International Civil Aviation Organization (ICAO) Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

Application Form for Emissions Units Programs

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SECTION I: ABOUT THIS ASSESSMENT

Background

Following the agreement at the 39th Assembly of the International Civil Aviation Organization (ICAO), governments and the aviation industry are getting ready to implement the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Together with other mitigation measures, CORSIA will help achieve international aviation's aspirational goal of carbon neutral growth from year 2020.

Aeroplane Operators will meet their offsetting requirements under CORSIA by purchasing and cancelling CORSIA eligible emissions units, which will be determined by the ICAO Council upon recommendations by its Technical Advisory Body (TAB), according to paragraph 20 d) of ICAO Assembly Resolution A39-3.

As an initial step, in November 2017, the ICAO Council provisionally approved CORSIA Emissions Unit Eligibility Criteria (EUC). Application of the EUC will serve as the basis for the Council's decisions on CORSIA-eligible emissions units.

To make further progress on the application of the EUC, the ICAO Council requested its Committee on Aviation Environmental Protection (CAEP) to informally test emissions unit programs against the EUC. The results and recommendations of the informal testing were provided to the Council, including the recommendation for the EUC to be used by the TAB in this assessment process.

Subsequently, in March 2019, the ICAO Council unanimously approved the EUC for use by the TAB in undertaking its tasks. At the same time, the ICAO Council also approved the 19 members of the TAB and its Terms of Reference (TOR).

ICAO has invited emissions unit programs to apply for the assessment, which will involve collecting information from each program through this program application form.

Through this assessment, the TAB will develop recommendations on the list of eligible emissions unit programs (and potentially project types) for use under the CORSIA, which will then be considered by the ICAO Council to make its decision on CORSIA eligible emissions units.

This form is accompanied by Appendix A "*Supplementary Information for Assessment of Emissions Unit Programs*", containing the EUC and *Guidelines for Criteria Interpretation*. These EUC and Guidelines are provided to inform programs' completion of this application form, in which they are cross-referenced **by paragraph number.**

Program responses to this application form will serve as the primary basis for the assessment. Such assessment may involve e.g. clarification questions, an in-person interview, and a completeness check of the application, as further requested. Programs which are invited for an in-person interview will receive advance notice of the time and date of the interview.

The working language of the assessment process is English. If the program documents and information are not published in English, the program should fully describe in English (rather than summarize) this information in the fields provided in this form, and in response to any additional questions. Translation services are not available for this process. Those programs that need to translate documents prior to submission may contact the ICAO Secretariat regarding accommodation.

Disclaimer: The information contained in the application, and any supporting evidence or clarification provided by the applicant including information designated as "business confidential" by the applicant, will be provided to the members of the TAB to properly assess the Program and make recommendations to the ICAO Council. The application and such other evidence or clarification will be made publicly available on the ICAO CORSIA website for the public to provide comments, except for information which the applicant designates as "business confidential". The applicant shall bear all expenses related to the collection of information for the preparation of the application, preparation and submission of the application to the ICAO Secretariat and provision of any subsequent clarification sought by the Secretariat and/or the members of the TAB. Under no circumstances shall ICAO be responsible for the reimbursement of such or any other expenses borne by the applicant in this regard, or any loss or damages that the applicant may incur in relation to the assessment and outcome of this process.

SECTION II: INSTRUCTIONS

Submission and contacts

A Program is invited to complete and submit the form, and any accompanying evidence, through the ICAO CORSIA website no later than close of business on **12 July 2019**. Within seven business days of receiving this form, the Secretariat will notify the Program that its form was received.

If the Program has questions regarding the completion of this form, please contact ICAO Secretariat via email: officeenv@icao.int. Programs will be informed, in a timely manner, of clarifications provided by ICAO to any other program.

Form basis and cross-references

Questions in this form are derived from the criteria and guidelines introduced in Section I (above). To help inform the Program's completion of this form, each question includes the paragraph number for its corresponding criterion or guideline that can be found in Appendix A "*Supplementary Information for Assessment of Emissions Unit Programs*".

Form completeness

The Program is strongly encouraged to respond to all questions in this application form. If any question(s) in this form does not apply to the Program, please briefly explain the exception.

Where "evidence" is requested, programs are encouraged to substantiate their responses in any one of these ways (in order of preference):

- web-links to supporting documentation included along with the written summary response; with instructions for finding the relevant information within the linked source, if necessary;

- copying/pasting information directly into this form (no character limits) along with the written summary response;

- attaching supporting documentation to this form at the time of submission, with instructions for finding the relevant information within the attached document(s);

Please note that written summary responses are encouraged—supporting documentation should not be considered as an alternative.

To help manage file size, the Programs should limit supporting documentation to that which directly substantiates the Program's statements in this form.

Form scope

The Program may elect to submit for analysis all or only a portion of the activities supported by the Program.

In the template provided by Appendix B "Program Scope Information Request", the Program should clearly identify and submit along with this form information on the following:

a) activities that the Program submits for analysis by describing them in this form;

b) activities that the Program does not wish to submit for analysis, and so are not described in this form;

c) identification details (e.g., methodology date, version) for activities described in this form.

Information provided under "c" should allow for the unambiguous identification of all methodologies/protocols that the Program has approved for use as of the date of submission of this form.

Program revision

Where the Program has any immediate plans to revise the Program (e.g., its policies, procedures, measures) to enhance consistency with a given criterion or guideline, provide the following information in response to the relevant form question(s):

- Proposed revision(s);

- Process and proposed timeline to develop and implement the proposed revision(s);

- Process and timeline for external communication and implementation of the revision(s).

"Linked" certification schemes

This application form should be completed and submitted exclusively on behalf of the Program that was invited to participate in the assessment.

Some programs may supplement their standards by collaborating with other schemes that certify, e.g., the social or ecological "co-benefits" of mitigation. The Program can reflect a linked scheme's procedures in responses to this form, where this is seen as enhancing—i.e. going "above and beyond"—the Program's own procedures.

For example, the Program may describe how a linked scheme audits sustainable development outcomes; but is not expected to report the linked scheme's board members or staff persons.

Programs should clearly identify any information provided in this form that pertains to a linked certification scheme and/or only applies when a linked certification scheme is used.

Disclosure of program application forms

Applications and other information submitted by emissions unit programs will be publicly available on the ICAO CORSIA website, except for materials which the applicants designate as business confidential.

The public will be invited to submit comments on the programs applications including regarding their consistency with the emissions units criteria (EUC), through the ICAO CORSIA website, for consideration by the TAB following its initial assessment of program applications.

SECTION III: APPLICATION FORM

PART 1: General information

A. Program Information

Program name: CARBON FORESTS

Official mailing address: Grojecka 127, 02-124 Warsaw, POLAND

Telephone #: 48 22 58 98 300

Official web address: klimat.lasy.gov.pl

B. Program *Administrator* Information

Full name and title: Mariusz Błasiak, Head, R&D Dept. General Directorate of The State Forests

Employer / Company (*if not Program*): General Directorate of The State Forests

E-mail address: mariusz.blasiak@lasy.gov.pl

Telephone #: 48 22 58 98 300

C. Program *Representative* Information (*if different from Program Administrator*)

Full name and title:

Employer / Company (*if not Program*):

E-mail address:

Telephone #:

D. Program Senior Staff / Leadership (*e.g., President / CEO, board members*)

List the names and titles of Program's senior staff / leadership, including board members:

Andrzej Konieczny, Ph.D. Eng., Director General of The State Forests

PART 2: Program summary

Provide a summary description of your program

The pilot project is realized in 23 forest districts (out of 430 total) of the State Forests in chosen tree stands, altogether on an area of 12 thousand hectares, however, as separations are in homogenous pairs, around 6,000 ha are active and other 6,000 ha, with treatment as usual, are reference areas . In comparison, the forest area in Poland accounts to 9,3 million hectares, out of which 7,6 million hectares are managed by the State Forests. ***Around 1.000.000 ha qualifies for future designation as Carbon Forests, so future project is viable and easy for us.*** *The extent of the assessed effect of additional CO_2 absorption in the Pilot Carbon Forest Project is around 1 million tons in the period of 30 years, those calculations are done with the help of the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3). It means that in the years 2017-2046 on the aforementioned forest area included in the pilot project, almost 1 million tons* ***more*** *of CO_2 will be absorbed due to the realized additional actions (exemplary actions among these are: introducing the 2^{nd} story of trees and shrubs, afforestation, introduction of fast growing species, enlarging areas of natural regenerations and actions preventing damages of the soil surface). As we test 9 additional activities – forest management practices - we will use best performing techniques in the coming future.*

PART 3: Emissions Unit Program Design Elements

Note—where "evidence" is requested in *Part 3* and *Part 4*, the Program should provide web links to documentation. If that is not possible, then the program may provide responses in the text boxes provided and/or attached supporting documentation, as recommended in "SECTION II: INSTRUCTIONS—*Form Completeness*".

Note—"*Paragraph X.X*" in this form refers to corresponding paragraph(s) in Appendix A "*Supplementary Information for Assessment of Emissions Unit Programs*".

Note—Where the Program has any immediate plans to revise the Program (e.g., its policies, procedures, measures) to enhance consistency with a given criterion or guideline, provide the following information in response to the relevant form question(s):

- Proposed revision(s);
- Process and proposed timeline to develop and implement the proposed revision(s);
- Process and timeline for external communication and implementation of the revision(s).

3.1. Clear methodologies and protocols, and their development process

Summarize the Program's processes for developing and approving methodologies, including the timing and process for revision of existing methodologies:

Prior to pilot Carbon Forests Program establishment various research centers in Poland: The Forest Research Institute, the Poznań University of Life Sciences, Institute of Dendrology in Kórnik, Bureau for Forest Management and Geodesy, Taxus I.T., the University of Agriculture in Kraków conducted research, selecting additional activities. In the effect we use Reduced Impact Logging (VM0035), enrichment planting (from VM0005 Low to High productive (however 0005 was tailored for other hemisphere) plus fast growing species, afforestation, dead wood, soil protection-regeneration, Sobanski's Technique, Pioneer crops/Glades. and predictions using Carbon Modelling program (CBM-CFS3)which comes from Canada, however constant, ongoing development and improvement via addition of curves fit for Polish woods & habitats & sub-species. Canadian Budget Model is publicly available. We are open for implementation of different, new IT tool/model in CORSIA shall suggest internationally recognized one, exploitable to monitor and reflect changes in stands of Polish forests.

Provide *evidence*[1] *of the public availability* of a) the Program's current processes for developing methodologies and protocols and b) the methodologies / protocols themselves: (*Paragraph 2.1*)

As public entity in the structure of the Ministry of the Environment, we are obligated to respond to any inquiry during 30 days period and disclose everything (but governmental restricted e.g. security) information.
Beside, websites were and are available: www.klimat.lasy.gov.pl ; www.lasy.gov.pl

3.2. Scope considerations

SECTION II: Application Form Scope includes questions related to this criterion. No additional information is requested here. *Scope sector: 14 (Forestry)*
We describe pilot-research program of Carbon Forests (previous name: Forest Carbon Farms).
And, what we propose is the project of future, full-blown commercial program tailored to be exactly what CORSIA requirements are.

3.3. Offset credit issuance and retirement procedures

Are procedures in place… (*Paragraph 2.3*)

[1] For this and subsequent "evidence" requests, evidence should be provided in the text box (e.g., web links to documentation), and/or in attachments, as recommended in "SECTION II: INSTRUCTIONS—*Form Completeness*".

a) for unit issuance and retirement / cancellation? Pool of units based on annual measurements is traceable x YES

b) related to the duration and renewal of crediting periods? Lifetime of the project is 30 years x YES

c) for unit discounting (*if any*)? x YES

Provide evidence of the relevant policies and procedures related to a) through c) (*if any*, in the case of "c"), including their availability to the public:

Bylaws #2/2017 superseded by Bylaws #67/2018 ; results via Carbon Modelling program CBM-CFS3
Results from three years of pilot program were auctioned (at discounted price) as a ***pro public bono*** *charity. All proceeds went toward pro-ecological and/or pro-public investments. All media informed about it, along with our websites.*

3.4 Identification and Tracking

Does the Program utilize an electronic registry or registries? (*Paragraph 2.4.2*) x YES

Provide web link(s) to the Program registry(ies) and indicate whether the registry is administered by the Program or outsourced to a third party (*Paragraph 2.4 (e)*):

For our ***first and only*** *auction (charity one) we designated special secure website, similar to our auction platforms, where we sell the timber in the amount of over $ 2.000.000.000 a year (so it is secure). Supervision by our own IT Dept. Units had been counted, but not marked with unique numbers. However, with planned full-blown program there will be strict electronic registry administered by our IT Dep. with The Directorate General supervision.*

Do / does the Program registry / registries:

a) have the capability to designate the ICAO eligibility status of particular units? (*Paragraph 2.4.3*) x YES

b) identify and facilitate tracking and transfer of unit ownership/holding from issuance to cancellation/retirement? (*Paragraphs 2.4 (d) and 2.4.4*) x YES

c) identify unit status, including retirement / cancellation, and issuance status? (*Paragraph 2.4.4*) x YES

d) assign unique serial numbers to issued units? (*Paragraphs 2.4 (b) and 2.4.5*) x YES

e) identify in serialization, or designate on a public platform, each unique unit's country and sector of origin, and vintage year? (*Paragraph 2.4.5*) x YES

Summarize and provide evidence of the relevant policies and procedures related to a) through e), including their availability to the public:

Bylaws # 67 is a public, governmental document with access via the internet; all future amendments (as above) will be publicly discussed and hang on the website where available 24hrs a day – upon this CORSIA approval. Each unit to have the unique number.

List any/all international data exchange standards to which the Program's registry(ies) conform: (*Paragraph 2.4 (f)*) to be determined according to CORSIA

Some partial comparison was performed like market research, auction houses research, Verra & G.S. research

Are policies in place to prevent the Program registry administrators from having financial, commercial or fiduciary conflicts of interest in the governance or provision of registry services? (*Paragraph 2.4.6*) x YES

To address and isolate such conflicts, should they arise? (*Paragraph 2.4.6*) x YES

Summarize and provide evidence of the relevant policies and procedures, including their availability to the public:

Rules and regulations pertaining also to the question are itemized in Order #17 from March 11th/2016. The fiduciary relationship, obligations toward confidentiality of internal information, integrity etc. is mandatory.

Are provisions in place…

a) ensuring the screening of requests for registry accounts? (*Paragraph 2.4.7*) x YES

b) restricting the Program registry (or registries) accounts to registered businesses and individuals? (*Paragraph 2.4.7*) for charity purpose was business only x YES

c) ensuring the periodic audit or evaluation of registry compliance with security provisions? (*Paragraph 2.4.8*) x YES

Summarize registry security provisions, including related to a) through c); and provide evidence of the relevant policies and procedures, including their availability to the public:

Rules and regulations were posted prior to even the charity auction time via related link to sub-portal with the highest degree of the security level. Access had been granted after User was double checked plus additional security clearance took place. The particular policies will be described for full-blown program.
We may take advantage of our similar auction platforms (2) where we sell wood in serious amounts.
Our annual production is around 40 million of cubic meters, what translates into over two billion of dollars.
Websites are: www. http://drewno.zilp.lasy.gov.pl/drewno/ and https://www.e-drewno.pl/stock/

3.5 Legal nature and transfer of units

Does the Program define and ensure the underlying attributes and property aspects of a unit? (*Paragraph 2.5*) x YES

Summarize and provide evidence of the relevant policies and procedures, including their availability to the public:

BYLAWS of the pilot Project (To be revised for dedicated CORSIA program) describes attributes and timing of the procedure to convey the ownership of units. Along with new, full blown program we are ready, willing and able to describe it again, this time explaining CORSIA nature of units (certificates) and naturally all information will be available to general public

3.6 Validation and verification procedures

Are standards and procedures in place for… (*Paragraph 2.6*)

a) validation and verification processes? Internal V &V by scientists, readiness for formal x YES

b) validator and verifier accreditation? x YES

Provide evidence of the relevant policies and procedures related to a) and b), including their availability to the public:

Polish State Forests in general, across the country, do have PEFC and FSC standards, verification and all kind of diplomas. So far, with the pilot program charity action we haven't contracted Verra's or G.S./similar authorized bodies, but we will do so with CORSIA accredited Validation &Verification Bodies pending your approval. Again, everything to be publicly available.

3.7 Program governance

Does the Program publicly disclose who is responsible for the administration of the Program, and how decisions are made? (*Paragraph 2.7*) x YES

Provide evidence that this information is available to the public:

Media plus websites: www.klimat.lasy.gov.pl www.lasy.gov.pl www.projekty-rozwojowe.lasy.gov.pl With full documentation digitalized it is available in so called Biuletyn Informacji Publicznej (BIP) www.bip.lasy.gov.pl

Can the Program demonstrate that it has… (*Paragraph 2.7.2*)

a) been continuously governed and operational for at least the last two years? x YES

b) a plan for the long-term administration of multi-decadal program elements which includes possible responses to the dissolution of the Program in its current form? x YES

Provide evidence of the relevant policies and procedures related to a) and b):

Full documentation of field work (started January 2017) performed in 23 subject Forest Districts; Bylaws

Are policies in place to prevent the Program staff, board members, and management from having financial, commercial or fiduciary conflicts of interest in the governance or provision of program services? (*Paragraph 2.7.3*) x YES

To address and isolate such conflicts, should they arise? (*Paragraph 2.7.3*) x YES

Summarize and provide evidence of the relevant policies and procedures:

Rules and regulations pertaining also to the question are itemized in Order #17 from March 11th/2016. The fiduciary relationship, obligations toward confidentiality of internal information, integrity etc. is mandatory.

If applicable, can the Program demonstrate up-to-date professional liability insurance policy of at least USD$5M? (*Paragraph 2.7.4*) N/A

Provide evidence of such coverage:

Upon approval full scale CORSIA CARBON FOREST this program will be insured. We are able and willing to do so.

3.8 Transparency and public participation provisions

Does the Program publicly disclose… (*Paragraph 2.6*)

a) what information is captured and made available to different stakeholders? N/A

b) its local stakeholder consultation requirements (if applicable)? N/A

c) its public comments provisions and requirements, and how they are considered (if applicable)? N/A

Provide evidence of the public availability of items a) through c):

For our pilot research program public hearing were limited to scientist from different universities, institutes including different countries as well. Transparency and public participation will be mandatory with full-blown program (upon approval by CORSIA)

Does the Program conduct public comment periods? N/A / YES

Provide evidence of the relevant policies and procedures:

As explained already, information to be available in the net. With future program there will be grace period for Public comments available on our website.

3.9 Safeguards system

Are safeguards in place to address environmental and social risks? (*Paragraph 2.9*) x YES

Summarize and provide evidence of the relevant policies and procedures, including their availability to the public:

The environmental risk practically is not an issue, as we are, according to The Forest Act from 1991 obligated to address any vis majeure damage or cataclysm (e.g. by reforestation). Again, very conservative approach to results, huge reserve of units amount not for distribution provides risk elimination. On social side, jobs creation is the plus only.

3.10 Sustainable development criteria

Does the Program publicly disclose sustainable development criteria used (*if any*), and provisions for monitoring, reporting and verification in accordance with these criteria? (*Paragraph 2.10*)

x YES

Provide evidence of the public availability of any relevant policies and procedures:

The Program supports 13th Sustainable Development Goal – Climate action (by UN) . It's a strategic project of Poland, incorporated into Governmental Strategy of Responsible Development. Results are also monitored and reported to the Ministry of the Environment every month. Another document is Forestry Social Responsibility.

3.11 Avoidance of double counting, issuance and claiming

SECTION III, Part 4.7—Are only counted once towards a mitigation obligation includes questions related to this criterion. No additional information is requested here.

Each single unit (1 MT of CO2 equivalent) will have unique serial and ID number

PART 4: Carbon Offset Credit Integrity Assessment Criteria

Note—Where the Program has any immediate plans to revise the Program (e.g., its policies, procedures, measures) to enhance consistency with a given criterion or guideline, provide the following information in response to the relevant form question(s):

- Proposed revision(s);

- Process and proposed timeline to develop and implement the proposed revision(s);

- Process and timeline for external communication and implementation of the revision(s).

4.1 Are additional

What is the threshold for over-issuance risk beyond which the Program provisions or measures require a response? (*Quantify if possible*)

The program will use only part of predicted additionally (quantity of CO_2 from forest ecosystem reservoirs where additional activities will accumulate more CO_2) Conservative approach calls for 50% reserve.

Is additionality and baseline-setting assessed by an accredited and independent third-party verification entity, and reviewed by the Program? (*Paragraph 3.1*) x YES

Summarize and provide evidence of the relevant policies and procedures, including their availability to the public:

The State Forests as a public entity is obligated to share information requested by a citizen. The procedures of estimation carbon stocks was developed under scientific projects and results are available for the public. The pilot project Carbon Forests which directly leads to the carbon offset by additional carbon sequestration has strictly defined policies and procedures. The main goal of the project, that is additional effect results is periodically shared to the public in form of State Forests website news or conferences presentations. It was widely discussed during COP presentation in Katowice in December 2018 and further UNFCCC meetings. Our important tool, improved Canadian Budget Model, is publicly available. Work pertaining to CBM done mainly by third-party: Forest Research Institute.

Does the Program utilize one or more of the methods cited in Paragraph 3.1.2, which can be applied at the project- and/or program-level? (*Paragraphs 3.1.2 - 3.1.3*) x YES

Summarize and provide evidence of the relevant policies and procedures, including listing and describing any/all analysis / test types that the Program permits for use:

The additional carbon sequestration system described in the project documentation is organized into particular tasks that are to be performed in the field. It also includes the analyses, tests and predictions using Carbon Modelling program (CBM-CFS3). The tasks are listed in the Directive no 2 of the Director–General of the State Forests' dated January 17th 2017 (amended by BYLAWS # 67 / 2018)

If the Program designates certain activities as automatically additional (e.g., through a "positive list" of eligible project types), does the Program provide clear evidence on how the activity was determined to be additional? (*Paragraph 3.1*)

Summarize and provide evidence of the availability to the public of relevant policies and procedures, including the criteria used to determine additionality:

The procedures and policies are open to the public. They are periodically shared to the public by the State Forests on their website and presentations. The calculations are performed on publicly available application (Canadian Budget Model). The outcome of the works is to determine which of the additional activities give the best results. Additional activities (efforts) are not prescribed for business as usual operations. The incoming program will benefit from the experience of existing PILOT program.

Describe how the procedures described in this section provide a reasonable assurance that the mitigation would not have occurred in the absence of the offset program: (*Paragraph 3.1*)

Mitigation would and will occur, what is the natural merit and asset of the forest, but without additional activities would be essentially and ***measureably*** *much less..* *In our pilot project we measure absorption of reference (business as usual) separations, absorption of separations with additional activities so results come from the objective comparison of results from around 6000 ha active Carbon Forest and around 6000 ha of reference areas Carbon Forests*

4.2 Are based on a realistic and credible baseline

Are procedures in place to issue emissions units against realistic, defensible, and conservative baseline estimations of emissions? (*Paragraph 3.2*) x YES

Summarize and provide evidence of the relevant policies and procedures, including that baselines and underlying assumptions are publicly disclosed:

The baseline directly results from the Forest Management Plans. Forest management plans are created in the State Forests every 10 years by third-party experts, whom Head reports to the Environmental Minister. During the development of forest management plans, public consultations take place. Forest management plans are approved by the Ministry of the Environment. The procedure is described in The Forest Act (enclosed link: https://www.ecolex.org/details/legislation/forest-act-1991-lex-faoc003359/). Measurement 10 years later indicate effects of our management during the decade and are done by third-party mentioned above. That's why our active Carbon Forests and reference Carbon Forests are so momentous to indicate baselines.

Are procedures in place to ensure that methods of developing baselines, including modelling, benchmarking or the use of historical data, use assumptions, methodologies, and values do not over-estimate mitigation from an activity? (*Paragraph 3.2.2*) x YES

Summarize and provide evidence of the relevant policies and procedures:

The calculations based on CBM-CFS3, when natural or anthropogenic disturbances can be included in modelling process.

Are procedures in place for activities to respond, as appropriate, to changing baseline conditions that were not expected at the time of registration? (*Paragraph 3.2.3*) x YES

Summarize and provide evidence of the relevant policies and procedures:

The baseline is updated together with new forest management plan creation, that is every 10 years. Moreover, in case of future Carbon Forest area, to be based on forest management plan, on the top will be based on field works methodology developed for pilot Carbon Forests, including stands characteristics.

4.3 Are quantified, monitored, reported, and verified

Are procedures in place to ensure that…

a) emissions units are based on accurate measurements and valid quantification methods/protocols? (*Paragraph 3.3*) x YES

b) validation occurs prior to or in tandem with verification? (*Paragraph 3.3.2*) x YES

c) results of validation and verification are made publicly available? (*Paragraph 3.3.2*) x YES

d) monitoring, measuring, and reporting of both activities and the resulting mitigation is conducted at specified intervals throughout the duration of the crediting period? (*Paragraph 3.3*) x YES

e) mitigation is measured and verified by an accredited and independent third-party verification entity? (*Paragraph 3.3*) x YES

f) *ex-post* verification of mitigation is required in advance of issuance of emissions units? (*Paragraph 3.3*) x YES

Summarize and provide evidence of the relevant policies and procedures related to a) throughf):

The State Forests support science projects, i.e.:
1) the REMBIOFOR research project entitled "Remote sensing-based assessment of woody biomass and carbon storage in forests" and was financially supported by The National Centre for Research and Development, Poland under the BIOSTRATEG program (agreement no. BIOSTRATEG1/267755/4/ NCBR/2015)
2) Carbon Forests (previous name; Forest Carbon Farms) – whole project is financed from the State Forests' own resources.
3) ForBioSensing LIFE+ project PL Comprehensive monitoring of stand dynamics in Bialowieza Forest supported with remote sensing techniques is co-funded by the European Commission under European Union financial instrument LIFE+ and by the National Fund for Environmental Protection and Water Management

Are provisions in place… *(Paragraph 3.3.3)*

a) to manage and/or prevent conflicts of interest between accredited third-party(ies) performing the validation and/or verification procedures, and the Program and the activities it supports? x YES

b) requiring accredited third-party(ies) to disclose any conflict of interest? x YES

c) to address and isolate such conflicts, should they arise? x YES

Summarize and provide evidence of the relevant policies and procedures:

Validation and verification to be performed by two different CORSIA approved BODIES ,with no doubt honesty and integrity. Existing pilot program had not require V&V, however we started preliminary contacts with voluntary market authorities (e.g. Verra, Plan Vivo, Lloyd's Reg.) contemplating certification. When we found CORSIA we put everything else on holding pattern.

Are procedures in place requiring that renewal of any activity at the end of its crediting period includes a reevaluation and update of baseline? *(Paragraph 3.3.4)* x YES

Summarize and provide evidence of the relevant policies and procedures:

The forest stands included in project are a part of national forests, when all stands are individually identified and the changes in structure are noted and archived. Moreover forest management plans (the aforementioned baseline for the project) are created in the State Forests every 10 years and the changes are reflected.

Are procedures in place to transparently identify units that are issued *ex-ante* and thus ineligible for use in the CORSIA? *(Paragraph 3.3.5)*

Provide evidence of the relevant policies and procedures:

The CORSIA CARBON FORESTS planned program will provide (by definition) only EX-POST results - based certificates and only such will be issued.

4.4 Have a clear and transparent chain of custody

SECTION III, Part 3.4—Identification and tracking includes questions related to this criterion. No additional information is requested here.

4.5 Represent permanent emissions reductions

List any emissions sectors (if possible, activity types) supported by the Program that present a potential risk of reversal of emissions reductions, avoidance, or carbon sequestration:

In our, Forestry Sector there is a natural phenomenon of both: emission and absorption. However, as absorption is greater, forests in Poland absorb NETTO between 35 and 40 million MT of CO2 every year, (e.g. in 2015: 36 500 000 MT) Our program goes directly for enhancement of absorption.

What is the minimum scale of reversal for which the Program provisions or measures require a response? (Quantify if possible) N/A

N/A

For sectors/activity types identified in the first question in this section, are procedures / provisions in place to require and support these activities to...

a) undertake a risk assessment that accounts for, *inter alia*, any potential causes, relative scale, and relative likelihood of reversals? (*Paragraph 3.5.2*) x YES

b) monitor identified risks of reversals? (*Paragraph 3.5.3*) x YES

c) mitigate identified risks of reversals? (*Paragraph 3.5.3*) x YES

d) ensure full compensation for material reversals of mitigation issued as emissions units and used toward offsetting obligations under the CORSIA? (*Paragraph 3.5.4*) x YES

Summarize and provide evidence of the relevant policies and procedures related to a) through d):

Particular provisions will be implemented under CORSIA'S guidance.

Are provisions in place that... (*Paragraph 3.5.5*)

a) confer liability on the activity proponent to monitor, mitigate, and respond to reversals in a manner mandated in the Program procedures? x YES

b) require activity proponents, upon being made aware of a material reversal event, to notify the Program within a specified number of days? x YES

c) confer responsibility to the Program to, upon such notification, ensure and confirm that such reversals are fully compensated in a manner mandated in the Program procedures? x YES

Summarize and provide evidence of the relevant policies and procedures related to a) through c):

Monitoring and addressing irregularities is our duty (Bylaws, The Forest Act)

Does the Program have the capability to ensure that any emissions units which compensate for the material reversal of mitigation issued as emissions units and used toward offsetting obligations under the CORSIA are fully eligible for use under the CORSIA? (*Paragraph 3.5.6*)

Summarize and provide evidence of the relevant policies and procedures:

The reserve will serve this need (will compensate).

Would the Program be willing and able, upon request, to demonstrate that its permanence provisions can fully compensate for the reversal of mitigation issued as emissions units and used under the CORSIA? (*Paragraph 3.5.7*) x YES

4.6 Assess and mitigate against potential increase in emissions elsewhere

List any emissions sectors (if possible, activity types) supported by the Program that present a potential risk of material emissions leakage:

N/A

Are measures in place to assess and mitigate incidences of material leakage of emissions that may result from the implementation of an offset project or program? (*Paragraph 3.6*) N/A YES

Summarize and provide evidence of the relevant policies and procedures:

Are provisions in place requiring activities that pose a risk of leakage when implemented at the project-level to be implemented at a national level, or on an interim basis on a subnational level, in order to mitigate the risk of leakage? (*Paragraph 3.6.2*) N/A YES

Summarize and provide evidence of the relevant policies and procedures:

Are procedures in place requiring activities to monitor identified leakage? (*Paragraph 3.6.3*) N/A YES

Summarize and provide evidence of the relevant policies and procedures:

Are procedures in place requiring activities to deduct from their accounting emissions from any identified leakage that reduces the mitigation benefits of the activities? (*Paragraph 3.6.4*) N/A YES

Summarize and provide evidence of the relevant policies and procedures:

N/A

4.7 Are only counted once towards a mitigation obligation

Are measures in place to avoid the following, as defined in the corresponding Paragraphs, particularly with respect to registry-related protocols and/or oversight?

a) double-issuance? (*Paragraphs 3.7.1 and 3.7.5*) x YES

b) double-use? (*Paragraphs 3.7.2 and 3.7.6*) x YES

c) double-selling? (*Paragraph 3.7.7*) x YES

Summarize and provide evidence of the relevant policies and procedures related to a) through c):

Each (generated ex-post only) unit will have unique serial and I.D. number. Our own IT Department secure systems prevent from double – issuance, double- use, double selling. So far we had not have any need to issue such serial and unique numbers, but with full-blown program we will.

Are measures in place (or *would the Program be willing and able to put in place measures*) to avoid double-claiming as defined in *Paragraph 3.7.3*? x YES

As resolved as in *Paragraphs 3.7.8 – 3.7.9*? x YES

Summarize and provide evidence of any relevant policies and procedures:

The Project will be dedicated exclusively to CORSIA. Later, upon your pre-approval, Bylaws #67 will be amended by the Director General of The State Forests of The Republic of Poland

If no measures are currently in place, describe what measures the Program would consider putting in place in relation to the guidelines in *Paragraphs 3.7.3* and *Paragraphs 3.7.8 – 3.7.9*:

As above, plus we are willing and ready to implement additional measures according to CORSIA.

Are measures in place (or *would the Program be willing and able to put in place measures*) to...

a) make publicly available any national government decisions related to accounting for the underlying mitigation associated with units used in ICAO, including the contents of host country attestations described in the criterion guidelines (*Paragraph 3.7.10*)	N/A
b) update information pertaining to host country attestation as often as necessary to avoid double-claiming? (*Paragraph 3.7.10*)	N/A
c) monitor for double-claiming by relevant government agency(ies) that otherwise attested to their intention to not double-claim the mitigation? (*Paragraph 3.7.11*)	N/A
d) report to ICAO's relevant bodies, as requested, performance information related to, *inter alia*, any material instances of and Program responses to country-level double-claiming; the nature of, and any changes to, the number, scale, and/or scope of host country attestations; any relevant changes to related Program measures? (*Paragraph 3.7.12*)	N/A
e) to compensate for, replace, or otherwise reconcile double-claimed mitigation associated with units used under the CORSIA which the host country's national accounting focal point or designee otherwise attested to its intention to not double-claim? (*Paragraph 3.7.13*)	N/A

Summarize and provide evidence of any relevant policies and procedures related to a) through e):

All applicable requirements will be in place.

If no measures are currently in place, describe what measures the Program would consider putting in place in relation to the guidelines in *Paragraphs 3.7.10 – 3.7.13*:

The guidelines pertain –as we understand- to the situation like with CDM, where the investor was from the country different from the project site country. In any case our IT system, with triple control, would never allow for it.

4.8 Do no net harm

Are procedures in place to ensure that offset projects do not violate local, state/provincial, national or international regulations or obligations? (*Paragraph 3.8*)	x YES

Summarize and provide evidence of the relevant policies and procedures:

State Forests all general activities, work, administration etc.is regulated by The Forest Act (1991). We also not only obey but enforce Nature Conservation Act (2004) and many other legal acts related to our duties and ultimate goal to protect and enlarge the forests for future generations and to mitigate the climate change.

Provide evidence that the Program complies with social and environmental safeguards: (*Paragraph 3.8*)

The program benefits both: the environment and the society

Provide evidence of the Program's public disclosure of the institutions, processes, and procedures that are used to implement, monitor, and enforce safeguards to identify, assess and manage environmental and social risks: (*Paragraph 3.8*)

As we benefit from the experience from somehow similar projects from the past (e.g. protection of endanger trees species) we found that this type of climate-oriented, environment-oriented, nature-oriented programs do not generate this type of risk.

PART 5: Program comments

Are there any additional comments the Program wishes to make to support the information provided in this form?

Yes, we are enclosing program description, in particular activities generating enhanced absorption plus the description of our computing tool:

"Modelling carbon budget on the local and global scale in the State Forests Holding and developing scientific input parameters and management scenarios for Poland" and "Development of scientific foundations and methodological solutions supporting the Pilot Development Project – The Forest Carbon Project" are research and implementation projects developed to adapt the "Carbon Budget Model of the Canadian Forest Sector model (CBM-CFS3)" to the conditions of Poland.

It is used to calculate the forest carbon stock for international reporting, forest management planning, control of forest certification requirements, implementation of sustainable forest management and support for the ongoing decision-making process in forestry.

According to independent experts [Harold 2016], this model is the most advanced and complementary software to simulate the spatial dynamics of all carbon reservoirs in forests. It complies with the guidelines of "Good Practice Guidance for Land use, Land-Use Change and Forestry" published by the Intergovernmental Panel on Climate Change (IPCC) under the UN Framework Convention on Climate Change (UNFCCC).

It is also probably the most widely used model, evidenced by the number of downloads registered on the Canadian Resources website (the model has been downloaded over 1500 times from addresses from nearly 50 countries of the world). The software acronym – "CBM-CFS" shows up in more than 350 publications, based on Scopus database.

The model was developed to model the carbon balance in Canada. In any other country, it requires to identify a study site with a Canadian province or territory, as well as the ecosystem zone, unless there is a suitably adapted archived database (AIDB), which contains:

- administrative units,
- ecological zones, which should be relatively homogeneous in terms of climate and frequency of disturbances,
- climate data,
- allometric equations, i.e. volume or biomass conversion equations at the forest stand level,
- a disturbance matrix which determines how carbon is transferred among pools of the ecosystem as a result of a specific disturbance,
- yield (growth) curves (tables),
- wood density,
- organic matter decomposition index.

The necessary minimum to create input data for the CBM-CFS3 model is to determine the species and age of trees, at the forest stand level. The modeling includes the entire set of biomass components, including large timber, small timber, foliage, large roots, small roots and dead organic matter.

In the project, data for over 170 forest districts were prepared and submitted. Detailed results have been described in partial reports. They allowed to draw the following general conclusions:

- One of the easiest ways to extend the period of carbon retention (significantly affecting the size of harvest) is to extend the harvesting age, unless it reduces the technical quality of wood raw material and consequently does not cause its decomposition sooner after switching to the wood product pool.
- Intensification of absorbed carbon in the initial stage of stand growth can be used best in fast growing trees plantation. The product of such plantations would be a full-value wood raw material, possible to be used in construction or a similar field.
- Further improvement of the principles of cultivation, protection and use of the forest, aiming at forest management on the one hand, and production of full-value wood raw material on the other hand it is also a way to increase the absorption and retention of carbon in forest ecosystems.
- Keeping sustainable forest management, aimed at limiting damage from insect gradation, fungi, forest fires, and other natural disturbances has a significant impact on the carbon balance in forest ecosystems.
- Increasing biomass by introducing additional species of forest trees and shrubs, and thus better utilization of the habitat's potential means that carbon absorption increases.

Literature

Harold S.J. Zald, Thomas A. Spies, Mark E. Harmon, and Mark J. Twery Forest Carbon Calculators: A Review for Managers, Policymakers, and Educators, Journal of Forestry • March 2016

Kull, S.J.; Rampley, G.J., Morken, S.; Metsaranta, J.; Neilson, E.T.; Kurz, W.A. 2011. Operational-scale Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) version 1.2: user's guide. Nat. Resour. Can., Can. For. Serv., Nor. For. Cent., Edmonton, AB.

Kurz, W.A.; Dymond, C.C.; White, T.M.; Stinson, G.; Shaw, C.H.; Rampley, G.J.; Smyth, C.E.; Simpson, B.N.; Neilson, E.T.; Trofymow, J.A.; Metsaranta, J.M.; Apps, M.J. 2009. CBM-CFS3: a model of carbon-dynamics in forestry and land-use change implementing IPCC standards. Ecological Modelling 220(4): 480-504.

Moroni, M.T.; Shaw, C.H.; Otahal, P. 2010a. Forest carbon stocks in Newfoundland boreal forests of harvest and natural disturbance origin I: Field study. Can. J. For. Res. 40:2135-2145.

General scenario and additional forest management efforts
IMPORTANT:

What we want to achieve now is: we expect to have **CORSIA** approval for our approach to testing, PILOT program of Carbon Forests, but what we **are planning** upon your approval is, to ESTABLISHING full-blown program over greater area, this time for commercial, **CORSIA-standards** certificates, where we will utilize selected additional actions (better forest management techniques) out of what we tested in presented pilot program, which is already two and a half years in effect. What is also important, according to one of our upper level management Executives, State Forests may consider an acquirement of land (mostly former agricultural usage) dedicated to our subject project! Afforestation, Underplanting & Sobanski's to be our bread & butter.

From an environmental perspective, Polish State Forests play a critical role in protecting water quantity and quality, supporting a rich biological diversity, maintaining soil productivity, and storing carbon. Our Carbon Forests Pilot Program focuses on what is itemized above, however obviously in particular on CO2 absorption . Water from forested landscapes is cleaner than that from any other category of land use. The filtration and runoff control provided by a forest not only maintains water quality but also regulates the amount of flow in water bodies — keeping high water extremes to a lower level and low water flows to a higher level than what would be expected from a less protected watershed. The forest functions that protect water quality also serve to maintain soil productivity by preventing erosion. With proper attention to leaving appropriate amounts of logging residue, forest management involving selected type of harvests can still build, or at least maintain, soil nutrient levels, organic matter, and microorganisms. Appropriate harvest practices also minimize compaction and other physical changes to soil properties that might occur under clear-cut harvest (and in general, different land uses). What we do within the borders of designated CARBON FORESTS (CF) areas, we do additional efforts, additional practices of forest management recommended by numerous of scientists after years of pre-project field research, including :

- extended and updated stand description and inventories
  - ✓ establishing the value of the stand characteristics which will allow the modeling of carbon stocks in different reservoirs
  - ✓ tree stands included in the CFs and reference areas
- Basic Carbon Sample Plot (BCSP) - selection of representative parts of stands for sampling of organic material
  - ✓ soil exploration, different types of soil samples from different genetic levels
  - ✓ undergrowth - cutting and chipping
  - ✓ forest floor, litter (uniform grid of circle sample plots of 0,2 m^2)
  - ✓ tree stand-sample trees (sectional measurements, determination of fresh biomass of all tree components, sampling for laboratory testing from the aboveground and underground parts of BCSP, including dead roots)
  - ✓ securing and transporting the samples to the laboratory

and after dozens of brainstorms, before additional practices were selected.

Please find the list of our additional practices:

AFFORESTATION – introduction of saplings on former agricultural land (or other, e.g. wasteland); agricultural melioration, if necessary, mechanical preparation of the soil, most often into stripes using the LPZ-75 plow, manual planting of Scots pine and deciduous species of the age 1 year or older Scots pine saplings; planting using the appropriate spacing according to ZHL (Forest Silviculture Guidelines), e.g. Scots pine - 10 thousand plants per ha; species composition corresponding to the habitat; also activities maintaining the stability: cultivation care, protection against animals; if necessary corrections (replanting). All this pertaining to the lands which have not been included in forestry production activities for a long time e.g. post-agricultural areas. Like renewal, afforestation may be natural or artificial, however natural occurs seldom when land was not a forest before - pending the presence of immediate adjacent stands.

FAST GROWING TREE SPECIES - planting with the participation (predominance) of fast-growing species (mainly Douglas fir - Pseudotsuga, larch –Larix Polonica), sometimes the use of fast-growing species not predicted in Forest Silviculture Guidelines e.g. Douglas fir instead of Spruce; activities depend on the way the crop is planted, usually an artificial underplanting of 2-year-old saplings in the proper spacing according to Forest Silviculture Guidelines; it is allowed that the fast-growing species "replaces" the main species only partially.

SOBANSKI'S TECHNIQUE Semi-natural but really more on artificial side technique innovated by forester Sobanski. Firstly, he requires from the followers to: • Identify site/species suitability • Assess potential mixtures suitable for the site • Maximize species diversity • Identify species management requirements • Check provenance documentation • Identify forest objectives • Identify constraints and opportunities relating to riparian zones, biodiversity, landscape and other environmental factors • Ensure correct management practice. The main idea is: First, in the fall, with one pass of a light tractor, we make a streaky shallow plowing with a milling cutter, after a few seconds sowing the deciduous species, later to be the second leading (often oak) with admixtures like pear tree, rowan, rose, wild apple tree. In the formatted strips of fluffed soil in spring, we plant pine seedlings, between which then seedlings from seed sown in autumn will appear! Numbers should reach minimum 8 thousand Scots pine plants per 1 ha, 3-5 thousand oak plants introduced by sowing. The oak should usually be fenced earlier.

UNDERPLANTING Increased diversity will have an impact on forest practice. The high position of Pinus Silvestris in Poland has meant that forestry operations reflect the requirements of the species. As it is relatively easy to grow, suitable for a wide range of sites, and is uniform under plantation conditions, with clearly defined growth rates and rotations. All of these factors enabled the standardization of forest practice, although this does not imply that best practice was always the case. That is why we do underplanting (even up to 4000 ball planting per ha) beech trees or oaks or - if soil is poor- birch trees. Likely, we keep in mind cultivation care, protection against animals; if necessary – replanting.

SILVICULTURAL SYSTEM, like change of clear-cut felling to shelterwood cutting (e.g. stripe shelterwood) or shelterwood cutting to group shelterwood method. **Shelterwood cutting** refers to the progression of forest cuttings leading to the establishment of a new generation of seedlings of a particular species or group of species without planting.[1] This silvicultural system is normally implemented in forests that are considered mature, often after two main thinnings. The desired species are usually long-lived and their seedlings would naturally tend to start under partial shade. The shelterwood system gives enough light for the desired species to establish without giving enough light for the weeds that are adapted to full sun. Once the desired species is established, subsequent cuttings give the new seedlings more light and the growing space is fully passed to the new generation. Another words the use of silvicultural systems with a higher degree of complexity and usually longer regeneration period. Mainly: I silvicultural system into II silvicultural system, II*->IV*; III*->IV,V etc. (according to Forest Silviculture Guidelines)

SURFACE PROTECTION-ORIENTED HARVESTING. That, as extraction time comes, we practice skidding and forwarding vs. traditional extraction what used to heavily damage the surface of the soil. Along with skid tracks/trails efficient planning and religiously observed instructions not to trespass, makes improvement. As a result, the size (%) of the surface (and in depth) damage to the soil surface is significantly reduced. Poor harvesting practices can favor soil organisms that cause disease or damage to standing timber. The reduced aeration and increased ponding and soil wetness associated with compaction and rutting favors the growth of Phytophthora. These thrive under saturated soil conditions where they feed on the fine roots of trees and other plants, causing growth reductions or death. The wounding of tree roots and stems by skidders and other harvesting equipment or by prescribed fires increases susceptibility to Armillaria fungi. Some species of Armillaria are pathogenic, eventually killing trees that have been initially wounded during harvesting, prescribed burning, or other management activity. Generally, protecting the soil from compaction, rutting, erosion, organic matter loss, and excessive nutrient depletion favors soil organisms that are the most beneficial for maintaining healthy forests. Implementing practices that protect the physical and chemical properties of the soil also protects the habitat of the soil organisms and sustains their populations.

SOIL PROTECTING RENEWAL Likely important as described above. Instead of full or partial soil preparation - planting with smaller share (size,%) soil preparation (e.g. instead of plowing full preparation in strips or plates and instead of mechanical soil preparation into stripes - local preparation (in small spots) or planting without soil preparation, treatments aimed at reducing or completely reducing the uncovering of the soil cover during the forest regeneration process, expressed for example, in a reduced area% of soil preparation or in a less invasive way of preparing it. We give up full blown plowing. We use small spot for discing and even planting wedge/dagger to do not damage the surface of the soil.

OPEN GLADES/ FAILED CLEARINGS Openings in forested landscapes can be either natural openings, such as glades that exist due to shallow drought-prone soils, or openings created through intentional clearing. Where glades exist, they provide distinct and important habitat type that many species utilize and benefit from. They are most often found on south and west-facing slopes or ridge tops. The native species that occur on glades are more drought tolerant. It is recommended that glades be managed to somehow promote these species, however, we plant either artificially (or semi-natural Sobanski's) for Scots pine for certain habitat conditions - 12 thousand / ha instead of 8 thousand / ha.

REGENERATION FROM NATURAL SEEDING - the works aiming to regenerate the forest by natural seeding regardless of the surface category (open, under shelter, non-forest) initiated as a result of forest management measures and in a size (share) much larger than the typical for given conditions (e.g. obtaining a large part or whole regeneration of the area of the pine trees cultivation as a result of successful natural seeding where the normal path provides artificial planting or obtaining natural regeneration for other species in a larger than expected share in the stand- for example, the total mixed broadleaved forest cultivation achieved as a result of seeding of Beech and Spruce;

SECTION IV: SIGNATURE

I certify that I am the administrator or authorized representative ("Program Representative") of the emissions unit program ("Program") represented in a) this form, b) evidence accompanying this form, and c) any subsequent oral and/or written correspondence (a-c: "Program Submission") between the Program and ICAO; and that I am duly authorized to represent the Program in all matters related to ICAO's analysis of this application form; and that ICAO will be promptly informed of any changes to the contact person(s) or contact information listed in this form.

As the Program Representative, I certify that all information in this form is true, accurate, and complete to the best of my knowledge.

As the Program Representative, I acknowledge that:

the Program's participation in the assessment does not guarantee, equate to, or prejudge future decisions by Council regarding CORSIA-eligible emissions units; and

the ICAO is not responsible for and shall not be liable for any losses, damages, liabilities, or expenses that the Program may incur arising from or associated with its voluntary participation in the assessment; and

as a condition of participating in the assessment, the Program will not at any point publicly disseminate, communicate, or otherwise disclose the nature, content, or status of communications between the Program and ICAO, and of the assessment process generally, unless the Program has received prior notice from the ICAO Secretariat that such information has been and/or can be publicly disclosed.

Signed:

Krzysztof Janeczko, Ph.D. Eng., Deputy Director of Economy	2019-07-12
Full name of Program Representative (*Print*)	Date signed (*Print*)

ZASTĘPCA DYREKTORA GENERALNEGO
ds. Ekonomicznych

Program Representative (*Signature*)
dr inż. Krzysztof Janeczko

(This signature page may be printed, signed, scanned and submitted as a separate file attachment)

Program Application Form, Appendix B

Program Scope Information Request

CONTENTS: This document collects information from emissions unit programs pertaining to the following:

Sheet A) Activities the program describes in this form, which will be assessed by ICAO's body of experts
Sheet B) Any activities that the program does not wish to submit for assessment
Sheet C) List of all methodologies / protocols that support activities described under Sheet A

SHEET A: DESCRIBED ACTIVITIES *(Here, list activities supported by the program that are described in this form for further assessment)*

Sector	Supported activity type(s)	Implementation level(s)	Geography(ies)
Forestry	AFFORESTATION	Introduction of saplings on former agricultural land (or other, e.g. wasteland); agricultural melioration, if necessary, mechanical preparation of the soil, most often into stripes using the LPZ-75 plow, manual planting of Scots pine and deciduous species of the age 1 year or older Scots pine saplings; planting using the appropriate spacing according to ZHL (Forest Silviculture Guidelines), e.g. Scots pine - 10 thousand plants per ha; species composition corresponding to the habitat; also activities maintaining the stability: cultivation care, protection against animals; if necessary corrections (replanting). All this pertaining to the lands which have not been included in forestry production activities for a long time e.g. post-agricultural areas. Like renewal, afforestation may be natural or artificial, however natural occures seldom when land was not a forest before - pending the presence of immediate adjacent stands.	Poland (possible to be used in central and eastern Europe)
Forestry	FAST GROWING TREE SPECIES	planting with the participation (predominance) of fast-growing species (mainly Douglas fir - Pseudotsuga, larch –Larix Polonica), sometimes the use of fast-growing species not predicted in Forest Silviculture Guidelines e.g. Douglas fir instead of Spruce; activities depend on the way the crop is planted, usually an artificial underplanting of 2-year-old saplings in the proper spacing according to Forest Silviculture Guidelines; it is allowed that the fast-growing species "replaces" the main species only partially.	Poland (possible to be used in central and eastern Europe)

Forestry	SOBANSKI’S TECHNIQUE	Semi-natural but really more on artificial side technique innovated by forester Sobanski. Firstly, he requires from the followers to: • Identify site/species suitability • Assess potential mixtures suitable for the site • Maximize species diversity • Identify species management requirements • Check provenance documentation • Identify forest objectives • Identify constraints and opportunities relating to riparian zones, biodiversity, landscape and other environmental factors • Ensure correct management practice. The main idea is: First, in the fall, with one pass of a light tractor, we make a streaky shallow plowing with a milling cutter, after a few seconds sowing the deciduous species, later to be the second leading (often oak) with admixtures like pear tree, rowan, rose, wild apple tree. In the formated strips of fluffed soil in spring, we plant pine seedlings, between which then seedlings from seed sown in autumn will appear! Numbers should reach minimum 8 thousand Scots pine plants per 1 ha, 3-5 thousand oak plants introduced by sowing. The oak should usually be fenced earlier.	Poland (possible to be used in central and eastern Europe)
Forestry	UNDERPLANTING	Increased diversity will have an impact on forest practice. The high position of Pinus Silvestris in Poland has meant that forestry operations reflect the requirements of the species. As it is relatively easy to grow, suitable for a wide range of sites, and is uniform under plantation conditions, with clearly defined growth rates and rotations. All of these factors enabled the standardisation of forest practice, although this does not imply that best practice was always the case. That is why we do underplanting (even up to 4000 ball planting per ha) beech trees or oaks or - if soil is poor- birch trees. Likely, we keep in mind cultivation care, protection against animals; if necessary – replanting.	Poland (possible to be used in central and eastern Europe)

Forestry	SILVICULTURAL SYSTEM	Like change of clear-cut felling to shelterwood cutting (e.g. stripe shelterwood) or shelterwood cutting to group shelterwood method. Shelterwood cutting refers to the progression of forest cuttings leading to the establishment of a new generation of seedlings of a particular species or group of species without planting.[1] This silvicultural system is normally implemented in forests that are considered mature, often after two main thinnings. The desired species are usually long-lived and their seedlings would naturally tend to start under partial shade. The shelterwood system gives enough light for the desired species to establish without giving enough light for the weeds that are adapted to full sun. Once the desired species is established, subsequent cuttings give the new seedlings more light and the growing space is fully passed to the new generation. Another words the use of silvicultural systems with a higher degree of complexity and usually longer regeneration period. Mainly: I silvicultural system into II silvicultural system, II*->IV*; III*->IV,V etc. (according to Forest Silviculture Guidelines).	Poland (possible to be used in central and eastern Europe)
Forestry	SURFACE PROTECTION-ORIENTED HARVESTING	As a result, the size (%) of the surface (and in depth) damage to the soil surface is significantly reduced. Poor harvesting practices can favor soil organisms that cause disease or damage to standing timber. The reduced aeration and increased ponding and soil wetness associated with compaction and rutting favors the growth of Phytophthora. These thrive under saturated soil conditions where they feed on the fine roots of trees and other plants, causing growth reductions or death. The wounding of tree roots and stems by skidders and other harvesting equipment or by prescribed fires increases susceptibility to Armillaria fungi. Some species of Armillaria are pathogenic, eventually killing trees that have been initially wounded during harvesting, prescribed burning, or other management activity. Generally, protecting the soil from compaction, rutting, erosion, organic matter loss, and excessive nutrient depletion favors soil organisms that are the most beneficial for maintaining healthy forests. Implementing practices that protect the physical and chemical properties of the soil also protects the habitat of the soil organisms and sustains their populations.	Poland (possible to be used in central and eastern Europe)

Forestry	SOIL PROTECTING RENEWAL	Likely important as described above. Instead of full or partial soil preparation - planting with smaller share (size,%) soil preparation (e.g. instead of plowing full preparation in strips or plates and instead of mechanical soil preparation into stripes - local preparation (in small spots) or planting without soil preparation, treatments aimed at reducing or completely reducing the uncovering of the soil cover during the forest regeneration process, expressed for example, in a reduced area% of soil preparation or in a less invasive way of preparing it. We give up full blown plowing. We use small spot for discing and even planting wedge/dagger to do not damage the surface of the soil.	Poland (possible to be used in central and eastern Europe)
Forestry	OPEN GLADES/ FAILED CLEARINGS	Openings in forested landscapes can be either natural openings, such as glades that exist due to shallow drought-prone soils, or openings created through intentional clearing. Where glades exist, they provide distinct and important habitat type that many species utilize and benefit from. They are most often found on south and west-facing slopes or ridge tops. The native species that occur on glades are more drought tolerant. It is recommended that glades be managed to somehow promote these species, however, we plant either artificially (or semi-natural Sobanski's) for Scots pine for certain habitat conditions - 12 thousand / ha instead of 8 thousand / ha.	Poland (possible to be used in central and eastern Europe)
Forestry	REGENERATION FROM NATURAL SEEDING	The works aiming to regenerate the forest by natural seeding regardless of the surface category (open, under shelter, non-forest) initiated as a result of forest management measures and in a size (share) much larger than the typical for given conditions (e.g. obtaining a large part or whole regeneration of the area of the pine trees cultivation as a result of successful natural seeding where the normal path provides artificial planting or obtaining natural regeneration for other species in a larger than expected share in the stand- for example, the total montane mixed broadleaved forest cultivation achieved as a result of seeding of Beech and Spruce.	Poland (possible to be used in central and eastern Europe)

SHEET B: EXCLUDED ACTIVITIES *(Here, list activities supported by the program that are not described in this form for further assessment)*

Sector	Supported activity type(s)	Implementation level(s)	Geography(ies)
e.g. Waste, Energy	e.g., Landfill methane capture; Coal mine methane capture;	e.g., Project-level only; Programs of activities; Sector-scale	e.g., Global; Non-Annex I-only; Country X only
forestry	Fassnacht F.E., Latifi H., Stereńczak K., Modzelewska A., Lefsky M., Waser L.T., Straub C., Ghosh A. 2016. Review of studies on tree species classification from remotely sensed data. Remote Sensning of Environment, 186: 64-87.	Spatially explicit information on tree species composition of managed and natural forests, plantations and urban vegetation provides valuable information for nature conservationists as well as for forest and urban managers and is frequently required over large spatial extents. Over the last four decades, advances in remote sensing technology have enabled the classification of tree species from veral sensor types. While studies using remote sensing data to classify andmap tree species reach back several decades, a recent eview on the status, potentials, challenges and outlooks in this realmismissing. Here, we search for major trends in remote sensing echniques for tree species classification and discuss the effectiveness of different sensors and algorithms based on a literature review. This review demonstrates that the number of studies focusing on tree species classification has increased constantly over the last four decades and promising local scale approaches have been presented for several sensor types. However, there are few examples for ree species classifications over large geographic extents, and bridging the gap between current approaches and tree species nventories over large geographic extents is still one of the biggest challenges of this research field. Furthermore, we found only few studies which systematically described and examined the traits that drive the observed variance in the remote sensing signal and thereby enable or hamper species classifications. Most studies followed data-driven approaches and pursued an optimization of classification accuracy, while a concrete hypothesis or a targeted application was missing in all but a few exceptional studies. We recommend that future research efforts focus stronger on the causal understanding of why tree species classification approacheswork under certain conditions or – maybe evenmore important -why they do notwork in other cases. Thismight requiremore complex field acquisitions than those typically used in the reviewed studies. At the same time, we recommend reducing the number of purely data-driven studies and lgorithmbenchmarking studies as these studies are of limited value, especially if the experimental design is limited, e.g. the tree population is not representative and only a few sensors or acquisition settings are simultaneously investigated.	Global
forestry	Socha J., Pierzchalski M., Bałazy R., Ciesielski M., 2017. Modelling top height growth and site index using repeated laser scanning data. Forest Ecology and Management, 406: 307-317.	Forest site productivity, which is a quantitative estimate of the potential of a site to produce plant biomass, remains a fundamental variable in forestry. The most commonly used and widely accepted method of evaluating site productivity is the site index. Therefore, the construction of site index models describing top height (TH) growth with age remains a fundamental task for site productivity ifferentiation. Three main data sources have been used for site index model development to date: (1) repeated measurements on permanent sample plots (PSP); (2) temporary sample plot (TSP) data from periodic inventories; and (3) stem analysis (SA) data. Our study is practical application of change detection using airborne laser scanners for the development of top height growth models. We demonstrated how wall-to-wall airborne laser scanner (ALS) data obtained for large forest areas can be used in developing top height growth models for Norway spruce that appropriately reflect sitespecific growth trajectories. Site specific growth trajectories were successfully captured by repeated height measurements using ALS data from notably short 5-year period, which indicates that such a period between subsequent ALS observations is sufficient and surmounts the noise and other uncertainties connected with ALS systems and interannual TH growth variations. Height increment obtained by change detection using repeated airborne laser scanning (ALS) may be recognized as a new, fully valuable data source for TH growth and site index modelling. Repeated ALS observations can be a substitute for height growth data used in site index modelling and collected to-date from SA, PSP or TSP. It could be expected that improving ALS technologies, decreasing costs of laser scanning acquisition and increasing data availability will result in improving the accuracy of forest height growth estimates. Therefore, in the near future, both utility and increased predictive validity will lead to substantial increases in the importance of change detection using airborne laser scanners in forest growth modelling using the data from repeated ALS measurements. forest growth modelling using the data from repeated ALS measurements.	Poland
forestry	Wietecha M., Modzelewska A., Stereńczak K. 2017. Wykorzystanie lotniczej teledetekcji hiperspektralnej w klasyfikacji gatunkowej lasów strefy umiarkowanej. Sylwan, 161 (1): 3-17.	The review focuses on use of airborne hyperspectral imagery in forest species classification. Studies mentioned in the review concern hyperspectral image classification with use of various methods. Only research, where study area is located in Europe or North America were selected. Articles were reviewed with respect to used pre–processing methods, methods of feature selection or feature extraction, algorithms of image classification and trees species which were classified. The whole process of acquiring and working with hyperspectral data is described. Different approaches (e.g. use or skip atmospheric corrections) were compared. In each article, various deciduous and conifer species were classified. Studies comparing several classification algorithms (Spectral Angle Mapper, Support Vector Machine, Random Forest) were mentioned. In most cases SVM gives the best results. Species, which are classified with the highest accuracy, include Scots pine (Pinus sylvestris) and Norway spruce (Picea abies). Broadleaved species are, in general, classified with lower accuracy than conifer ones. Within broadleaved trees, European beech (Fagus sylvatica) and oaks (Quercus sp.) are classified with the highest accuracy.	Global
forestry	Bruchwald A., Dmyterko E., Miścicki S., Stereńczak K. 2017. Assessment of the accuracy of the forest district inventory method based on the stratified sampling. Sylwan 161 (11): 909-916.	The aim of the research was to assess the accuracy of the stratified sampling method used to estimate the standing volume of a forest district and to compare it with the accuracy of simple random sampling methods. The paper presents the variability of the variables affecting the accuracy of the stratified sampling method. We attempted to find the ways to increase this accuracy. The research was based on the empirical material collected on approximately 42,000 sample plots with a size of 50–500 m2, and with an average of 737 plots per forest district. The standard deviation of the merchantable volume of trees on sample plots ranged from 87 to 213 m3/ha, with an average of 128 m3/ha. The coefficient of variation ranged from 5.3 to 28.5% (the average 40.8%). Using a simple random sampling method, the standard error of the volume ranged from 3.3 to 10.0 m3/ha (the average 4.8 m3/ha) and the relative error – from 1.01 to 3.41% (the average 1.55%). The absolute error of the stratified sampling method under which strata are formed on the basis of the main tree species and its age ranged from 2.9 to 7.4 m3/ha, the average 4.2 m3/ha, and the relative error ranged from 0.65 to 1.95%, 1.02% on average (tab.). The accuracy of the stratified sampling method was by 15% higher than that of the simple random sampling method. We found that the relationship between the volume of a sample plot and the main tree species and its age measured by the correlation coefficient was 0.453 on average. For the relationship between volume and age of stands this coefficient was on average 0.422, while between volume and main tree species – only 0.118. Stand age – as an auxiliary variable in formation of strata – proved to be of moderate usefulness resulting from a small difference in the standing volume of stands in older age classes. Main tree species turned out to be of slight usefulness in formation of strata, therefore it seems reasonable to find some other auxiliary variables to replace it.	Poland

forestry	Jagodziński A.M., Dyderski M.K., Gęsikiewicz K., Horodecki P., Cysewska A., Wierczyńska S., Maciejczyk K. 2018. How do tree stand parameters affect young Scots pine biomass? – Allometric equations and biomass conversion and expansion factors. Forest Ecology and Managment, 409: 74-83.	Due to the impact of climate change and rising atmospheric carbon dioxide concentrations, assessment of forest carbon pools becomes a crucial task for forest ecology. One of the scientific gaps in this task is the assessment of young tree stands, not included in forest inventories, due to lack of merchantable volume. We aimed to provide a comprehensive set of allometric equations (AEs) and biomass conversion and expansion factors (BCEFs) for young Scots pine tree stands and to develop models of tree stand biomass based on stand features easy-measurable by remote sensing: height and density. We used data collected in 77 tree stands of Scots pine ranging in age from 3 to 20 years in Western and Central Poland, covering forest, post-agricultural and post-industrial sites. Our dataset included 423 sample trees. Our study resulted in collection of 256 site-specific AEs, 12 generalized AEs and equations allowing for dynamic BCEF calculation. Due to lack of BCEF applicability for young trees, we also provided age- and height-dependent functions allowing for precise biomass estimation at the tree-stand level. It was found that tree-stand biomass increased with tree-stand age, height and volume, and decreased with increasing density in the chronosequence. BCEFs decreased with tree-stand age, height and volume and increased with increasing density. Using these relationships we provided stand-level equations based on BCEFs and on tree height – the stand characteristic which is easily obtained from airborne data. These two models did not show a big difference in accuracy. Thus, height-based models are expected to be useful for extensive assessments of young tree stand biomass and carbon sequestration, allowing for better estimation of forest carbon pools. Moreover, our models, in comparison with IPCC guidelines, give more precise values of carbon pools and biomass of young Scots pine tree stands.	Poland
forestry	Stereńczak K., Lisańczuk M., Erfanifard Y. 2018. Delineation of homogeneous forest patches using combination of field measurements and LiDAR point clouds as a reliable reference for evaluation of low resolution global satellite data. Forest Ecosystems, 5:1.	Backgrounds: There are many satellite systems acquiring environmental data on the world. Acquired global remote sensing datasets require ground reference data in order to calibrate them and assess their quality. Regarding calibration and validation of these datasets with broad geographical extents, it is essential to register zones which might be considered as Homogeneous Patches (HPs). Such patches enable an optimal calibration of satellite data/sensors, and what is more important is an analysis of components which significantly influence electro-magnetic signals registered by satellite sensors. Methods: We proposed two structurally different methods to identify HPs: predefined thresholding-based one (static one), and statistical thresholding-based technique (dynamic one). In the first method, 3 different thresholds were used: 5%, 10%, and 20%. Next, it was aimed to assess how delineated HPs were spatially matched to satellite data with coarse spatial resolution. Selected cell sizes were 25, 50, 100, 250, and 500 m. The number of particular grid cells which almost entirely fell into registered HPs was counted (leaving 2% cell area tolerance level). This procedure was executed separately for each variant and selected structural variables, as well as for their intersection parts. Results: The results of this investigation revealed that ALS data might have the potential in the identification of HPs of forest stands. We showed that different ALS based variables and thresholds of HPs definition influenced areas which can be treated as similar and homogeneous. We proved that integration of more than one structural variable limits size of the HPs, in contrast, visual interpretation revealed that inside such patches vegetation structure is more constant. Conclusions: We concluded that ALS data can be used as a potential source of data to "enlarge" small ground sample plots and to be used for evaluation and calibration of remotely sensed datasets provided by global systems with coarse spatial resolutions.	Poland
forestry	Stereńczak K., Lisańczuk M., Parkitna K., Mitelsztedt K., Mroczek P., Miścicki S. 2018. Influence of number and size of sample plots on modelling growing stock volume based on airborne laser scanning. Wood, 61, 201.	Current forest growing stock inventory methods used in Poland are based on statistical methods using field measurements of trees on circular sample plots. Such measurements are carried out with traditional equipment, i.e. callipers and range finders. Nowadays, remote sensing based inventory techniques are becoming more popular and have already been applied in North America and some Scandinavian countries. Remote sensing based forest inventories require a certain amount of ground sample plots, which serve either as reference data used for model calibration and/or as a validation dataset for the assessment of the accuracy of modelled variables. Using a set of 900 ground sample plots and Airborne Laser Scanner (ALS) from the Milicz forest district, a statistical model for the estimation of plot growing stock volume was developed. Next, the developed model was once again fitted to different variants of sample plot size and number of sample plots. Each variant was selected from a full 900 sample plot set. The selection started from 800, 700, 600, …, down to 25 plots, respectively, and was carried out in proportion to the dominant tree age range. To account for the area effect, each plot number variant was similarly tested with various sample plot areas, i.e. 500, 400, …, 100 m2. Sampling in each variant was repeated in order to take into account the effect of a single selection. The results showed a strong relationship between obtained modelling errors and the size and number of used sample plots. It has been demonstrated that the number of sample plots has no influence on the accuracy of GSV estimation above about 300-400 sample plots (about 500 sample plots for bias), whereas sample plot size has a visible impact on estimation accuracy, which reduces with decreasing sample plot size, regardless of the number of sample plots. If it is about precision, results showed that the influence of a single selection to be relevant only below 300-400 plots (about 500 for bias) and the same trend can be observed in each sample plot size variant. The results showed it is possible to strongly reduce the number of ground sample plots (minimum 300-400), while still maintaining decent accuracy and precision levels, at least in similarly investigated forest conditions.	Poland
forestry	Ochał W., Wertz B., Grabczyński S., Orzeł S. 2018. Dokładność określania świeżej masy strzał jodły na podstawie przeliczników wagowo-objętościowych. Sylwan, 162(4): 277-287.	Ochał W., Wertz B., Grabczyński S., Orzeł S. 2018. Dokładność określania świeżej masy strzał jodły na podstawie przeliczników wagowo−objętościowych. Sylwan 162 (4): 277−287. The paper describes the accuracy of estimation of silver fir stem fresh mass on the basis of volume to weight conversion factor, derived from samples, collected from few different places along the stem. The research material contained 13 sample trees selected from homogenous 70−years old stand, situated in mountainous area of the Beskid Sądecki in Polish part of the Carpathians (S Poland). Volume over the bark of sample trees was calculated with section−wise method and the whole stem fresh biomass was directly weighted. For each sample tree three stem discs were collected at 1/6, 1/2 and 5/6 of tree height, their weight and volume were precisely determined and the biomass conversion factors (equivalent of stem ensity) were calculated. The assessment of the accuracy of whole fresh stem biomass was conducted according to five variants: for the iomass conversion factors derived from each individual stem disc (lower, middle or upper), from weighted mean density and on the basis of the constructed mixed model, where relative height and diameter were treated as fixed effects and influence of individual trees was included as a random term. The volume of sample fir stems ranged from 0.15 to 2.22 m3, while their fresh biomass varied between 138.1 and 1896.7 kg. Obtained results show that variation of the density was higher within stems than between them coefficient of variation amounted to 8.4% i 3.3% respectively). The average density increased along stem, from 835.6 kg/m3 for lower part (1/6H) to 986.8 kg/m3 for the upper part (5/6H). Estimating the biomass on the basis of just lower stem disc resulted in the average relative error equal to –5.8%, while for middle stem disc the error was +1.2%, and for upper disc +11.3%. The use of conversion factors derived from weighted average density of all three stem discs resulted in average bias equal to –1,7% with standard error 1,0%. Despite the presence of mean bias of –2.3%, the constructed density model gave the most precise estimation of the stem biomass (standard error 0.7%), which indicates the reasons for its further improvements and usage.	Poland
forestry	Jagodziński, A.M.; Dyderski, M.K.; Gęsikiewicz, K.; Horodecki, P. Tree- and Stand-Level Biomass Estimation in a Larix decidua Mill. Chronosequence. Forests 2018, 9, 587.	Carbon pool assessments in forests is one of the most important tasks of forest ecology. Despite thewide cultivation range, and economical and traditional importance, the aboveground biomass of European larch (Larix deciduaMill.) stands is poorly harcterized. To increase knowledge about forest biomass accumulation and to provide a set of tools for aboveground biomass estimation, we studied a chronosequence of 12 larch forest stands (7–120 years old). From these stands, we measured the biomass of 96 sample trees ranging from 1.9 to 57.9 cm in diameter at breast height. We provided age-specific and generalized allometric equations, biomass conversion and expansion factors (BCEFs) and iomassmodels based on forest stand characteristics. Aboveground biomass of stands ranged from 4.46 (7-year-old forest stand) to 445.76Mg ha□1 (106-year-old). Stand biomass increased with ncreasing stand age, basal area, mean diameter, height and total stem volume and decreased with increasing density. BCEFs of the aboveground biomass and stemwere almost constant (mean BCEFs of 0.4688 and 0.3833Mgm□3, respectively). Our eneralizedmodels at the tree and stand level had lower bias in predicting the biomass of the forest stands studied, than other publishedmodels. The set of tools provided fills the gap in biomass estimation caused by the low number of studies on larch biomass, which allows for better estimation of forest carbon pools.	Poland

forestry	Stereńczak K., Mielcarek M., Wertz B., Bronisz K., Zajączkowski G., Jagodziński A.M., Ochał W., Skorupski M. 2019. Factors influencing the accuracy of ground-based tree-height measurements for major European tree species. Journal of Environmental Management, 231: 1284-1292.	Tree height is one of the most important forest characteristics and is one of the crucial measurements taken for either practical or scientific reasons. However, the accuracy of a tree-height measurement may vary in relation to many factors. The work described here thus sought to evaluate the accuracy of ground-based tree-height measurements for major forest-forming tree species of the temperate and boreal zones. The focus was on the importance of factors affecting accuracy of the measurements in question at larger geographical scales. In line with the above research goals, data were gathered from 299 stands throughout Poland and heights of 2388 sample trees of eight species, growing in different stands and site conditions, were measured; heights were then compared with measured lengths of felled trees as a reference. In total, 10 variables to determine factors that may influence ground-based tree-height measurement accuracy were used. We merged them into 4 groups: measurements, topography, stand and biometric-related factors. Results showed that biometric and topographic factors had the greatest relative influence on the accuracy of measurements of tree height. Tree length and species, followed by the slope of the terrain, tree age, and height above sea level were the most important factors found to affect accuracy. In most of the cases studied the terrestrial tree-height measurements were underestimated when set against definitive measurements of length. This was true for all species studied except oak, for which height measurements were typically overestimated. Notwithstanding the broad geographical scope of the work, the particular device used and the team factor were only found to have a marginal influence on measurement accuracy.	Poland
forestry	Jandl R., Lindner M., Vesterdal L., Bauwens B., Baritz R., Hagedorn F., Johnson D.W., Minkkinen K., Byrne K.A., 2007, How strongly can forest management influence soil carbon sequestration?, Geoderma 137 (2007) 253–268	We reviewed the experimental evidence for long-term carbon (C) sequestration in soils as consequence of specific forest management strategies. Utilization of terrestrial C sinks alleviates the burden of countries which are committed to reducing their greenhouse gas emissions. Land-use changes such as those which result from afforestation and management of fast-growing tree species, have an immediate effect on the regional rate of C sequestration by incorporating carbon dioxide (CO_2) in plant biomass. The potential for such practices is limited in Europe by environmental and political constraints. The management of existing forests can also increase C sequestration, but earlier reviews found conflicting evidence regarding the effects of forest management on soil C pools. We analyzed the effects of harvesting, thinning, fertilization application, drainage, tree species selection, and control of natural disturbances on soil C dynamics. We focused on factors that affect the C input to the soil and the C release via decomposition of soil organic matter (SOM). The differentiation of SOM into labile and stable soil C fractions is important. There is ample evidence about the effects of management on the amount of C in the organic layers of the forest floor, but much less information about measurable effects of management on stable C pools in the mineral soil. The C storage capacity of the stable pool can be enhanced by increasing the productivity of the forest and thereby increasing the C input to the soil. Minimizing the disturbances in the stand structure and soil reduces the risk of unintended C losses. The establishment of mixed species forests increases the stability of the forest and can avoid high rates of SOM decomposition. The rate of C accumulation and its distribution within the soil profile differs between tree species. Differences in the stability of SOM as a direct species effect have not yet been reported.	Global
forestry	Jandl R., Vesterdal L., Olsson M., Bens O., Badeck F., Rock J., Carbon sequestration and forest management, CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 2007 2, No. 017	Forest management has the potential to increase the terrestrial C pool. According to the rules of the Kyoto Protocol and of the United Nations Framework Convention on Climate Change, forestry can generate a sink for greenhouse gases that can contribute to meeting the national commitment to emissions reductions. Afforestation is a common strategy that over the course of decades leads to the incorporation of carbon dioxide (CO_2) in plant biomass. However, site types such as wetlands and peatlands may even be a source of greenhouse gases when they are afforested. Adapted management of existing forests may have a less obvious or slower effect on the terrestrial C pool. It is mainly relevant in countries that already have a large forest cover. We analysed the effects of harvesting, rotation length, thinning, fertilizer application and tree-species selection. All these treatments have an impact on the forest productivity and consequently on C sequestration in the ecosystem. Many forest treatments are already an integral part of sustainable forestry practice. In the context of C sequestration and its accounting in national greenhouse-gas budgets, ecosystem stability is highly rated. Forests that are robust against disturbances up to a certain degree of severity are better suited for political commitments than stands of maximum productivity with a high risk of damages.	Global
forestry	Lei Zhang, Peng Zhang, Mukui Yu and Tonggui Wu, Soil organic carbon content and stocks in an age-sequence of Metasequoia glyptostroboides plantations in coastal area, East China, 4th International Conference on Sustainable Energy and Environmental Engineering (ICSEEE 2015)	Information on soil organic carbon (SOC) content and stocks is not available in coastal shelter forests, East China, although a large area of forests has been established there in the past 30 years. Dawn Redwood (Metasequoia glyptostroboides) is one of the most commonly tree species for shelter plantation in eastern coasts of China, but it is unknown on the temporal distribution of SOC content and stock in the M. glyptostroboides plantations. In this study, SOC contents and stocks, and soil properties were determined in an age-sequence (23, 27, and 33 years old) of M. glyptostroboides plantations in Shanghai, East China. SOC content and stocks increased gradually with the increasing stand age, and the total SOC stocks in the depth of 0-100 cm increased by 53.20% with stand age from 23 to 33 years stand. Meanwhile, SOC showed good relationships with soil physical properties (such as soil particle composition) and chemical properties (such as soil nitrogen and potassium concentrations). Our results indicate that afforestation with M. glyptostroboides can promote SOC content and stocks and improve nutrient conditions in coastal lands, and provide data for estimating ecosystem carbon stocks of coastal shelter forests in China.	China
forestry	Pedro Moura-Costa, Tropical Forestry Practices for Carbon Sequestration, In: Dipterocarp Forest EcoSystems – Towards Sustainable Management. Schulte, A. & Schone, D. (Eds.). World Scientific, Singapore, 1996. Pp. 308-334.	Carbon sequestration through forestry has the potential to play a significant role in ameliorating global environmental problems such as atmospheric accumulation of GHG's and climate change. This chapter provides an overview of various aspects related to carbon sequestration through forestry. It describes the main concepts of carbon fixation; the trends in global environmental policy are discussed; different forestry practices are listed; examples of existing projects are given; and finally, a case study of a carbon sequestration project in Malaysia is described. The paper also discusses issues related to the quantification of carbon sequestration potential of different forestry options. This section was included with the intention of specifically highlighting some problems related to commercial transactions for carbon sequestration.	Malaysia
forestry	Hof A.R., Dymond C.C., Mladenoff D.J., Climate change mitigation through adaptation: the effectiveness of forest diversification by novel tree planting regimes, Ecosphere 8(11).	Climate change is projected to have negative implications for forest ecosystems and their dependent communities and industries. Adaptation studies of forestry practices have focused on maintaining the provisioning of ecosystem services; however, those practices may have implications for climate change mitigation as well by increasing biological sinks or reducing emissions. Assessments of the effectiveness of adaptation strategies to mitigate climate change are therefore needed; however, they have not been done for the world's northern coniferous forests. Diversifying the forest by planting tree species more likely suited to a future climate is a potential adaptation strategy to increase resilience. The efficacy of this strategy to reduce the risks of climate change is uncertain, and other ecosystem services provided by the forest are also likely to be affected. We used a spatially explicit forest landscape modeling framework (LANDIS-II) to simulate the effects of planting a range of native tree species in colder areas than where they are currently planted in a managed temperate coniferous forest landscape in British Columbia, Canada. We investigated impacts on carbon pools, fluxes, tree species diversity, and harvest levels under different climate scenarios for 100 yr (2015–2115) and found that the capacity of our forest landscape to sequester carbon would largely depend on the precipitation rates in the future, rather than on temperature We further found that, irrespective of the climate prediction model, current planting standards led to relatively low levels of resilience as indicated by carbon fluxes and stocks, net primary productivity (NPP), and species diversity. In contrast, planting a mix of alternative tree species was generally superior in increasing the resilience indicators: carbon stocks and fluxes, NPP, and tree species diversity, but not harvest rates. The second best novel planting regime involved adding Pinus contorta to the stocking standard in three ecoregions; however, that species is susceptible to a high number of insects and pathogens. We conclude that although the capacity of temperate coniferous forest landscapes to sequester carbon in the future is largely dependent on the precipitation regime, negative effects may be counteracted to some extent by increasing resilience through tree species diversity in forests.	Canada

forestry	Rupert Seidl, Werner Rammer, Petra Lasch, Franz-Werner Badeck and Manfred J. Lexer, Does Conversion of Even-Aged, Secondary Coniferous Forests Affect Carbon Sequestration? A Simulation Study under Changing Environmental Conditions, Silva Fennica 42(3)	To circumvent problems associated with even-aged, pure coniferous stands propagated outside their natural range alternative management strategies and conversion programs are currently discussed in Central Europe. However, a mainstreaming of such adapted silvicultural systems with climate change mitigation objectives is missing to date. In this study the objective was to assess in situ C storage under conditions of climate change in a secondary Norway spruce (Picea abies (L.) Karst.) forest management unit in Austria. Four management strategies (Norway spruce age class forestry, transition to continuous cover forestry with Norway spruce, conversion to mixed conifer/broadleaved stands, no management) were investigated under current climate and two transient climate change scenarios in a simulation study. By comparing the results of two independent forest ecosystem models (PICUS v1.41, 4C) applied under identical forcings and boundary conditions we aimed at addressing uncertainties in model-based projections. A transition to continuous cover forestry increased C storage in all climate scenarios (+45.4 tC·ha–1 to +74.0 tC·ha–1 over the 100 year analysis period) compared to the approximately balanced C budget under the age class system. For the mixed conifer/broadleaved management variant predictions of the two models diverged significantly (+29.4 tC·ha–1 and –10.6 tC·ha–1 in PICUS and 4C respectively, current climate). With regard to climate change impacts both models agreed on distinct effects on productivity but lower sensitivity of C stocks due to compensation from respiration and adaptive harvest levels. In conclusion, considering the potential effects of silvicultural decisions on C stocks climate change mitigation should be addressed explicitly in programs advocating targeted change in management paradigms.	Austria
forestry	Erhun Kula, Afforestation with carbon sequestration and land use policy in Northern Ireland, Land Use Policy 27 (2010) 749–752	In forestry Northern Ireland is one of the most impoverished parts of the European Union as well as the United Kingdom. During the last 10–15 years as afforestation projects gathered speed in many parts of the British Isles there has been no notable change in Ulster. One main ontributor to this problem was the political uncertainty and violence which has now largely been remedied since the establishment of the devolved government in 2007. In addition to the recently established political stability there is an equally welcoming factor which is likely to impact positively upon the fortune of forestry sector in the province; that is carbon trading rights under the Kyoto Protocol. The use of new forests as credit towards reducing carbon dioxide emission is an important part of the Kyoto deal and quantities of sequestrated carbon can now be used to offset against emissions elsewhere and in this way they become real benefits like timber values. Therefore, the amount of carbon dioxide removed from the atmosphere by way of afforestation projects should be assessed in economic evaluation of forestry investment proposals. The main purpose of this paper is to carry out a cost–benefit analysis for an afforestation project in Northern Ireland with a view to finding out what difference carbon sequestration will make to the economic rate of return.	Northern Ireland
forestry	Trevor J. Hobbs, Craig R. Neumann, Wayne S. Meyer, Travis Moon, Brett A. Bryan, Models of reforestation productivity and carbon sequestration for land use and climate change adaptation planning in South Australia, Journal of Environmental Management 181 (2016) 279-288	Environmental management and regional land use planning has become more complex in recent years as growing world population, climate change, carbon markets and government policies for sustainability have emerged. Reforestation and agroforestry options for environmental benefits, carbon sequestration, economic development and biodiversity conservation are now important considerations of land use planners. New information has been collected and regionally-calibrated models have been developed to facilitate better regional land use planning decisions and counter the limitations of currently available models of reforestation productivity and carbon sequestration. Surveys of above-ground biomass of 264 reforestation sites (132 woodlots, 132 environmental plantings) within the agricultural regions of South Australia were conducted, and combined with spatial information on climate and soils, to develop new spatial and temporal models of plant density and above-ground biomass productivity from reforestation. The models can be used to estimate productivity and total carbon sequestration (i.e. aboveground þ below-ground biomass) under a continuous range of planting designs (e.g. variable proportions of trees and shrubs or plant densities), timeframes and future climate scenarios. Representative spatial models (1 ha resolution) for 3 reforestation designs (i.e. woodlots, typical environmental planting, biodiverse environmental plantings) 3 timeframes (i.e. 25, 45, 65 years) 4 possible climates (i.e. no change, mild, moderate, severe warming and drying) were generated (i.e. 36 scenarios) for use within land use planning tools.	Australia
forestry	Xianzeng Niu, Sjoerd W. Duiker, Carbon sequestration potential by afforestation of marginal agricultural land in the Midwestern U.S., Forest Ecology and Management 223 (2006) 415–427	Carbon sequestration has been well recognized as a viable option to slow the rise in atmospheric greenhouse gas concentration. The main goals of this study were to assess the carbon sequestration potential (CSP) by afforestation of marginal agricultural land (MagLand) and to identify hotspots for potential afforestation activities in the U.S. Midwest region (Michigan (MI), Indiana (IN), Ohio, Kentucky (KY), West Virginia, Pennsylvania (PA) and Maryland (MD)). The 1992 USGS National Land Cover Dataset and the State Soil Geographic (STATSGO) database were used to determine MagLand. Two forest types (coniferous and deciduous) and two management practices (short-rotation versus permanent forest) were combined to form four afforestation scenarios. Simulation models were employed to predict changes in four carbon pools: aboveground biomass, roots, forest floor, and soil organic carbon (SOC). A scenario-generating tool was developed to detect the hotspots. We estimated that there was a total of 6.5 million hectares (Mha) MagLand available in the U.S. Midwest region, which accounts for approximately 24% of the regional total agricultural land. The CSP capacity was predicted to be 508–540 Tg C (1 Tg = 1012 g) over 20 years and 1018–1080 Tg C over 50 years. The results indicate that afforestation of MagLand could offset 6–8% of current CO2 emissions by combustion of fossil fuel in the region. This analysis showed only slight differences in carbon sequestration between forest types or between short-rotation and permanent forest scenarios. Note that this calculation assumed that all suitable MagLand in the U.S. Midwest region was converted to forest and that ‘‘best carbon management’’ was adopted. The actual CSP could be less if the economical and social factors are taken into account. The most preferred locations for implementing the afforestation strategy were found to be concentrated along a west-east axis across the southern parts of Indiana, Ohio, and Pennsylvania, as well as in an area covering southern Michigan and northern parts of Indiana and Ohio. Overall, we conclude that afforestation of MagLand in the Midwest U.S. region offers great potential for carbon sequestration. Future studies are needed to evaluate its economic feasibility, social acceptability, and operation capability.	USA
forestry	Roland Olschewskia, Pablo C. Benı´tez, Secondary forests as temporary carbon sinks? The economic impact of accounting methods on reforestation projects in the tropics, Ecological Economics 55 (2005) 380– 394	Tropical forestry is often not competitive with agricultural land uses such as pasture for cattle ranching. Additional revenues from carbon sequestration generated by the Clean Development Mechanism (CDM) of the Kyoto Protocol can change this situation. In three different zones of north-western Ecuador, minimum compensation payments for carbon sequestration were determined, which would make reforestation a feasible land-use alternative. Based on our findings that these minimum prices depend on the net benefit of the respective land-use alternatives, and on the accounting regimes for CDM sink projects, we applied the accounting rules for temporary and long-term Certified Emission Reductions (CER) to two reforestation projects: forest plantation and natural regrowth of secondary forest. A comparison of these alternatives showed that secondary forest is an attractive alternative under both accounting regimes because of its low establishment costs and relative early timber revenues. After identifying the zone most suitable for carbon sink projects, we calculated net benefits of land-use changes in the event that certain prices for emission reductions were actually paid.We found that secondary forest becomes economically attractive, if the price of permanent credits is above $4.5/tCO2, whereas forest plantations require permanent CER prices of $7.0/tCO2. In both cases, the results are within the price margins forecasted by various institutions for the first commitment period of the Kyoto Protocol. The presented methodology is meant to support the decision making process on the supply side of a future CER market. Opportunity costs of land-use changes have to be analyzed carefully before deciding in favor of long binding forestry projects. Assigning temporary credits to naturally regrown secondary forests could–although excluded from CDM during the first commitment period–combine the advantages of a flexible accounting regime with the positive economic and ecological effects of this competitive land use.	Ecuador

forestry	Arturo Balderas Torres, Rob Marchant, Jon C. Lovett, James C.R. Smart, Richard Tipper, Analysis of the carbon sequestration costs of afforestation and reforestation agroforestry practices and the use of cost curves to evaluate their potential for implementation of climate change mitigation, Ecological Economics 69 (2010) 469–477	Carbon sequestration in forest sinks is an important strategy to remove greenhouse gases and to mitigate climate change; however its implementation has been limited under the Clean Development Mechanism of the Kyoto Protocol which has not created the incentives for widespread implementation. The objective of this paper is to analyze the sequestration costs of agroforestry afforestation and reforestation projects (ARPs) following a partial market equilibrium using average cost curves and economic break even analysis to identify the supply costs. The modelling done in this work contrasts the voluntary and clean development mechanism transaction costs. Data is based on the voluntary project, Scolel Té, being implemented in Mexico. Cost curves are developed for seven different sequestration options considering transaction and implementation costs; information from agricultural production in Chiapas Mexico is used to integrate opportunity costs of two agroforestry practices suggesting that sequestration costs may follow a "U" shape, with an initial reduction due to economies of scale and a subsequent increase caused by high opportunity costs. The widespread implementation of agroforestry options not requiring complete land conversion (e.g. living fences and coffee under shade) might be cost effective strategies not generating high opportunity costs. Results also suggest that payments in the early years of the project and lower transaction costs favour the development of ARPs in the voluntary market especially in marginal rural areas with high discount rates.	Mexico
forestry	Jan Lewandrowski, C.S. Kim, Marcel Aillery, Carbon sequestration through afforestation under uncertainty, Forest Policy and Economics 38 (2014) 90–96	Economic studies have demonstrated that agricultural landowners could mitigate significant quantities of greenhouse gas (GHG) emissions through afforestation. The associated carbon, however, must remain stored in soils or biomass for several decades to achieve substantial mitigation benefits. Policies and programs to enhance carbon sequestration in forest systems must accommodate the possibility of premature carbon releases. We develop a dynamic nested optimal-control model of carbon sequestration through afforestation given uncertainties associated with fire and pest hazards. Our framework highlights a number of factors that affect landowner decisions to invest in fire or pest prevention measures. For fire, we show the net influence of these factors is to encourage investment in prevention measures when the probability of fire occurring is less than the ratio of expected net economic benefits to expected gross economic benefits of adopting fire prevention measures. For pests, we show that landowners will invest in prevention measures when the probability of fire is less than the ratio of the difference between net benefits before and after the discovery of tree pests to the difference between gross economic benefits before and after the discovery of pests. For both risks, landowners will over-invest in prevention if the other risk is ignored.	Global
forestry	V. Alaric Sample, Potential for Additional Carbon Sequestration through Regeneration of Nonstocked Forest Land in the United States, J. For. 115(4):309–318.	An analysis of 2014 forest inventory data for the contiguous United States shows nearly 8 million ha of forestland that are currently defined as nonstocked after recent natural and human disturbances. It is estimated that forest regeneration on these lands could result in an additional terrestrial sequestration of 48.9 million metric tons of CO2 equivalent (CO2e) annually. Analysis across a range of seven site productivity classes indicates that approximately 58% of the total area is productive timberland, defined as capable of producing merchantable volume of 1.4 m3/ha/year. It is estimated that regeneration of just the productive timberland portion of the total could produce an additional 44.4 million metric tons of CO2e annually in carbon sequestration. On National Forest System lands, more than 50% of the total potential carbon sequestration benefit from regenerating nonstocked lands could be achieved by reforesting just the top 30% of these lands in the moderate-to-high site productivity classes. On private lands, more than 70% of the total potential carbon benefit can be achieved by regenerating the most productive 30%.	USA
	D. Neil Bird, Eric Boysen, The Carbon Sequestration Potential from Afforestation in Ontario, Research Information Note 5 (2007).	Signifi cant area is available for afforestation on private farmland and nonfarmland across Ontario. Carbon sequestration is one of many benefi ts of planting trees on land that has not been forested in a long time. Others include ecosystem health, economic health, and ultimately human health. Afforestation requires a long-term commitment and investment by both management agencies and private landowners to maximize benefi ts to society and to the environment.	USA
forestry	Oscar J. Cacho, Robyn L. Hean and Russell M. Wise, Carbon-accounting methods and reforestation incentives, The Australian Journal of Agricultural and Resource Economics, 47:2, 153–179	The emission of greenhouse gases, particularly carbon dioxide, and the consequent potential for climate change are the focus of increasing international concern. Temporary land-use change and forestry projects (LUCF) can be implemented to offset permanent emissions of carbon dioxide from the energy sector. Several approaches to accounting for carbon sequestration in LUCF projects have been proposed. In the present paper, the economic implications of adopting four of these approaches are evaluated in a normative context. The analysis is based on simulation of Australian farm–forestry systems. Results are interpreted from the standpoint of both investors and landholders. The role of baselines and transaction costs are discussed.	Global
forestry	W. L. Silver, R. Ostertag, A. E. Lugo, The Potential for Carbon Sequestration Through Reforestation of Abandoned Tropical Agricultural and Pasture Lands, Restoration Ecology Vol. 8 No. 4, pp. 394–407	Approximately half of the tropical biome is in some stage of recovery from past human disturbance, most of which is in secondary forests growing on abandoned agricultural lands and pastures. Reforestation of these abandoned lands, both natural and managed, has been proposed as a means to help offset increasing carbon emissions to the atmosphere. In this paper we discuss the potential of these forests to serve as sinks for atmospheric carbon dioxide in aboveground biomass and soils. A review of literature data shows that aboveground biomass increases at a rate of 6.2 Mg ha 2 1 yr 2 1 during the first 20 years of succession, and at a rate of 2.9 Mg ha 2 1 yr 2 1 over the first 80 years of regrowth. During the first 20 years of regrowth, forests in wet life zones have the fastest rate of aboveground carbon accumulation with reforestation, followed by dry and moist forests. Soil carbon accumulated at a rate of 0.41 Mg ha 2 1 yr 2 1 over a 100-year period, and at faster rates during the first 20 years	Global
	Robin L. Chazdon, Eben N. Broadbent, Danaë M. A. Rozendaal, Frans Bongers (et al..,), Carbon sequestration potential of second-growth forest regeneration in the Latin American tropics, Sci. Adv. 2016; 2	Regrowth of tropical secondary forests following complete or nearly complete removal of forest vegetation actively stores carbon in aboveground biomass, partially counterbalancing carbon emissions from deforestation, forest degradation, burning of fossil fuels, and other anthropogenic sources. We estimate the age and spatial extent of lowland second-growth forests in the Latin American tropics and model their potential aboveground carbon accumulation over four decades. Our model shows that, in 2008, second-growth forests (1 to 60 years old) covered 2.4 million km2 of land (28.1%of the total study area).Over 40 years, these lands can potentially accumulate a total aboveground carbon stock of 8.48 Pg C (petagrams of carbon) in aboveground biomass via low-cost natural regeneration or assisted regeneration, corresponding to a total CO2 sequestration of 31.09 Pg CO2. This total is equivalent to carbon emissions from fossil fuel use and industrial processes in all of Latin America and the Caribbean from1993 to 2014. Ten countries account for 95% of this carbon storage potential, led by Brazil, Colombia, Mexico, and Venezuela. We model future land-use scenarios to guide national carbon mitigation policies. Permitting natural regeneration on 40% of lowland pastures potentially stores an additional 2.0 Pg C over 40 years. Our study provides information and maps to guide national-level forest-based carbon mitigation plans on the basis of estimated rates of natural regeneration and pasture abandonment. Coupled with avoided deforestation and sustainable forestmanagement, natural regeneration of second-growth forests provides a low-costmechanism that yields a high carbon sequestration potential with multiple benefits for biodiversity and ecosystem services.	Latin America
forestry	HB Fan, WF Liu, JP Wu, YY Li, YH Yuan, YC Liao, RZ Huang, Ecosystem Carbon Pools in Mixed Stands of Hardwood Species and Masson Pine, Journal of Tropical Forest Science 25(2): 151–156 (2013)	Transformation of conifer monoculture into mixed conifer–hardwood plantations has been considered as an efficient management practice to sustain forest productivity. However, effects of this management practice on ecosystem carbon sequestration are still unclear. In this study, seedlings of five hardwood species (Michelia macclurei, Castanopsis fissa, Castanopsis sclerophylla, Castanopsis kawakamii and yclobalanopsis myrsinaefolia) were planted separately under a Pinus massoniana (Pm) stand, and designated as Pm–Mm, Pm–Cf, Pm–Cs, Pm–Ck and Pm–Cm respectively. After 16 years of establishment, total ecosystem carbon increased by 18.0, 53.8, 25.2, 21.7 and 38.7 t ha-1 in the Pm–Mm, Pm–Cf, Pm–Cs, Pm–Ck and Pm–Cm stands respectively compared with Pm stand. Aboveground carbon storage increased from 97.72 t ha-1 in the Pm stand to 109.52, 131.31, 107.77, 115.76 and 123.37 t ha-1 in the five mixed stands respectively, greatly due to an increase in hardwood tree biomass. Mineral soil carbon stock (0–60 cm) was 55.0 t ha-1 in the Pm stand and 61.0, 72.4, 69.6, 58.6 and 66.8 t ha-1 in the five mixtures respectively. Our results suggested that stand improvement by underplanting could be proposed as forest management option for increasing ecosystem carbon sequestration.	China

forestry	Obersteiner M., Alexandrov G., Benitez P.C., McCallum I., Kraxner F., Riahi K., Rokityanskiy D., Yamagata Y., Global Supply of Biomass for Energy and Carbon Sequestration from afforestation/reforestation activities, Mitigation and Adaptation Strategies for Global Change (2006) 11: 1003–1021	In this paper we provide an analytical framework to estimate the joint production of biomass and carbon sequestration from afforestation and reforestation activities. The analysis is based on geographical explicit information on a half-degree resolution. For each grid-cell the model estimates forest growth using a global vegetation model and chooses forest management rules. Land prices, cost of forest production and harvesting are determined as a function of grid specific site productivity, population density and estimates of economic wealth. The sensitivity of the results due to scenario storylines is assessed using different population and economic growth assumptions, which are consistent with B1 and A2 of the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC-SRES) marker scenarios. Considerable differences in the economic supply schedules are found. However, technical potentials seem to converge given constancy in other underlying assumptions of the model.	Global
forestry	Anne Sofie Elberg Nielsen, Andrew J. Plantinga, and Ralph J. Alig, New Cost Estimates for Carbon Sequestration Through Afforestation in the United States, United States Department of Agriculture Forest Service	This report provides new cost estimates for carbon sequestration through afforestation in the United States. We extend existing studies of carbon sequestration costs in several important ways, while ensuring the transparency of our approach. We clearly identify all components of our cost estimates so that other researchers can reconstruct our results as well as use our data for other purposes. Our cost estimates have five distinguishing features: (1) we estimate costs for each county in the contiguous United States; (2) we include afforestation of rangeland, in addition to cropland and pasture; (3) our opportunity cost estimates account for capitalized returns to future development (including associated option values) in addition to returns to agricultural production; (4) we develop a new set of forest establishment costs for each county; and (5) we incorporate data on Holdridge life zones to limit afforestation in locations where temperature and moisture availability prohibit forest growth. We find that at a carbon price of $50/ton, approximately 200 million tons of carbon would be sequestered annually through afforestation. At a price of $100/ton, an additional 100 million tons of carbon would be sequestered each year. Our estimates closely match those in earlier econometric studies for relatively low carbon prices, but diverge at higher carbon prices. Accounting for climatic constraints on forest expansion has important effects on cost estimates.	USA
forestry	P. Boudewyn, X. Song, S. Magnussen, and M.D. Gillis, Model-based, volume-to-biomass conversion for forested and vegetated land in Canada, Natural Resources Canada, Canadian Forest Service Pacific Forestry Centre, Victoria, British Columbia Information Report, BC-X-411, 2007	The demand for forest biomass information has increased substantially in recent years, and, in response, new models have been developed to estimate biomass of forest stands and the more common vegetated, non-treed areas in Canada. The modeling approach is distinct for the kind of stand (or polygon) under consideration, and includes techniques that can be used to estimate all the above-ground biomass components, including stem wood, stem bark, branches, and foliage. Plot data supplied from forest inventory agencies throughout Canada formed the basis of developing empirical volume-to-biomass conversion models for forested (treed) land. For non-treed vegetated areas without volume, look-up tables containing mean biomass values were produced from published scientific studies about plant biomass production. Empirical models and look-up tables are presented with examples of how they can be used to estimate biomass for specific combinations of classifiers. Together, the models and tables provide a consistent and comprehensible set of tools that can be used to estimate biomass components for stands, vegetated areas, or broader groupings of both, in Canada.	Canada
forestry	W.A. Kurz, C.H. Shaw, C. Boisvenue, G. Stinson, J. Metsaranta, D. Leckie, A. Dyk, C. Smyth, and E.T. Neilson, Carbon in Canada's boreal forest — A synthesis, Environ. Rev. 21: 260–292 (2013)	Canada's managed boreal forest, 54% of the nation's total boreal forest area, stores 28 Pg carbon (C) in biomass, dead organic matter, and soil pools. The net C balance is dominated by the difference of two large continuous fluxes: C uptake (net primary production) and release during decomposition (heterotrophic respiration). Additional releases of C can be high in years, or in areas, that experience large anthropogenic or natural disturbances. From 1990 to 2008, Canada's managed boreal forest has acted as C sink of 28 Tg C year−1, removing CO2 from the atmosphere to replace the 17 Tg of C annually harvested and store an additional 11 Tg of C year−1 in ecosystem C pools. A large fraction (57%) of the C harvested since 1990 remains stored in wood products and solid waste disposal sites in Canada and abroad, replacing C emitted from the decay or burning of wood harvested prior to 1990 and contributing to net increases in product and landfill C pools. Wood product use has reduced emissions in other sectors by substituting for emission-intensive products (concrete, steel). The C balance of the unmanaged boreal forest is currently unknown. The future C balance of the Canadian boreal forest will affect the global atmospheric C budget and influence the mitigation efforts required to attain atmosphericCO2 stabilization targets. The single biggest threat toCstocks is human-caused climate change. LargeCstocks have accumulated in the boreal because decomposition is limited by cold temperatures and often anoxic environments. Increases in temperatures and disturbance rates could result in a large net C source during the remainder of this century and beyond. Uncertainties about the impacts of global change remain high, but we emphasize the asymmetry of risk: sustained large-scale increases in productivity are unlikely to be of sufficient magnitude to offset higher emissions from increased disturbances and heterotrophic respiration. Reducing the uncertainties of the current and future C balance of Canada's 270 Mha of boreal forest requires addressing gaps in monitoring, observation, and quantification of forest C dynamics, with particular attention to 125 Mha of unmanaged boreal forest with extensive areas of deep organic soils, peatlands, and permafrost containing large quantities of C that are vulnerable to global warming.	Canada
forestry	W.A. Kurz, C.C. Dymond, T.M. White, G. Stinson, C.H. Shaw, G.J. Rampley, C. Smyth, B.N. Simpson, E.T. Neilson, J.A. Trofymow, J. Metsaranta, M.J. Apps, CBM-CFS3: A model of carbon-dynamics in forestry and land-use change implementing IPCC standards, Ecological Modelling 220 (2009), 480-504.	The scientific community, forest managers, environmental organizations, carbon-offset trading systems and policy-makers require tools to account for forest carbon stocks and carbon stock changes. In this paper we describe updates to the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) implemented over the past years. This model of carbon-dynamics implements a Tier 3 approach of the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance for reporting on carbon stocks and carbon stock changes resulting from Land Use, Land-use Change and Forestry (LULUCF). The CBMCFS3 is a generic modelling framework that can be applied at the stand, landscape and national levels. The model provides a spatially referenced, ierarchical system for integrating datasets originating from different forest inventory and monitoring programs and includes a structure that allows for tracking of land areas by different land-use and landuse change classes. Ecosystem pools in CBM-CFS3 can be easily mapped to IPCC-defined pools and validated against field measurements. The model uses sophisticated algorithms for converting volume to biomass and explicitly simulates individual annual disturbance events (natural and anthropogenic). Several important scientific updates have been made to improve the representation of ecosystem structure and processes from previous versions of CBM-CFS. These include: (1) an expanded representation of dead organic matter and soil carbon, particularly standing dead trees, and a new algorithm for initializing these pools prior to simulation, (2) a change in the input data requirement for simulating growth from biomass to readily available merchantable volume curves, and new algorithms for converting volume to biomass, (3) improved prediction of belowground biomass, and (4) improved parameters for soil organic matter decay, fire, insect disturbances, and forest management. In addition, an operational-scale version of CBM-CFS3 is freely available and includes tools to import data in standard formats, including the output of several timber supply models that are commonly used in Canada. Although developed for Canadian forests, the flexible nature of the model has enabled it to be adapted for use in several other countries.	Canada
forestry	T.C. Lemprière, W.A. Kurz, E.H. Hogg, C. Schmoll, G.J. Rampley, D. Yemshanov, D.W. McKenney, R. Gilsenan, A. Beatch, D. Blain, J.S. Bhatti, and E. Krcmar, Canadian boreal forests and climate change mitigation, Environ. Rev. 21: 293–321 (2013)	Quantitative assessment of Canada's boreal forest mitigation potential is not yet possible, though the range of mitigation activities is known, requirements for sound analyses of options are increasingly understood, and there is emerging recognition that biogeophysical effects need greater attention. Use of a systems perspective highlights trade-offs between activities aimed at increasing carbon storage in the ecosystem, increasing carbon storage in harvested wood products (HWPs), or increasing the substitution benefits of using wood in place of fossil fuels or more emissions-intensive products. A systems perspective also suggests that erroneous conclusions about mitigation potential could result if analyses assume thatHWPcarbon is emitted at harvest, or bioenergy is carbon neutral. The greatest short-run boreal mitigation benefit generally would be achieved by avoiding greenhouse gas emissions; but over the longer run, there could be significant potential in activities that increase carbon removals. Mitigation activities could maximize landscape carbon uptake or maximize landscape carbon density, but not both simultaneously. The difference between the two is the rate at which HWPs are produced to meet society's demands, and mitigation activities could seek to delay or reduce HWP emissions and increase substitution benefits. Use of forest biomass for bioenergy could also contribute though the point in time at which this produces a net mitigation benefit relative to a fossil fuel alternative will be situation-specific. Key knowledge gaps exist in understanding boreal mitigation strategies that are robust to climate change and how mitigation could be integrated with adaptation to climate change.	Canada

forestry	Zhong Li, Werner A. Kurz, Michael J. Apps, and Sarah J. Beukema, Belowground biomass dynamics in the Carbon Budget Model of the Canadian Forest Sector: recent improvements and implications for the estimation of NPP and NEP, Can. J. For. Res. 33: 126–136 (2003)	In the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2), root biomass and dynamics are estimated using regression equations based on the literature. A recent analysis showed that some of these equations might overestimate belowground net primary production (NPPB). The objectives of this study were to update the compilation of root biomass and turnover data, to recalculate the regression equations and to evaluate the impact of the new equations on CBM-CFS2 estimates of net primary production (NPP) and net ecosystem production (NEP). We updated all equations based on 635 pairs of aboveground and belowground data compiled from published studies in the cold temperate and boreal forests. The new parameter for the equation to predict total root biomass for softwood species changed only slightly, but the changes for hardwood species were statistically significant. A new equation form, which improved the accuracy and biological interpretation, was used to predict fine root biomass as a proportion of total root biomass. The annual rate of fine root turnover was currently estimated to be 0.641 of fine root biomass. A comparison of NPP estimates from CBM-CFS2 with results from field measurements, empirical calculations and modeling indicated that the new root equations predicted reasonable NPPB values. The changes to the root equations had little effect on NEP estimates.	Canada
forestry	J.M. Metsaranta, W.A. Kurz, Inter-annual variability of ecosystem production in boreal jack pine forests (1975–2004) estimated from tree-ring data using CBM-CFS3, Ecological Modelling 224 (2012) 111– 123	We describe and apply a method of using tree-ring data and an ecosystem model to reconstruct past annual rates of ecosystem production. Annual data on merchantable wood volume increment and mortality obtained by dendrochronological stand reconstruction were used as input to the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) to estimate net ecosystem production (NEP), net primary production (NPP), and heterotrophic respiration (Rh) annually from 1975 to 2004 at 10 boreal jack pine (Pinus banksiana Lamb.) stands in Saskatchewan and Manitoba, Canada. From 1975 (when sites aged 41–60 years) to 2004 (when they aged 70–89 years), all sites were moderate C sinks except during some warmer than average years where estimated Rh increased. Across all sites and years, estimated annual NEP averaged 57 g Cm^{-2} yr^{-1} (range −31 to 176 g Cm^{-2} yr^{-1}), NPP 244 g Cm^{-2} yr^{-1} (147–376 g Cm^{-2} yr^{-1}), and Rh 187 g Cm^{-2} yr^{-1} (124–270 g Cm^{-2} yr^{-1}). Across all sites, NPP was related to stand age and density, which are proxies for successional changes in leaf area. Regionally, warm spring temperature increased NPP and defoliation by jack pine budworm 1 year previously reduced NPP. Our estimates of NPP, Rh, and NEP were plausible when compared to regional eddy covariance and carbon stock measurements. Interannual variability in ecosystem productivity contributes uncertainty to inventory-based assessments of regional forest C budgets that use yield curves predicting averaged growth over time. Our method could expand the spatial and temporal coverage of annual forest productivity estimates, providing additional data for the development of empirical models accounting for factors not presently considered by these models.	Canada
forestry	Roberto Pilli, Giacomo Grassi, Werner A. Kurz, Carolyn E. Smyth, Viorel Blujdea, Application of the CBM-CFS3 model to estimate Italy's forest carbon budget, 1995–2020, Ecological Modelling 266 (2013) 144– 171	The estimation of past and future forest carbon (C) dynamics in European countries is a challenging task due to complex and varying silvicultural systems, including uneven-aged forest management, and incomplete inventory data time series. In this study, we tested the use of the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) in Italy, a country exemplifying most of these challenges. Our objective was to develop estimates of forest carbon budgets of the Forest Management area (including all forests existing in 1990) for the period 1995–2009, and to simulate alternative scenarios of natural disturbance (fire) and harvest rates to 2020. A number of methodological challenges required modifications to the default model implementation. Based on National Forest Inventory (NFI) data, we (i) developed a historic library of yield curves derived from standing volume and age data, reflecting the effect of past silvicultural activities and natural disturbances, and a current library of yield curves derived from the current net annual increment; (ii) reconstructed the age structure for a period antecedent to the reference NFI year (2005), to compare the model results with data from other sources; and (iii) developed a novel approach for the simulation of uneven-aged forests. For the period 2000–2009, the model estimated an average annual sink of −23.7 Mt CO_2 yr^{-1} excluding fires in Italy's managed forests. Adding fires to the simulation reduced the sink to −20.5 Mt CO_2 yr^{-1}. The projected sink (excluding all fires) for the year 2020 was −23.4 Mt CO_2 yr^{-1} assuming average (2000–2009) harvest rates. A 36% increase in harvest rates by 2020 reduced the sink to −17.3 Mt CO_2 yr^{-1}. By comparing the model results with NFI data and other independent studies, we demonstrate the utility of the CBM-CFS3 both for estimating the current forest sink in even-aged and more complex uneven-aged silvicultural systems in Italy, and for exploring the impact of different harvest and natural disturbances scenarios in managed forests. This study demonstrates the utility of the CBM-CFS3 to national-scale estimation of past and future greenhouse gas emissions and provides the foundation for the model's future implementation to other European countries.	Italy
forestry	Roberto Pilli, Giacomo Grassi, Jose V Moris, Jose V Moris, Assessing the carbon sink of afforestation with the Carbon Budget Model at the country level: an example for Italy, iForest 8: 410-421	In the context of the Kyoto Protocol, the mandatory accounting of Afforestation and Reforestation (AR) activities requires estimating the forest carbon (C) stock changes for any direct human-induced expansion of forest since 1990. We used the Carbon Budget Model (CBM) to estimate C stock changes and emissions from fires on AR lands at country level. Italy was chosen because it has one of the highest annual rates of AR in Europe and the same model was recently applied to Italy's forest management area. We considered the time period 1990-2020 with two case studies reflecting different average annual rates of AR: 78 kha yr-1, based on the 2013 Italian National Inventory Report (NIR, official estimates), and 28 kha yr-1, based on the Italian Land Use Inventory System (IUTI estimates). We compared these two different AR rates with eight regional forest inventories and three independent local studies. The average annual C stock change estimated by CBM, excluding harvest or natural disturbances, was equal to 1738 Gg C yr-1 (official estimates) and 630 Gg C yr-1 (IUTI estimates). Results for the official estimates are consistent with the estimates reported by Italy to the KP for the period 2008-2010; for 2011 our estimates are about 20% higher than the country's data, probably due to different assumptions on the fire disturbances, the AR rate and the dead wood and litter pools. Furthermore, our analysis suggests that: (i) the impact on the AR sink of different assumptions of species composition is small; (ii) the amount of harvest provided by AR has been negligible for the past (< 3%) and is expected to be small in the near future (up to 8% in 2020); (iii) forest fires up to 2011 had a small impact on the AR sink (on average, < 100 Gg C yr-1). Finally the comparison of the historical AR rates reported by NIR and IUTI with other independent sources gives mixed results: the regional inventories support the AR rates reported by the NIR, while some local studies suggest AR rates somehow intermediate between NIR and IUTI. In conclusion, this study suggests that the CBM can be applied at country level to estimate the C stock changes resulting from AR, including the effect of harvest and fires, though only a comparison with results based on direct field measurements could verify the model's capability to estimate the real C stock change.	Italy
forestry	Roberto Pilli, Giacomo Grassi, Werner A. Kurz, Raúl Abad Viñas, Nuria Hue Guerrero, Modelling forest carbon stock changes as affected by harvest and natural disturbances. I. Comparison with countries' estimates for forest management, Carbon Balance Manage (2016) 11:5	Background: According to the post-2012 rules under the Kyoto protocol, developed countries that are signatories to the protocol have to estimate and report the greenhouse gas (GHG) emissions and removals from forest management (FM), with the option to exclude the emissions associated to natural disturbances, following the Intergovernmental Panel on Climate Change (IPCC) guidelines. To increase confidence in GHG estimates, the IPCC recommends performing verification activities, i.e. comparing country data with independent estimates. However, countries currently conduct relatively few verification efforts. The aim of this study is to implement a consistent methodological approach using the Carbon Budget Model (CBM) to estimate the net CO_2 emissions from FM in 26 European Union (EU) countries for the period 2000–2012, including the impacts of natural disturbances. We validated our results against a totally independent case study and then we compared the CBM results with the data reported by countries in their 2014 Greenhouse Gas Inventories (GHGIs) submitted to the United Nations Framework Convention on Climate Change (UNFCCC). Results: The match between the CBM results and the GHGIs was good in nine countries (i.e. the average of our results is within ±25 % compared to the GHGI and the correlation between CBM and GHGI is significant at $P < 0.05$) and partially good in ten countries. When the comparison was not satisfactory, in most cases we were able to identify possible reasons for these discrepancies, including: (1) a different representation of the interannual variability, e.g. where the GHGIs used the stock-change approach; (2) different assumptions for non-biomass pools, and for CO_2 emissions from fires and harvest residues. In few cases, further analysis will be needed to identify any possible inappropriate data used by the CBM or problems in the GHGI. Finally, the frequent updates to data and methods used by countries to prepare GHGI makes the implementation of a consistent modeling methodology challenging. Conclusions: This study indicates opportunities to use the CBM as tool to assist countries in estimating forest carbon dynamics, including the impact of natural disturbances, and to verify the country GHGIs at the EU level, consistent with the IPCC guidelines. A systematic comparison of the CBM with the GHGIs will certainly require additional efforts—including close cooperation between modelers and country experts. This approach should be seen as a necessary step in the process of continuous improvement of GHGIs, because it may help in identifying possible errors and ultimately in building confidence in the estimates reported by the countries.	Italy

forestry	Roberto Pilli, Giacomo Grassi, Werner A. Kurz, Giulia Fiorese, Alessandro Cescatti, The European forest sector: past and future carbon budget and fluxes under different management scenarios, Biogeosciences, 14, 2387–2405, 2017	The comprehensive analysis of carbon stocks and fluxes of managed European forests is a prerequisite to quantify their role in biomass production and climate change mitigation. We applied the Carbon Budget Model (CBM) to 26 European countries, parameterized with country information on the historical forest age structure, management practices, harvest regimes and the main natural disturbances. We modeled the C stocks for the five forest pools plus harvested wood products (HWPs) and the fluxes among these pools from 2000 to 2030. The aim is to quantify, using a consistent modeling framework for all 26 countries, the main C fluxes as affected by land-use changes, natural disturbances and forest management and to assess the impact of specific harvest and afforestation scenarios after 2012 on the mitigation potential of the EU forest sector. Substitution effects and the possible impacts of climate are not included in this analysis. Results show that for the historical period from 2000 to 2012 the net primary productivity (NPP) of the forest pools at the EU level is on average equal to 639 Tg C yr□1. The losses are dominated by heterotrophic respiration (409 TgC yr□1) and removals (110 TgC yr□1/, with direct fire emissions being only 1 Tg Cyr□1, leading to a net carbon stock change (i.e., sink) of 110 Tg C yr□1. Fellings also transferred 28 TgC yr□1 of harvest residues from biomass to dead organic matter pools. The average annual net sector exchange (NSE) of the forest system, i.e., the carbon stock changes in the forest pools including HWP, equals a sink of 122 Tg C yr□1 (i.e., about 19% of the NPP) for the historical period, and in 2030 it reaches 126, 101 and 151 TgC yr□1, assuming constant, increasing (C20 %) and decreasing (□20 %) scenarios, respectively, of both harvest and afforestation rates compared to the historical period. Under the constant harvest rate scenario, our findings show an incipient aging process of the forests existing in 1990: although NPP increases (C7 %), heterotrophic respiration increases at a greater rate (C13 %) and this leads to a decrease in the sink in the forest pools (□6 %) in 2030 compared to the historical period. By comparing the evolution of the biomass as a function of the NPP (i.e., the turnover time) for each country, we highlighted at least three groups of countries and turnover times. This means that, contrary to the assumptions proposed by other authors, this relationship cannot be assumed as a constant for all the EU countries, but specific conditions, such as the harvest rate, the current age structure and the forest composition, may contribute to the country-specific evolution of biomass stocks. The detailed picture of the C fluxes condensed in this study, and their evolution under different harvest scenarios, may represent both a benchmark for similar studies and a basis for broader analyses (e.g., including substitution effects of wood) on the mitigation potential of the EU forest sector.	Italy
forestry	C.H. Shaw, A.B. Hilger, J. Metsaranta, W.A. Kurz, G. Russo, F. Eichel, G. Stinson, C. Smyth, M. Filiatrault, Evaluation of simulated estimates of forest ecosystem carbon stocksusing ground plot data from Canada's National Forest Inventory, Ecological Modelling 272 (2014) 323– 347	Assessing the uncertainties in the estimates obtained from forest carbon budget models used for nationaland international reporting is essential, but model evaluations are rarely conducted mainly because oflack of appropriate, independent ground plot data sets. Ecosystem carbon stock estimates for 696 groundplots from Canada's new National Forest Inventory enabled the assessment of carbon stocks predicted bythe Carbon Budget Model of the Canadian Forest Sector 3 (CBM-CFS3). This model uses country-specificparameters, incorporates all five ecosystem carbon pools, and uses a simulation-based approach to pre-dict ecosystem C stocks from forest inventory data to implement a Tier-3 (most complex) approach of theIntergovernmental Panel on Climate Change Good Practice Guidance for Land Use, Land-Use Change andForestry (IPCC-GPG). The model is at the core of Canada's National Forest Carbon Monitoring, Account-ing, and Reporting System (NFCMARS). The set of ground plots meets the IPCC-GPG standard for modelevaluation as it is entirely independent of the model, but similar in type to that required for IPCC Tier-3inventory-based C stock estimation. Model simulations for each ground plot used only the type of inputdata available to the NFCMARS for the national inventory report in 2010 and none of the model's defaultparameters were altered. Ecosystem total C stocks estimated by CBM-CFS3 were unbiased (mean dif-ference = 1.9 Mg ha−1, p = 0.397), and significantly correlated (r = 0.54, p = 0.000) with ground plot-basedestimates. Contribution to ecosystem total C stocks error from soil was large, and from deadwood andaboveground biomass small. Results for percent error in the aboveground biomass (7.5%) and IPCC defineddeadwood (30.8%) pools compared favourably to the IPCC-GPG standards of 8% and 30%, respectively.Thus, we concluded that the CBM-CFS3 is reliable for reporting of C stocks in Canada's national green-house gas inventories. However, available standards for judging model reliability are few, and here weprovide recommendations for the development of practical standards. Analyses by leading species (n = 16)showed that error could often be attributed to a small subset of species and/or pools, allowing us toidentify where improvements of input data and/or the model would most contribute to reducing uncer-tainties. This C stock comparison is one of the first ever to follow the evaluation process recommendedby the IPCC-GPG for a Tier-3 model, and is a first step towards verification of greenhouse gas emissionand removal estimates based on C stock changes.	Canada
forestry	C. E. Smyth, G. Stinson, E. Neilson, T. C. Lemprière, M. Hafer, G. J. Rampley, W. A. Kurz, Quantifying the biophysical climate change mitigation potential of Canada's forest sector, Biogeosciences, 11, 3515–3529, 2014	The potential of forests and the forest sector to mitigate greenhouse gas (GHG) emissions is widely recognized, but challenging to quantify at a national scale. Forests and their carbon (C) sequestration potential are affected by management practices, where wood harvesting transfers C out of the forest into products, and subsequent regrowth allows further C sequestration. Here we determine the mitigation potential of the 2.3×106 km2 of Canada's managed forests from 2015 to 2050 using the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3), a harvested wood products (HWP) model that estimates emissions based on product half-life decay times, and an account of emission substitution benefits from the use of wood products and bioenergy.We examine several mitigation scenarios with different assumptions about forest management activity levels relative to a base case scenario, including improved growth from silvicultural activities, increased harvest and residue management for bioenergy, and reduced harvest for conservation. We combine forest management options with two mitigation scenarios for harvested wood product use involving an increase in either long-lived products or bioenergy uses. Results demonstrate large differences among alternative scenarios, and we identify potential mitigation scenarios with increasing benefits to the atmosphere for many decades into the future, as well as scenarios with no net benefit over many decades. The greatest mitigation impact was achieved through a mix of strategies that varied across the country and had cumulative mitigation of 254 TgCO2e in 2030, and 1180 TgCO2e in 2050. There was a trade-off between shortterm and long-term goals, in that maximizing short-term emissions reduction could reduce the forest sector's ability to contribute to longer-term objectives. We conclude that (i) national-scale forest sector mitigation options need to be assessed rigorously from a systems perspective to avoid the development of policies that deliver no net benefits to the atmosphere, (ii) a mix of strategies implemented across the country achieves the greatest mitigation impact, and (iii) because of the time delays in achieving carbon benefits for many forest-based mitigation activities, future contributions of the forest sector to climate mitigation can be maximized if implemented soon.	Canada
forestry	Stinson G., Kurz W.A., Smyth C.E., Neilson E.T., Dymond C.C., Metsaranta J.M., Boisvenue C., Rampley G.J., Li Q., White T.M., Blain D., An inventory-based analysis of Canada's managed forest carbon dynamics, 1990 to 2008, Global Change Biology (2011)	Canada's forests play an important role in the global carbon (C) cycle because of their large and dynamic C stocks. Detailed monitoring of C exchange between forests and the atmosphere and improved understanding of the processes that affect the net ecosystem exchange of C are needed to improve our understanding of the terrestrial C budget. We estimated the C budget of Canada's 2.3 106km2 managed forests from 1990 to 2008 using an empirical modelling approach driven by detailed forestry datasets. We estimated that average net primary production (NPP) during this period was 809 5TgCyr 1 (352 gCm 2 yr 1) and net ecosystem production (NEP) was 71 9TgCyr 1 (31 gCm 2 yr 1). Harvesting transferred 45 4TgCyr 1 out of the ecosystemand 45 4TgCyr 1 within the ecosystem (from living biomass to dead organic matter pools). Fires released 23 16 TgCyr 1 directly to the atmosphere, and fires, insects and other natural disturbances transferred 52 41 TgCyr 1 from biomass to dead organic matter pools, from where C will gradually be released through decomposition. Net biome production (NBP) was only 2 20 TgCyr 1 (1 gCm 2 yr 1); the low C sequestration ratio (NBP/NPP50.3%) is attributed to the high average age of Canada's managed forests and the impact of natural disturbances. Although net losses of ecosystem C occurred during several years due to large fires and widespread bark beetle outbreak, Canada'smanaged forests were a sink for atmospheric CO2 in all years, with an uptake of 50 18 TgCyr 1 [net ecosystem exchange (NEE) of CO25 22 gCm 2 yr 1].	Canada

SHEET C: METHODOLOGIES / PROTOCOLS LIST *(Here, list all methodologies / protocols that support activities described in Sheet A)*

Methodology name	**Unique Methodology / Protocol Identifier**	**Applicable methodology version(s)**	**Date of entry into force of most recent version**	**Prior versions of the methodology that are credited by the Program** (if applicable)	**Greenhouse / other gases addressed in methodology**	**Web link to methodology**
Operational-scale Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) version 1.2: user's guide. 2016. Kull, S.J; Rampley, G.J.; Morken, S.; Metsaranta, J.; Neilson, E.T.; Kurz, W.A. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alberta. 346 p.		version 1.2: user's guide	2016			http://cfs.nrcan.gc.ca/publications?id=36556