forest Service timber supply study). These changes inflated my original sequestration capacity figures considerably. The 1990 estimates changed to roughly 33.8% of total anthropogenic emissions. By 1995, however, that had declined to 30.9% of 1995 emissions.

My estimates consider the annual tonnes of carbon absorbed by growing trees on productive forest land and carbon sequestered by the existing inventory of peatland annual carbon absorbed by the existing is the annual growth of trees and the annual absorption by peatlands of carbon in the atmosphere. Thus the estimates only provide estimates of the potential absorptive capacity of the forests and peatlands of Alberta and not actual.

Carbon Fixation on Forestlands

The Boreal forests of Canada play a critical role in C fixation or sequestering. Boreal forests in general dominate the dynamics of the terrestrial carbon cycle (Sedjo, 1993) and account for roughly 50% of the natural exchange of carbon dioxide (Maini, 1994). They act as massive, net carbon sinks or storage reservoirs (MacKenzie, 1994). Earlier estimates by van Kooten et. al. (1992) indicate that 97.7 Mt of C is sequestered per annum, or roughly 62 percent of the total C sequestered by all Canadian forests.

Of Alberta's total 66.1 million hectare land base, roughly 57% or 37.75 million hectares is forest land, primarily Boreal and some Cordellian forest. Of the total forest land area, 25.4 million hectares is productive forest land[5] or suitable for commercial timber harvestingally owned.

It is possible to estimate the amount of C sequestered by Alberta's forests by using data on C sequestered in a cubic meter of growing timber (green wood), the total area of productive forest land, and the productivity (growth per unit area per annum) of forests.

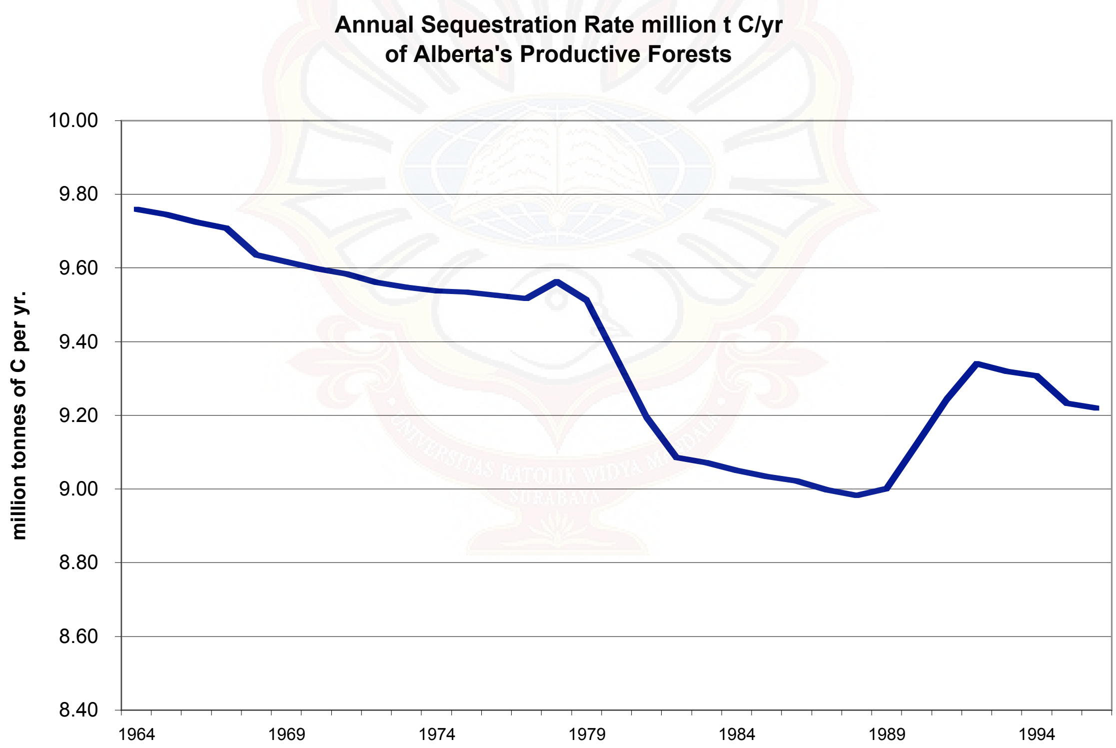
Based on previous estimates (Anielski, 1992) we estimate that the average carbon content of Alberta's timber growing stock at roughly 189 kg/m3 of wood. (a weighted average for all species using the 1991 Alberta Land and Forest Service inventory). Using an average

[4] The difference is due to the estimates of methane released from Alberta's peatlands which were significantly lower in the case of Kurz and Apps (1992; 59-60) 0.074 million tonnes of C equivalent per annum compared to my estimates based on Gorham (1991) which came to 1.77 million tonnes per annum.
[5] Includes both provincial, federal and private productive forest land.

provincial growth rate of 2.00 m3/ha/yr, average carbon content, and the area of productive forest land, it is possible to make crude estimates of the annual carbon sequestration rates of Alberta's productive forest land base. The average sequestration rate equates to an average 0.378 t C/ha/yr for Alberta's timber growing stock inventory in 1991. This is roughly 6% greater than the 0.355 t C/ha/yr carbon sequestration from net growth of the Boreal West-Cordellian forest ecoregions estimated for 1986 by Kurz and Apps (1992).

The total C equivalent sequestered by Alberta's productive forest land base (which contains the carbon sequestering growing stock of timber) is estimated to be 9.58 million tonnes (Mt) of carbon in 1988 and has declined to roughly 9.55 million tonnes of C in 1995.[6]

Using the estimated changes in productive forest land area from the 1995 timber capital account (Anielski, 1996) and the assumed sequestration rates it is possible to construct a rough estimate of historical carbon sequestration capacity of Alberta's forests. The graph shows a steady decline in the sequestration capacity of Alberta's forests due mainly to the impacts of assumed permanent removals from oil and gas development activities (e.g. seismic lines). Overall, the forest is likely in a relatively steady state.



[6] The original 1992 estimates estimated annual sequestration rates of 8.17 million tonnes per annum based on a lower growth rate (MAI – mean annual increment) of 1.70 m3/ha/yr. Based on the recent Timber Supply Status Report prepared by Alberta Environmental Protection, the average provincial MAI has been revised upwards to 2.00 m3/ha/yr.

Peatlands – The Silent Better Half

One of the silent and least profiled partners in the carbon budget of Alberta is peatland. Peatlands contain not only massive tonnage of carbon, they also contribute to the annual net accumulation of carbon, rivaling the accumulation through the net growth of trees. For example, Kurz and Apps (1992) estimates that for the Boreal West (which includes Alberta) ecoclimatic zone, carbon sequestered by peatlands (11.18 million tonnes) net is roughly 56% of the carbon sequestered by the net growth of forest biomass (trees) (19.84 million tonnes).

Given this account, peatlands take on significant strategic importance both as a store and annual carbon storage sink. Given their strategic importance and the economic value of their carbon budget services, may challenge the prudence of converting peatlands to marginal agricultural land or as a fuel source.

Alberta's peatlands cover roughly 12.67 million hectares or 20 percent of the total provincial land area (Alberta Forestry, Lands and Wildlife, 1990). This amounts to an estimated 36.1 billion tonnes (oven dry) of peat (Tarnocai, 1984). Alberta contains roughly 11 percent of the total Canadian peat resource.

Peatlands are vital to the carbon cycle, particularly as a carbon sink. Forestry Canada (1991) estimates that peatlands contain roughly 60 percent (135 billion tonnes) of the total carbon of forested lands in Canada, significantly more than the forests and forest soils combined. Using the formulas for estimating carbon storage by Gorham (1991), it is estimated that Alberta's peatlands contain roughly 16.88 billion tonnes of carbon (= 12.673 million ha (area of peatland) x 10,000 m^2/ha(conversion factor) x 2.3 m (depth of peat) x $112x10^3$ g/m^3 (mean bulk density of peat) x 0.517 (carbon content of dry mass)).

We then estimate the annual net accumulation of carbon based on the work of Kurz and Apps (1992) who estimated annual absorption rates of 3.466 million tonnes of C equivalent per annum for Alberta's peatlands. This works out to a per hectare annual sequestration rate of 0.273 t C/ha/yr or roughly 72% the per hectare absorption rate of Alberta's Boreal-Cordellian forest net growth.

Drainage of peatland and harvesting as a fuel source has been rather insignificant, to date. Roughly 1,700 ha have been drained for forestry and agricultural purposes (Anielski, 1992). More recent data is not available though more peat is being consumed as a "renewable" fuel source as a byproduct of pealtand conversion to agriculture by companies such as Drayton Valley Power.

Alberta's Increasing Carbon Deficit

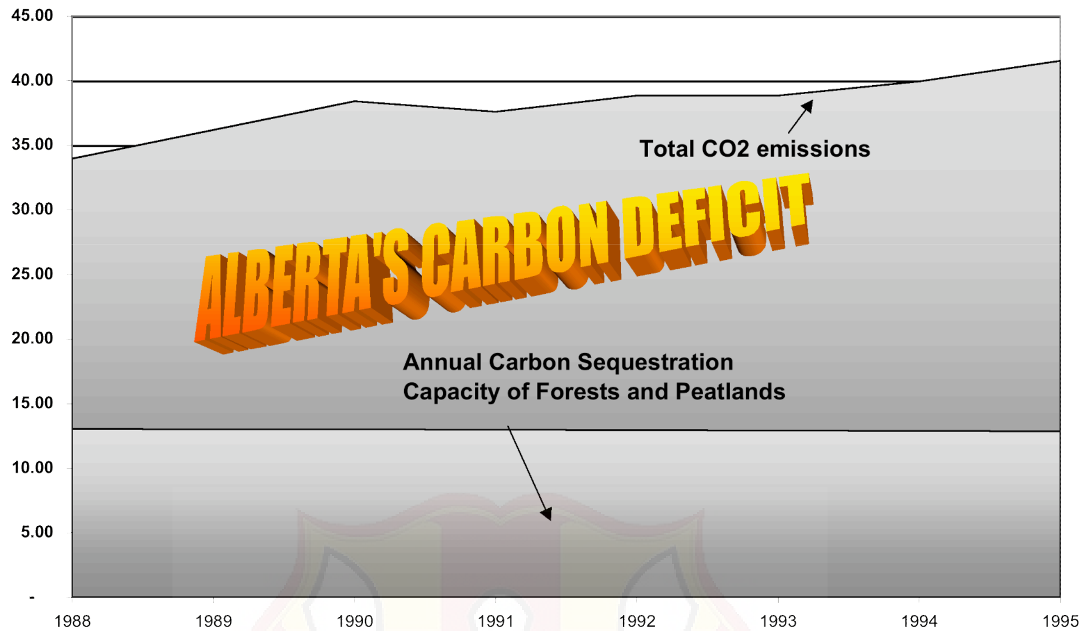
If the Canadian carbon budget for 1985-1989 is correct, that the forests and peatlands are already in a carbon net deficit position, what does this suggest for Alberta given we are already faced with increased anthropogenic emissions since 1990, with the prospect of increasing emissions from billions in new oilsands production development, and given the rather steady state of Alberta's existing forest and peatland land base? Can we make a reasonable dint in the carbon deficit?

While our account focuses on the capacity of forests and peatlands to sequester carbon annually, we may be fighting a losing battle as fires and other impacts on the carbon budget leave us in a net deficit position before we begin to deal with the impact on our carbon deficit of anthropogenic emissions, which will continue to rise in absolute terms as Alberta's economy expands.

When the deficit is viewed only in terms of the balance between net sequestration capacity of growing trees and sequestering peatlands and anthropogenic emissions the net carbon deficit has been increasing as emissions have risen from 1990 levels. In 1995 total anthropogenic carbon dioxide emissions were estimated at 152.1 million tonnes (up 8.2% from 140.6 million tonnes in 1990) or the equivalent of 38.38 million tonnes of carbon. Carbon sequestration capacity of forests and peatlands declined from 34.0% in 1990 to 31.3% in 1995 due to both an increase in absolute emissions and a reduction in fully-stocked forest land and peatland due to industrial development. Forests and peatlands are estimated to have sequestered roughly 13.0 million tonnes of carbon in 1995.

The following graph shows Alberta's estimated carbon deficit with respect to forests and peatlands – the difference between the theoretical absorptive capacity of forest biomass (trees) and peatlands and total anthropogenic emissions from industrial and household sources.

Carbon Dioxide Emissions versus Absorptive Capacity of Forests and Peatlands 1988-1995 Alberta



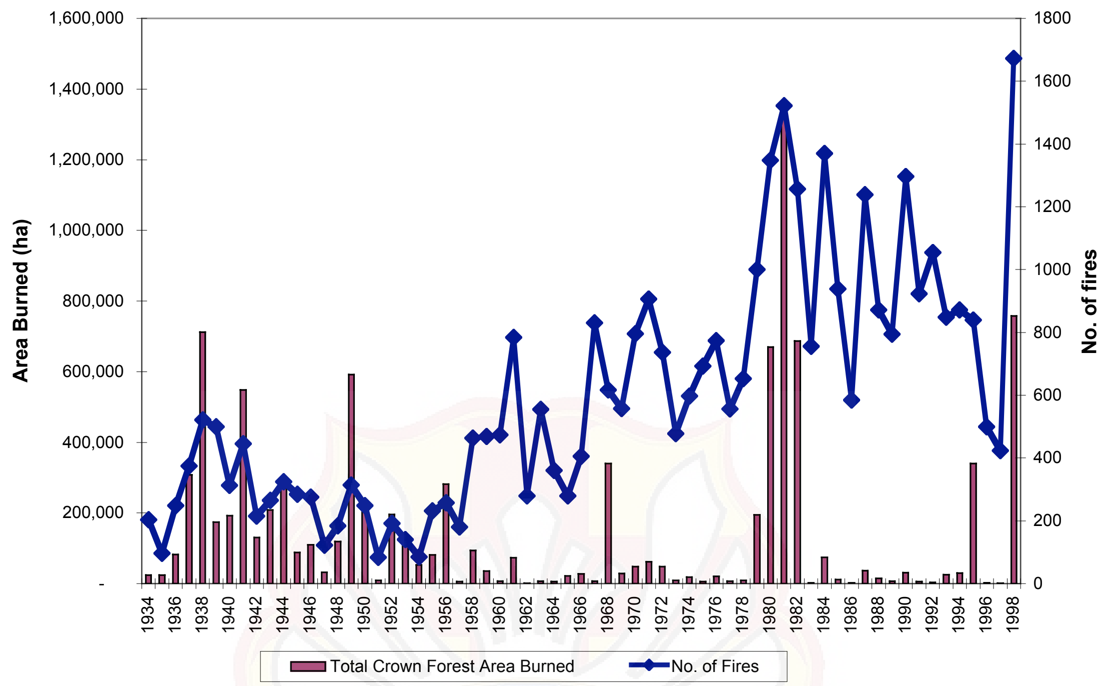
The growing carbon deficit shows that Alberta faces considerable challenges in meeting the Kyoto emissions reduction challenge, certainly in terms of absolute emission reductions. Alberta can ill afford to allow the degradation or depletion of the forest biomass and the vitally important peatlands that play such a significant role in Alberta's carbon budget.

The Unpredictable and Catastrophic Impact of Fire

Fire more than harvesting threatens the carbon budget of Alberta. Some studies have predicted that as a result of global warming the frequency and intensity of fires in the Boreal Forest are likely to increase (Myers, 1997, Kasischke et.al., 1995). Since fires decrease forest biomass and release carbon, this is an important positive feedback that may well exacerbate global warming trends (Alberta Environmental Protection, 1998).

While one year does not make a trend, the catastrophic fires of 1998 are cause for concern. The 1998 fire season has, to date, recorded the most fires since records were kept in 1934 — 1,672 fires. Roughly 758, 200 hectares of forest burned (an area 1.3 times the area of Prince Edward Island), the second largest area burned since 1934. The graph appears to confirm that the incidence of fires is increasing even if there is no evident trend in the intensity or size of fires in the 1980s; possibly a result of better detection.

Alberta Fire History: Area Burned vs. Number of Fires 1934-1998



What is significant about the 1998 fire season is that roughly 60% of the area burned was juvenile stands of high-carbon sequestering trees, much of which had been reforested at great expense to the forest industry. Moreover, mature high carbon stores of merchantable timber are lost thereby reducing the forest biomass and releasing more carbon to the atmosphere. It is highly probable that 1998 will be a net carbon source year.

The incidence of wildfires, more than any other factor, seems to pose the greatest risk to Alberta's efforts at managing carbon as a stock and flow of natural capital and threatens to thwart Canada's attempts to the Kyoto absolute carbon emission reduction targets if we are judged on the basis of a net carbon income basis.

We might presume that suppression of the incidence of fires is a desirable carbon management objective. However, Price et.al (1997) found in their carbon budget models of the Boreal-Cordellian forest of Weldwood of Canada's FMA at Hinton, that managing a forest for wood production may lead to greater C storage than occurs in the natural forest ecosystem, however, only in cases where natural disturbances from fire, insects and disease are more frequent than the sustained yield harvest rotation age. Their models show that estimated long-term increases in C storage from management practices assume that natural disturbances (fires and pathogens) can be completely suppressed and that the fire cycle (frequency of burns), which has historically averaged 50-year cycles. The rate of natural disturbance in Canada's forests is apparently on the increase erasing some of the gains made in the 1960s and 1970s in fire cycles (Canadian Council of Forest

Ministers, 1998). The bottom line is that there is an ongoing threat from wildfires to upsetting the best efforts of forest managers in managing forests and carbon stores.

While the costs of fire suppression in 1998 run in the millions, the economic benefits in terms of carbon from preserving large areas of natural forest from going up in smoke will become increasingly important under a carbon management regime. Indeed sound cost-benefit analysis is required to assess the relative "carbon" returns of investment from fire management in the protection of both merchantable timber but carbon sinks. The opportunity cost of each tonne of carbon sequestration forgone as a result of fire can be assessed within the framework of a carbon capital account expressed in monetary terms in assessing the returns on investment from costly fire suppression expenditures.

A prudent policy response necessitates the ongoing vigilance of protecting forests from burning, at least in the short-term as we make other attempts at reducing absolute greenhouse gas emissions.

The Importance of Energy Development on Alberta's Carbon Deficit

The growth of Alberta's energy sector has come with enormous impacts on the forest land base with the criss-crossed patterns of seismic lines that have effectively resulted in the permanent removal of carbon sequestering forest biomass – trees. Indeed some experts (including Brad Stelfox) are now estimating that the impact of oil and gas activity on the forests of Alberta has been underestimated when examining satellite inventory and adding up the area of forest disturbed from the energy industry's activities.

There is remarkably little government data on the area of forest impacted by the energy sector. Stelfox's inventory work is important to developing a more complete assessment of the interrelationship of the energy industry's activities in the forest and the carbon budget of Alberta. Based on the 1995 timber capital account (Anielski, 1996) we estimate (using Land and Forest Service statistics) that historically roughly 600,000 hectares of productive forest land is lying bare of high-carbon sequestering trees due to the impact of oil and gas activity (seismic lines, pipelines, other dispositions), roads and other disposition.[7] Much of this area remains deforested with low carbon yielding biomass such as alfalfa growing on vast areas of seismic lines. In terms of carbon sequestering capacity this area would be equivalent to a paltry 0.227 million tonnes of additional carbon sequestration capacity per year (based on 0.378 tonnes of carbon/ha/yr sequestered by Alberta's forest inventory in 1991). Even reforesting this entire area of land developed for energy and other industrial uses would hardly put a dent in absorbing part of the 41.5 million tonnes of carbon emitted in 1995.

Part of the carbon management solution must undoubtedly include a strategy to maximize the carbon sequestration capacity of these otherwise bare forest lands resulting from energy exploration and development.

[7] This is likely a highly conservative estimate.

The Economics of Carbon Sequestration by Forests

The economic importance of forests and peatlands in the sequestration of carbon are undoubtedly signficant given their physical importance in Alberta's carbon account. But how should we value these services?

Economic values have been estimated for carbon sequestration by forests by Van Kooten (1998, 1992), Sedjo (1997, 1995) and Anielski (1992). Van Kooten (1998) estimates "reasonable" carbon shadow prices of $20 and $50 per tonne and a high value of $100 per tonne of C equivalent. While such estimates are not precise nor are they based on the market price of carbon (which is currently trading at roughly U.S. $1.00-$3.50 per tonne of C equivalent) they are used to illustrate the potential economic values in the economy.

Based on Van Kooten's estimates, the value of Alberta's forests and peatlands in sequestering carbon in 1995 are estimated from $228 million (@$20/t C) to $572 million (@ $50/t C) to a high value of $1,141 million (@ $100/t C).[8] Compare these figures to the following economic indicators for Alberta's forest industry in 1997 (Natural Resources Canada, 1998):

- Value of exports $2,300 million
- Value of shipments $4,500 million
- Wages and salaries $ 595 million

Since it will be the economics that will ultimately dictate investment decisions in carbon management options, including enhanced carbon sequestration through the planting of hybrid poplar trees, soil management and other forest management options, such economic valuation efforts are necessary in combination with financial analysis of various carbon management options.

Compared with current market value for a tonne of carbon, based on limited international trades, of between U.S. $1.00-$3.50 per tonne of C equivalent, these shadow prices seem inflated. However, the carbon trading market has only begun to heat up.

Another relevant figure is provided by Roger Sedjo of Resources for the Future (Washington, D.C.) who estimates the cost of natural regeneration in per tonne of C to be U.S.$5.00/t C and U.S. $8.00/t C for reforestation ($93/ha (natural regeneration) and $324/ha (reforestation). Neil Bird of Woodrising Consulting estimates that the discounted value of the capital cost of all electricity infrastructure in the U.S. to amount to roughly $9.00/t C. Thus at current market rates, no one would be willing to pay more than $9.00/t C for carbon sequestration or reduction options.

---

[8] This does not take into account the increasing scarcity value of forests and peatlands which were actually in decline in terms of total area. As more sequestration capacity is lost the more valuable are the services of the existing forests and peatlands.

Conclusions and Policy Issues - Beyond Kyoto

Carbon capital accounts are vital to formulating a prudent strategy for the management of carbon in fulfilling the spirit and letter of the Kyoto Protocol for Canada and Alberta.

While carbon accounting is complex due to incomplete knowledge of the science of carbon stocks and flows, even a preliminary account is necessary to provide a reality check on the physical and economic benefits that can be expected from pursuing various carbon management, post-Kyoto.

Unfortunately, current carbon accounts suggest that we are already significantly behind the eight-ball with a large carbon net deficit. The carbon accounts suggest that forests and peatlands may already be net sources of carbon thus provide little sequestration capacity to absorb increasing anthropogenic emissions. When the net carbon deficit of forests is added to the absolute emissions from anthropogenic sources, Alberta's carbon deficit is signficant. The extent to which carbon management through forest management and soil management options seem insignificant relative to the size of our provincial carbon deficit.

Nevertheless, efforts must be made to attempt to deal with the carbon deficit and oru carbon trade deficit within the eccosystem borders of Alberta, Canada and indeed globally. There are many policy options that should be explored from a carbon sequestration and economic perspective. These include:

- All existing productive forest land, peatlands and arable agricultural lands should be "managed" to ensure maximum carbon sequestration capacity. This requires the identification of all low-yielding lands that could be converted to high-carbon yielding biomass such as reforestation of seismic lines or other low-carbon, yet carbon viable lands that sit idle.
- While carbon sequestration benefits from forest and peatland management may be rather insignificant in relationship to the total carbon deficit, ensuring the maximum sequestration capacity is critical in both the short and long-term, as technical and economical solutions to absolute emission reductions are found and shifts are made to renewable energy sources.
- Management of wildfire will be critical in protecting carbon absorbing timber capital, both young and old, safeguarding both the carbon income of mature trees and the carbon income of young seedlings that have been established under natural or managed conditions. More than any other factor, fires pose the greatest risk to carbon management as has been evidenced by Canada's net carbon deficit in forests since 1985.
- Peatlands play a vital role both as carbon store and as an annual absorber of carbon, thus the need to sustain the existing peatlands land base thereby sustaining the carbon capital and the carbon income contained therein.

References

Alberta Bureau of Statistics (1991). *Alberta Economic Accounts (1990)*. Alberta Treasury, Edmonton.

Alberta Environmental Protection (1998). *The Boreal Forest Natural Region of Alberta*. April 1998.

Alberta Forestry, Lands and Wildlife (1991). *Peat Resource Management Discussion Paper*. Edmonton.

Anielski, Mark (1997). *Is Alberta Running Out of Nature's Capital* (Alberta's oil, gas, and coal natural capital accounts). Presentation to the Department of Economics, University of Alberta, March 1997.

Anielski, Mark (1996). *Accounting for the Sustainability of Alberta's Forests - The 1995 Timber Resource Account*. Unpublished paper. Edmonton, Alberta.

Anielski, Mark (1992). *Natural Resource Accounting: Assessing the Sustainability of Alberta's Forest Resources.* Alberta Forestry, Lands and Wildlife, Edmonton.

Anielski, Mark (1992). Accounting for Carbon Fixation by Alberta's Forests and Peatlands. Presented at the Second Meeting of the International Society of Ecological Economics (ISEE) "Investing in Natural Capital - A Prerequisite for Sustainability", Stockholm, Sweden. August 3-6, 1992.

Anielski, Mark (1992*). Resource Accounting: Indicators of the Sustainability of Alberta's Forest Resources*. Paper presented at the International Society of Ecological Economics meeting in Stockholm, Sweden, August 1992

Daly, Herman E. and John B. Cobb Jr. (1994). *For the Common Good – Redirecting the Economy Toward Community, the Environment, and a Sustainable Future*. Beacon Press, Boston.

Decanio, Stephen. (1997). *The Economics of Climate Change*. Redefining Progress, San Francisco. October 1997.

Federal-Provincial-Territorial Task Force (1990). *Report of the Federal-Provincial-Territorial Task Force on Energy and Environment*. Federal-Provincial-Territorial Conference of Ministers of Energy, Kananaskis, Alberta, April 2. Mimeograph.

Forestry Canada (1991). *State of Forestry in Canada - 1990 Report to Parliament*. Minister of Supply and Services Canada, Ottawa.

Gorham, E (1991). 'Northern Peatlands: Role in the Carbon Cycle and Probable Responses to Climatic Warming.' *Ecological Applications*, 1(2): 182-195.

Hultkrantz, Lars (1991). *National Account of Timber and Forest Environment Resources in Sweden*. Sveriges Lantsbrukuniversitet, Institutionen For Skogsekonomi, University of Umea, Sweden.

Jaques, A.P. (1990). *National Inventory of Sources and Emissions of Carbon Dioxide*. Report EPS 5/AP/2. Ottawa: Environment Canada, May.

Kasischke, E.S., Christensen, N.L., Jr., and Stocks, B.J. (1995). Fire, global warming, and the carbon balance of forests. *Ecological Applications*, 5, no. 2, 437-451.

Kurz, WA, MJ Apps. 1996. Chapter 14: Retrospective assessment of carbon flows in Canadian boreal forests. In: MJ Apps and DT Price (Eds). "Forest Ecosystems, Forest Management and the Global Carbon Cycle", NATO ASI Series I (Global Environmental Change), Vol I 40, Springer-Verlag Academic publishers, Heidelberg, 173-182.

Lerohl, Mel (1992*). Extended Capital and Income Accounts for Land Based Activities in Alberta.* Paper presented at the Conference on Forestry and Environment: Economic Perspectives, Jasper, Alberta, March 1992.

Myers, N. (1997). The world's forests and their ecosystem services. P. 215-235, in : Daily, G.C. (editor*), Nature's Services: Societal Dependence on Natural Ecosystems.* Island Press, Washington, D.C., 392 pp.

Natural Resources Canada (1998*). The State of Canada's Forests: The People's Forests 1997-98*. Government of Canada, Natural Resources Canada.

Pollard, D.F.W. (1991). 'Forestry in British Columbia: Planning for Future Climate Today.' *Forestry Chronicle* 67 (August): 336-41.

Price DR, DH Halliwell, MJ Apps, WA Kurz and SR Curry. (1997). Comprehensive assessment of carbon stocks and fluxes in a Boreal-Cordellian forest management unit. *Canadian Journal of Forest Research*. 27:2005-2016.

Repetto, Robert and Duncan Austin. (1997). *The Costs of Climate Protection: A Guide for the Perplexed*. World Resources Institute, Washington D.C.

Rizzo, B. and E. Wiken (1989). 'Assessing the Sensitivity of Canada's Ecosystems to Climate Change.' In *Landscape-Ecological Impacts of Climate Change*. Discussion Report on Fennoscandian Regions. Proceeding of a Conference, Lunteren, Netherlands, Dec. 3-7, p.94-111.

Sanghi, A.K. and K.S. Michael (1991). 'Carbon Sequestering Through Reforestation: Cost and Potential for New York.' Abstract in *Bridging to the 21st Century*. Proceedings of the Air and Waste Management Association Annual Meeting and Exhibition.

Sedjo, R.A., R.N. Sampson and J. Wisniewski (editors), (1997*). Economics of Carbon Sequestration in Forestry*. Boca Raton, FA: Lewis Publishers (CRC Press).

Sedjo, R.A. J. Wisniewski, A.V. Sample and J.D. Kinsman. (1995). The Economics of Managing Carbon via Forestry: Assessment of Existing Studies, *Environmental and Resource Economics* 6: 139-65.

Sedjo, R.A. and A.M. Solomon (1989).
"Climate and Forests." In *Greenhouse Warming: Abatement and Adaption*, N.J. Rosenberg, W.E. Easterling III, P.R. Crosson and J. Darmstadter (eds.), Washington: Resources for the Future.

Smith, Roger (1992). *Income Growth, Government Spending, and Wasting Assets - Alberta's Oil and Gas*._ Canadian Public Policy - Analyse de Politiques, XVIII:4:387-412.

Tarnocai, C. (1984). *Peat Resources of Canada.* Land Resource Research Institute, Research Branch, Agriculture Canada, Ottawa.

Van Kooten, G.C. and Edwin Bulte. (1998). *How Much Ancient Forest Should Society Retain? Carbon Uptake, Recreation and Other Values*. Unpublished as of May 19, 1998 for the Sustainable Forest Management National Centre of Excellence.

Van Kooten, G.C., Louise M. Arthur and W.R. Wilson (1992). "Potential to Sequester Carbon in Canadian Forests: Some Economic Considerations." *Canadian Public Policy*, June 1992.

Van Kooten, G.C., W.A. Thompson and I. Vertinsky (1992). *Turning Down the Heat in Canada: Reforestation When Benefits of CO_2 Reduction are Included.* Forestry Economics and Policy Analysis Research Unit, University of British Columbia, Vancouver.