Raport științific anual
***privind implementarea proiectului*:**

„Mobilizarea și monitorizarea efortului cu impact climatic pozitiv din sectorul forestier”

(*cod* ERANET-FACCE ERAGAS - FORCLIMIT) Contract 82/2017

Etapa 2: Compilarea datelor climatice, completarea bazei de date pentru dinamica biomasei și validarea Yasso15

Perioada de implementare: 01.01.2018-31.12.2018

1. Introducere. Contextul științific.

Consorțiul FORCLIMIT susține ca potențialul de reducere de emisii asociat pădurilor din Europa este semnificativ, cu toate acestea, este insuficient utilizat în cadrul politicilor UE privind clima, și dăm ca exemplu Regulemantul LULUCF (Regulation (EU) 2018/841 of the European Parliament and of the Council of 30 May 2018 on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU (Text with EEA relevance). Luand nota de insuficienta efortului global de reduceri de emisii, Parlementul European recomanda printr-o rezolutie din Noiembrie 2018 ca UE sa devina neutrala climatic la jumatatea acestui secol, ceea ce justifica si mai mult nevoia de clarificare a contributiei padurii si sectorului folosintei terenului.

Până în prezent, resursele forestiere și sectorul forestier european au compensat aproximativ 13% din emisiile cauzate de utilizarea combustibililor fosili în Europa, reprezentând aproximativ 569 Mt CO2/an (Nabuurs et al., 2015), rezultate din sechestrarea carbonului în păduri și din activități de evitare a reducerilor de emisii. În această propunere, ne concentrăm în mod special pe potențialul de reducere de emisii al pădurilor și al resurselor forestiere (o parte semnificativă a așa numitului sector LULUCF ce include folosinta terenurilor) în cadrul mai larg al sectorului AFOLU (IPCC, 2006), care include Agricultura pe langa LULUCF. Potențialul suplimentar disponibil de reducere de emisii al pădurilor, al solurilor și al resurselor forestiere este ridicat, însă acest potențial este incert, pe de o parte, din cauza lipsei de stimulente din partea politicilor existente și, pe de altă parte, din cauza incertitudinii privind aplicarea și efectele activităților desfășurate în acest sens de proprietarii de păduri și utilizatorii de resurse lemnoase. Noi abordăm aceste două aspecte împreună, deoarece numai astfel pot fi făcute progrese evidente.

FORCLIMIT are trei **obiective principale**:

(1) să analizeze și să propună îmbunătățiri ale cadrului de contabilizare reduceri de emisii intr-un cadru de politici unificate internațional, care să faciliteze o contabilizare consistentă a emisiilor din păduri din diferite țări;

(2) să analizeze strategiile economice și ale politicilor existente în motivarea proprietarilor de terenuri ca aceștia să depună eforturi pentru reducerile de emisii din păduri și lanțul de custodie al lemnului;

(3) să adauge la sistemul MRV actual, care vizează doar estimarea nationala a emisiilor, posibilitatea de estimare îmbunătățită la scara mica, ex. Arboret, unitate de administrare, precum și evaluarea măsurilor economice și a politicilor existente. Acest lucru este demonstrat prin trei studii de caz în trei țări diferite: Olanda, Romania si Suedia.

2. Metode si rezultate

Activitățile realizate in 2018 sunt prezentate in format de publicare in anexe. Urmatoarele titluri prezinta succint aspectul stiintific abordat si legatura cu pachetele angajate prin contract. Pentru fiecare titlu sunt mentionati contribuitorii principali. De asemenea se face referite si la articolele publicate (inregistrate si pe platforma la raportarea pentru anul 2018):

a) Rezultate curente privind experimentul privind"cuantificarea descompunerii litierei prin metoda litter bag" (C. Petritan, M. Miclaus)

Rezultatele sunt prezentate in Anexa 1. Activitatea face parte din WP4. Metodologia initiala a fost descrisa in Raportul anual din primul an de implementare 2017 (Raport 1), aici fiind repetata pentru transparenta si continuitate cu ajustari minime in urma aplicarii in teren. Experimentul asociat a constat în amplasarea a 640 plicuri cu litieră și a 448 plicuri cu lemn mort în 4 tipuri de pădure de pe raza O.S. Pădurile Șincii (jud. Brașov). Experimentul va fi urmărit pentru o perioadă de 3 ani prin prelevare de probe potrivit calendarului din metodologie.

În anul 2018 au fost prelevate câte 8 plicuri de litieră în lunile Aprilie, Mai, Iunie, Iulie și August conform agendei prestabilite in anul 2017. Pe baza analizei statistice a datelor obținute în urma uscării și cântăririi probelor de litieră s-a constatat o variabilitate destul de redusă a masei acestora, și astfel s-a convenit ca la următoarele termene de prelevare să fie recoltate doar 5 plicuri pe variantă. Am optat pentru această schimbare și ca urmare avantajului conferit de aceasta, si anume posibilitatea de a extinde perioada de recoltare pentru încă un an (2020). Astfel, în anul 2019 se vor efectua 3 recoltări în M5 (Mai), M7 si M9, iar în anul 2020 alte 3 recoltări în M5 (Mai), M7 si M9, procesul de descompunere fiind mult mai lent decât ne-am așteptat. Ca urmare, în lunile Septembrie și Octombrie 2017 au fost recoltate câte 5 probe pentru fiecare variantă studiată. De asemenea în lunile Iulie și Octombrie 2017 au fost recoltate câte 7 probe pentru fiecare variantă de studiu în cazul experimentului de descompunere a lemnului de mici dimensiuni (sub 5.6 cm diametru). Și în acest caz am redus de la 8 la 7 numărul de probe pentru fiecare recoltare ceea ce ne oferă avantajul unei prelevări suplimentare dedicată anului 4 (2021).

Probele au fost recoltate și transportate în laborator unde după câteva zile de uscare la temperatura camerei au fost scoase din plicuri, curățate de orice impuritate externă și uscate 5 zile la 80 grade în etuvă. În urma recântăririi după uscare, am putut determina care a fost procentul de pierdere în biomasă prin raportarea la masa inițială (masa avută la momentul instalării în teren).

În figura 1 (**anexa 1**) este redată dinamica descompunerii frunzelor și acelor în primele 12 luni ale experimentului pentru toate cele 8 variante de studiu, cu punerea accentului pe scoaterea în evidență a variabilității în cadrul fiecărei etape de recoltare. În figura 2 și tabelul 1 din anexa 1 sunt redate modelele și coeficienții aferenți acestora, modele ce descriu relația dintre cantitățile de masă rămasă exprimate ca și procent din masa inițială și timpul de descompunere (exprimat în luni). Cele mai mari rate de descompunere, dar și cele mai mari valori ale coeficienților de determinare ale modelelor au fost înregistrate la specia brad, cu o uşoară tendinţă de superioritate pentru arboretul virgin comparativ cu cel parcurs cu lucrări. Contrar aşteptărilor, fagul, singura specie de foioase din cele trei studiate, prezintă ratele de descompunere cele mai mici, având de asemenea și cele mai mici valori ale coeficientului de determinare pentru modelul exponențial negativ folosit la ajustarea dinamicii descompunerii. Molidul prezintă valori intermediare celorlalte două specii. La speciile de rășinoase, descompunerea în pădurea virgină a fost mai intensă comparativ cu pădurea parcursă, în timp ce la fag a fost depistat un comportament contrar.

Așa cum se poate vedea din Figura 3 a anexei 1, la categoria de lemn foarte subțire (d=0.1-2cm) cea mai mare rată de descompunere s-a înregistrat la specia bradul din pădurea virgină (pierdere în biomasă de 20% în Iulie și 25% în Octombrie), urmată îndeaproape de fagul din arboretul pur (21% Iulie și 23 % Octombrie). La polul opus, cea mai mică rată a fost semnalată la molidișul pur (aproximativ 5% în Iulie 13% în Octombrie). În cadrul clasei de mărime lemn mijlociu (d=2.1-4.0) (figura 3 b), fagul a prezentat cele mai ridicate rate de descompunere, în timp ce molidul cele mai mici. Ratele de descompunere ale lemnului de la cea mai mare categorie de grosime (d=4.1-5.6 cm) (figura 3 c) au fost similare pentru toate cele 8 variante structurate (cu variații între 5 și 10%). În ceea ce privește influența managementului asupra gradelor de descompunere, prin comparația ratelor de descompunere a celor 3 specii din pădurea parcursă cu intervenții silviculturale cu ratele înregistrate în pădurea virgină, s-au găsit diferențe semnificative doar la specia brad și clasa de lemn foarte subțire (o rată mai mare în pădurea neparcursă). Din punct de vedere al influenței amestecului asupra descompunerii, fagul a prezentat în arboretul pur rate de descompunere aproape duble comparativ cu pădurea de amestec atât pentru clasa de diametre mici, precum și pentru clasa de dimensiuni mijlocii.

Conform modelului carbonului din sol și de descompunere a litierei (Yasso15) litiera se descompune în 4 grupuri de componente, așa-numitul AWEN(A-substanțe hidrosolubile în acid, W-substanțe solubile în apă, E-solvenți (ex. etanol sau diclorometan), W-substanțe care nu sunt nici solubile nici hidrosolubile). Am proiectat ca un total de 144 de probe (3 specii x 2 tipuri de material –litieră și lemn de dimensiuni mici x 3 perioade de recoltare – la început de experiment –Noiembrie 207, la mijloc de experiment Noiembrie 2018 si la sfârșit de proiect Noiembrie 2019 x 8 replicații) să fie trimise în Finlanda, la partenerul finlandez, care pe baza protocolului aferent să fie determinate aceste 4 grupuri de componente. A fost trimis deja primul set de probe în primăvara lui 2018 și se află în lucru în laboratorul finlandez, urmând ca în cel mai scurt timp să fie trimisă și a doua rundă de probe la un an după începerea experimentului.

b) Elaborarea bazei de date cu volumul lemnului comercial pe picior din Inventarul Forestier National (V. Blujdea, I. Dutca)

Baza de date completa la nivel national este disponibila in formatul solicitat de CBM-CFS3 (volum pe picior si cresterea curenta anuala in volum a lemnului comercial fara scoarta) si EFISCEN 4.2.(volum pe picior si cresterea curenta anuala in volum a lemnului comercial cu scoarta). Modelul ales pentru ajustarea volumului lemnului comercial pe picior si a cresterii curente cumulate a sa a fost Chapman-Richards. Parametrii acestor ecuatii, pentru 10 tipuri de padure sunt prezentati in **Anexa 2a**. Metoda de ajustare este regresia neliniara in R folosind aplicatia nlrob (pachetul „robustbase", URL: http://robustbase.r-forge.r-project.org/). Creșterea curentă anuala și volumul lemnului întreg pe picior detaliate pe regiuni de dezvoltare, 10 tipuri de pădure/specii de arbori și clase de vârsta de 10 ani sunt disponibile din primul ciclu al Inventarului Forestier National. **Anexa 2b** prezenta varianta curenta a articolului privind analiza comparativa a celor doua modele CBM-CFS si EFISCEN – ce urmeaza a fi transmis spre publicare pana in luna martie 2019 (sarcina 6.5 din WP6). Un articol privind solutiile de adaptare a bazelor de date specifice CBM-CFS este publicat cu contributia echipei de proiect (https://link.springer.com/article/10.1007/s13595-018-0743-5). Analiza incertitudinii estimarilor a fost tratata si din perspectiva pietei lemnului la nivel european este publicat cu contributia echipei de proiect (http://www.sisef.it/iforest/pdf/?id=ifor2636-011).

c) Analiza incertitudinii metodelor utilizate pentru detectarea schimbarii folosintei terenului prin metode diferite (M. Miclaus, V. Blujdea)

Acesta raspunde obligatiilor asociate sarcinilor din pachetul 3 si 5. Imbunatatirea consistentei metodelor de estimare a schimbarii stocurilor de carbon cu suprafata terenurilor este una din marile provocari legate de implemetaea inventarelor de gaze cu efect de sera si a reducerior de emisii asociate obligatiilor internationale (Protocolul de la Kyoto, Acordul de la Pari/legislatia uniunii euroepene). Activitatea face parte din cadrul WP5. Compararea a trei metode utilizate in diverse sisteme de raportare este descrisa in versiunea avansata de articol inclusa in **Anexa 3.**

d) Studiu privind specificitatea modelelor alometrice (I. Dutca, V. Blujdea)

Acesta raspunde obligatiilor asociate sarcinii 5.2. Este general recunoscut ca modelele alometrice necesare pentru estimarea biomasei in păduri sunt specifice zonei din care au fost eșantionați arborii. Asta pentru ca forma arborilor este influențată de genotip dar si de factorii de mediu cum ar fi solul, clima dar si competiția dintre arbori. Plecând de la premisa ca aceste caracteristici au o variabilitate spațială, concluzionam ca si alometria arborilor are o variabilitate spațială. Folosind modele ierarhice cu interceptul variabil, am putut arata cat de mult sunt afectate aceste modele de variabilitatea spațială. Coeficientul de corelație intraclasa este des folosit in sociologie pentru a arata proporția variantei modelului, cauzata de diferențele dintre grupuri. In mod similar, noi am arătat ca diferențele dintre plantațiile tinere de molid

(Picea abies) in Romania produc proporții foarte mari din varianta totala a modelului alometric. Aceasta proporție a variat intre 33 si 86% din varianta totala a modelului, in funcție de variabila independenta folosita si componenta arborilor estimata. Am mai arătat ca, folosind diametrul ca variabila independenta in model efectele produse de gruparea arborilor eșantionați in plantații este mai mic decât atunci când folosim înălțimea arborilor. Atunci când sunt folosite ambele variabile (diametrul si înălțimea) este mai bine sa fie folosita o variabila combinata (D2H) deoarece efectul plantației asupra modelului este mai mic. Dintre componentele arborilor, biomasa fusului are o specificitate mai mare decât biomasa frunzelor sau ramurilor.

Rezultatele obținute sunt foarte importante pentru domeniul estimării carbonului in păduri, pentru ca in acest fel se poate decide daca modelele elaborate pentru un arboret pot fi folosite si in alte arborete. Deși se vorbește foarte des despre specificitatea modelelor alometrice, acest studiu este primul studiu care arata intr-un mod cantitativ ca specificitatea modelelor alometrice are foarte ridicata. Acest studiu a fost publicat in revista Biomass & Bioenergy nr. 116 din Septembrie 2018. Varianta publicata a articolului este disponibila la: https://www.sciencedirect.com/science/article/pii/S0961953418301259?via%3Dihub or https://doi.org/10.1016/j.biombioe.2018.05.013.

e) Studiu privind incertitudinea din modele alometrice

Acesta raspunde obligatiilor asociate sarcinii 5.2. Incertitudinea estimărilor de biomasa este esențiala pentru succesul implementării masurilor pentru reducerea emisiilor de carbon din păduri. Asta pentru ca estimările de biomasa din păduri nu se bazează pe măsurarea întregii populații ci se bazează pe eșantionare statistica prin care se poate estima media populației cu o anumita precizie.

Modele alometrice folosesc variabile ușor de măsurat (e.g. diametrul si/sau înălțimea) pentru a estima caracteristici greu de măsurat ale arborilor (e.g. biomasa). Însă diametrul si înălțimea arborilor sunt caracteristici care sunt corelate, deoarece arborii cu diametrul mai mare au de regula si o înălțime mai mare. Ca urmare, modele alometrice bazate pe ambele variabile independente pot prezenta colinearitate intre variabile, ceea ce duce la o creștere a erorilor standard ale parametrilor regresiei si implicit la o creștere a incertitudinii modelului. Folosind seturi de date de biomasa pentru foarte mulți arbori am arătat ca utilizând variabila combinata (in defavoarea utilizării variabilelor separate) conduce la estimări mai precise (incertitudine a estimării mai mica). Incertitudinile estimărilor au fost testate pentru suprafețe mari de pădure, utilizând metode Monte-Carlo de propagare a incertitudinilor. Cu toate acestea, diferențele produse au fost in general mici, încât pot fi ignorate. Însă modul de estimare al parametrilor (transformare logaritmica vs. model nelinear) au produs diferențe mai mari in ceea ce privește incertitudinea estimării comparativ cu modul de asociere a variabilelor in model (variabila combinata vs. variabile separate). Deși transformarea logaritmica este foarte utilizata pentru a elabora modele alometrice, se pare ca modelul neliniar produce estimări mult mai precise. Un draft al acestui manuscris este atașat in **anexa 4**.

f) Administrarea bazei de date a proiectului

- procesarea statistică se face cu prioritate în R (open source): https://cran.r-project.org/bin/windows/base/
- modul de stocare și actualizare a bazei de date: fișiere Excel pentru EFISCEN si Microsoft Access pentru CBM-CFS.

g) Sprijin activități incluse in alte pachete de lucru din FORCLIMIT

- informare continua cu privire la regulile de contabilizare a reducerilor de emisii din sectorul folosinței terenurilor incluse în Pachetul energie clima 2030 (https://ec.europa.eu/clima/policies/strategies/2030_en), in sprijinul Pachetelor de lucru 1 si 2 ale FORCLIMIT.

3. Managementul proiectului

Toate sarcinile asumate prin contract sunt antamate si in stadiu corespunzator primei jumatati a perioadei de implementare a proiectului. Cele mai dificile aspecte, respectiv adaptarea bazelor de date si definitivarea scripturilor pentru pre-procesare si armonizare date sunt rezolvate pentru EFISCEN (varianta clasica) si CBM-CFS3. Intelegerea bazelor teoretice pentru noul model EFISCEN-space sunt avansate si urmeaza a fi elaborata o baza de date specifica in vederea rularii sale. Capacitatea de rulare a noului modelul Yasso15 este incetinita de ritmul experimentului de descompunere (Anex 1) si de analiza bio-chimica (de Institutul Meteorologic partener din Finlanda), insa rezultatele sunt conforme cu teoria, si reprezinta primele rezulate de acest fel din europa de est.

Sunt organizate intalniri periodice pentru o zi de lucru in comun, cel putin odata la 3 saptamani. Calendarul de colectare probe de sol (pentru validarea modelului) si descompunere litiera este mentinut cu strictete.

4. Vizibilitate nationala si internatională a proiectului FORCLIMIT

- actualizarea continua a site-ului asociat al proiectului (http://www.forestinventory.no/forclimit/)

- workshop-uri privind evolutia p[roiectului, adresate personalului didactic, studentilor si factorilor de decizie din 8 martie 2018 si 14 Decembrie 2018;
- prezenta lui V. Blujdea la EUSTAFOR in calitate de key speaker în Belgia, la ***Brussels***, în perioada ***24-25 Septembrie 2018*** la întâlnirea "***LULUCF: practical consequences for the forest-based sector***, *Joint workshop on the practical consequences of the introduction of the Regulation for the inclusion of Land Use, Land Use Change and Forestry (LULUCF) within the 2030 EU Climate and Energy framework"*, organizat de ***EUSTAFOR și Biroul Regiunii Toscana din Brussels (https://eustafor.eu/lulucf-practical-consequences-for-the-forest-based-sector/).***

Referitor la **comunicarea excelentă avută cu partenerii europeni implicați în proiect** amintim

- întâlnirea avută între toate instituțiile partenere la Brasov, în perioada 17-20 Septembrie 2018;
- deplasarea la Wageningen a doi membrii ai ecipei de proiect , V. Blujdea si I. Dutca pentru armonizarea bazelor de date in vederea rularii CBM-CFS si EFISCEN;
- prezenta unui expert WUR (Dr. R. Sikkema) la Brasov in perioada 10-15 Septembrie 2018 pentru validari rezulate moedel CBM si EFISCEN;
- prezenta membru echipa de proiect M. Miclaus la Upsala in 25.11-01.12. 2018 pentru redactarea articol in vederea publicarii.

Brașov, 4.12.2018 **Dr. ing. Viorel Blujdea**

Anexa 1. Decomposition of needle/leaf and small wood litter from European beech, Norway spruce and Silver fir: influence of mixture, climate (temperature x altitude) and forest management

1.Introduction

Litter decomposition is a fundamental process of forest ecosystems for the carbon and nutrients cycles (dead organic matter is transfered from the above-ground part of trees to the forest floor, where under the action of microorganisms and soil fauna is decomposed gradually depending on climate factors (temperature, precipitation) (Gholz et al. 2000), substrate availability/soil properties (Vesterdal 1999) and litter quality (Cornwell et al. 2008). In a meta-analysis, grouping data for 818 species from 66 decomposition experimments on six continents, Cornwell et al. (2008) found that plant functional traits as litter quality is more important than climate factors affecting litter decomposition rate (the species driven differences control predominatly the litter decomposition rate wordlwidely).

2.Material and methods

Site

The study site is located in Transilvanian side of Southern Carpathians (Fagaras Mountains), Padurile Sincii forest district.

The study was carried out on European beech (Fagus sylvatica) leaves, and Norway spruce (Picea abies) and Silver fir (Abies alba) needle litter, but also on small wood litter of all three species. In October 2017, fresh fallen brown leaves were collected beneath several randomly distributed trees, while the needles were collected from branches cut from several trees selected at random. In November 2017, small wood pieces were collected from branches cut from trees recently harvested during the thinning interventions. Both litter types (leaves/needles and small wood) were stored 2 weeks in laboratory at air temperature. The litterbags were made of ??nets (20 x 30 cm; 1 mm mesh size? for beech and 10 x 10 cm; ..mm mesh size for needles) and filled with 10-20 g leaves and 5-15 g needles, respectively and labelled properly. In 6th of November 2017, on each of the four study sites 80 litterbags per species (8 replicates of 10 samplings campaigns over three years) were placed on the soil. Subsequent samples were taken according to a preplanned schedule (every month starting with 24th of April till 24 October). We dried a first set of bags at 80 C for five days and weighed and calculated for each species an average correction factor as ratio between oven dry mass and air-dry mass. We applied this correction factor to all litterbags in order to obtain the initial oven-dry mass of each leaf amount of every litterbag (we multiplied air-dry mass of all leaf bags for humidity by the average correction factor).

Data analysis

The relationship of the mass loss of leaves and needles and decomposition time is often modelled by a negative exponential decay model:

$$Mt=M0 \times \exp(-k \times t),$$

where:

-Mt is the mass at time t,

-M0 is the initial mass (mass at time 0),

-t is time in months

-k is the exponential decay coefficient or decomposition rate.

In our case, we used mass remaining as % from initial mass account (consequently, M0 = 100).

3.Results

3.1. Leaf/needle litter decomposition

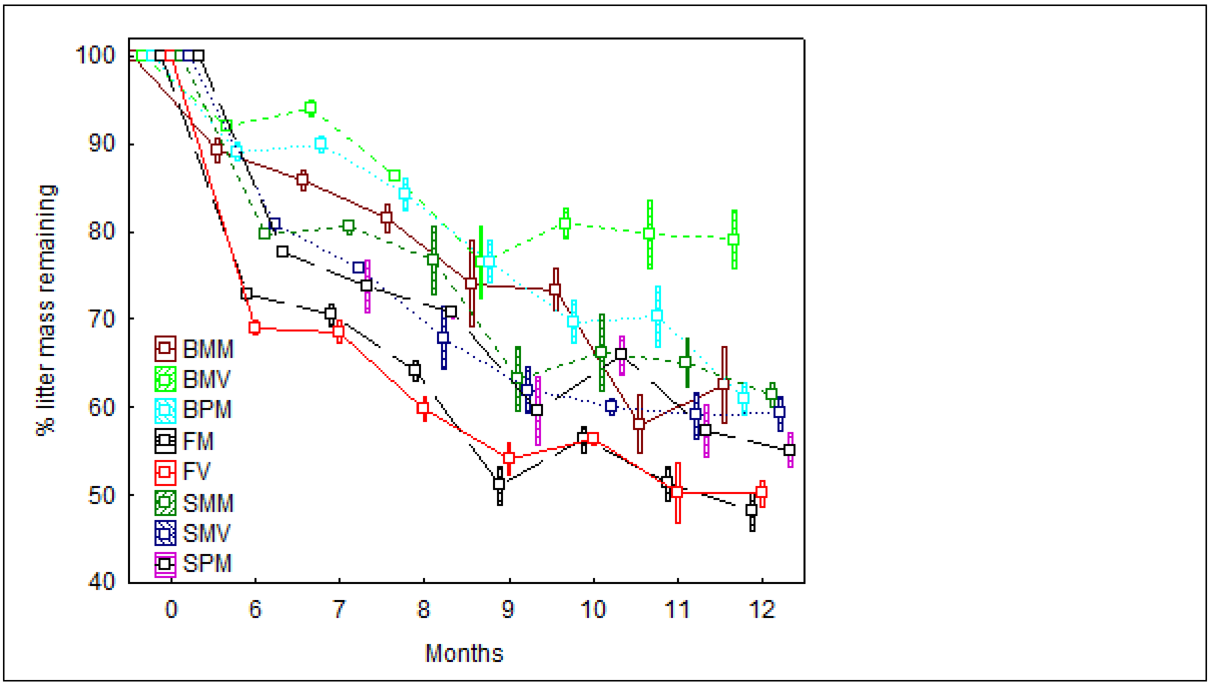


Fig.1. Leaf/needle mass remainig (as % from initial amount) for all investigated variants after each bags collection.

During the first year of experiment the mass loss

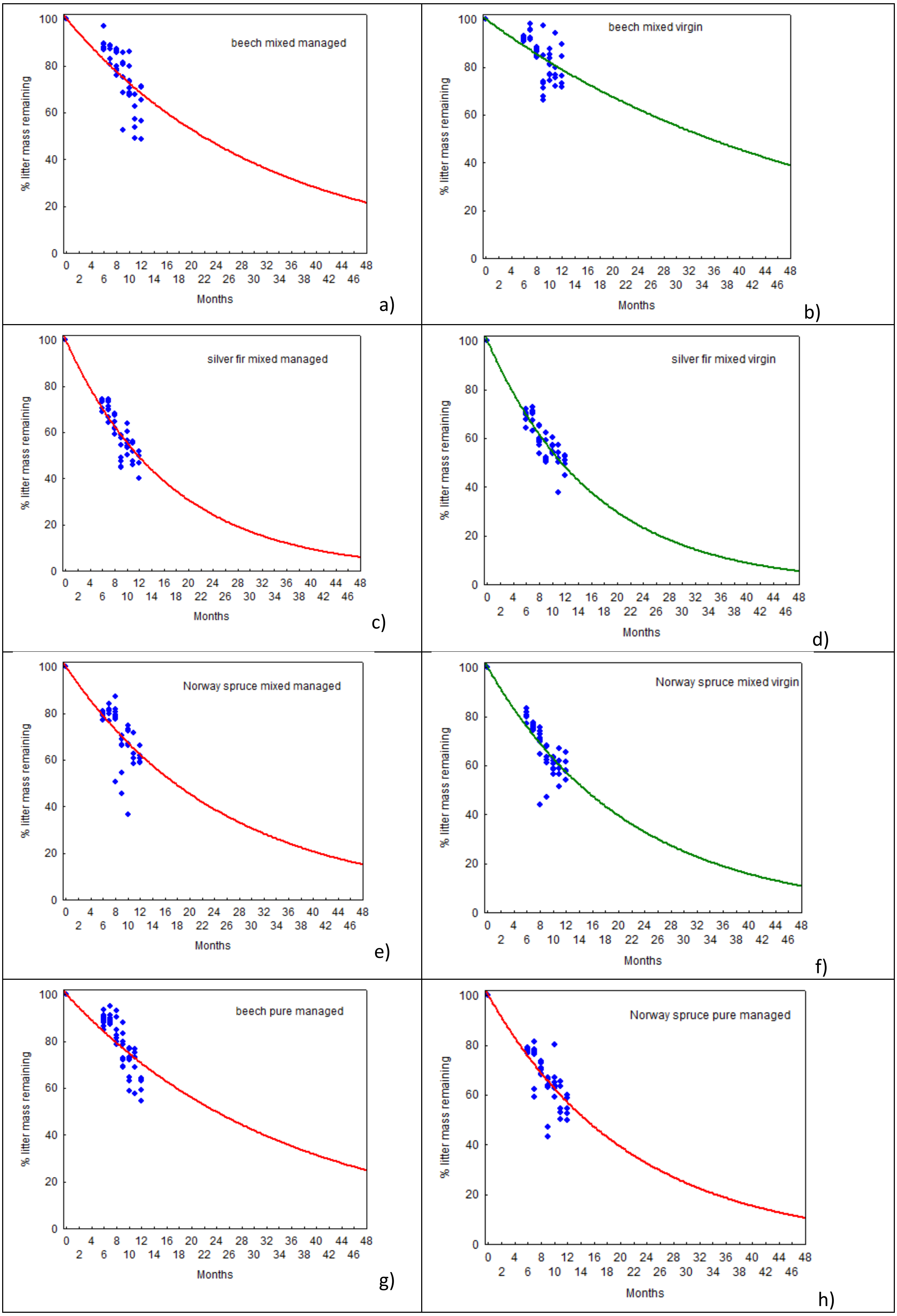
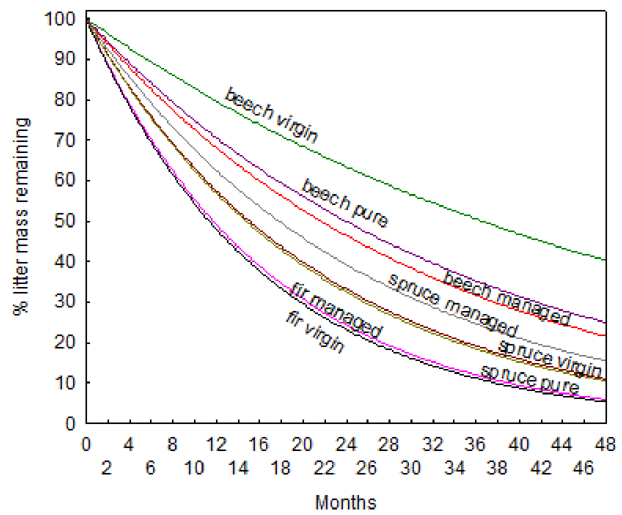

% litter mass remaining
Months
beech mixed managed
a)
beech mixed virgin
b)
silver fir mixed managed
c)
silver fir mixed virgin
d)
Norway spruce mixed managed
e)
Norway spruce mixed virgin
f)
beech pure managed
g)
Norway spruce pure managed
h)

Fig.2. Litter mass remaining (as % from initial amount) modelled as a function of decomposition time (months) (y=100 x exp(-k x)) for each studied variant (a-beech mixed managed, b-beech mixed virgin, c-silver fir mixed managed, d-silver fir mixed virgin, e-spruce mixed managed, f-spruce mixed virgin, g-beech pure managed, h-spruce pure managed).

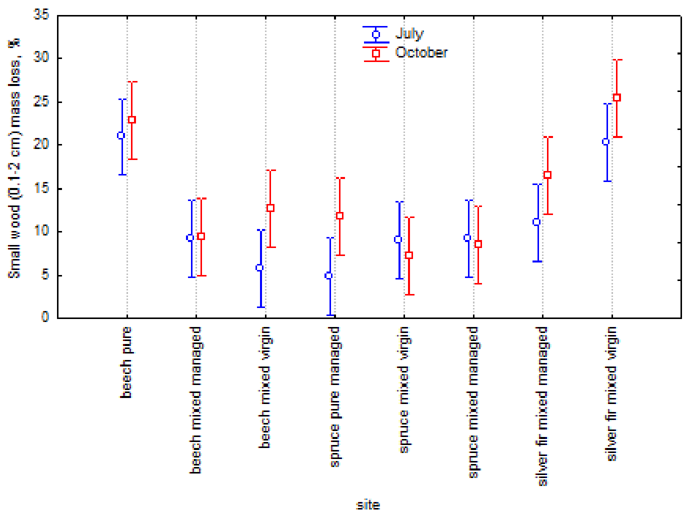
Table 1. Regression analysis (%mass remaining=100 x exp(-k x time)).

	K	p_k	R^2
Beech mixed managed	0,0319	0,000	0,51
Beech mixed virgin	0,0196	0,000	0,38
Silver fir mixed managed	0,0588	0,000	0,79
Silver fir mixed virgin	0,0606	0,000	0,81
Norway spruce mixed managed	0,0393	0,000	0,48
Norway spruce mixed virgin	0,0462	0,000	0,69
Norway spruce pure managed	0,0467	0,000	0,63
Beech pure managed	0,0289	0,000	0,55

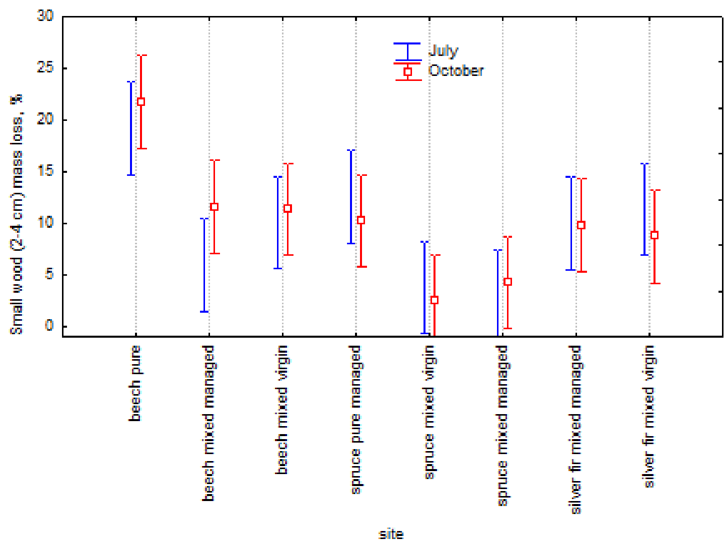


3.2. Small wood litter decomposition

a)



b)



c)

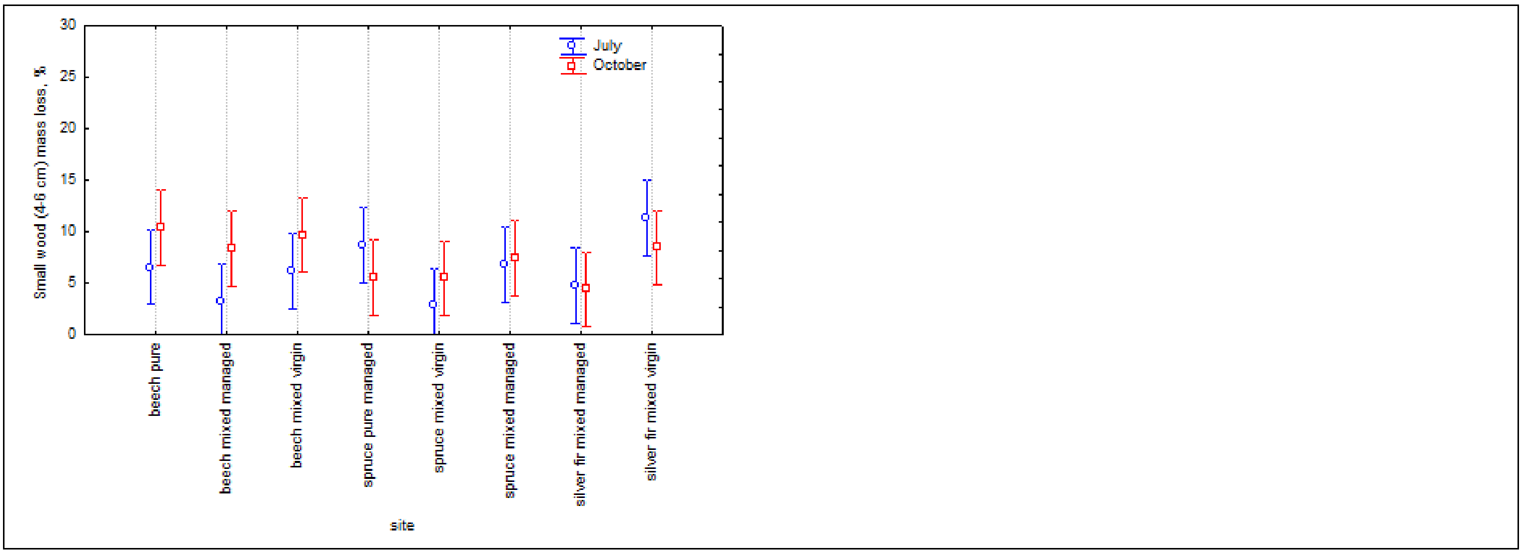


Fig.3. Small wood litter mass loss (as % from initial amount) for all forest/species variants (a) wood with d=0.1-2 cm, b) d=2.1-4.0 cm, c) d=4.1-5.6 cm

Anexa 2. Informatii privind armonizarea bazelor de date in vederea validarii reciproce a medelelor CBM-CFS si EFISCEN

Anexa 2a. Criteriile de clasificare si parametrii agregați regional pentru baza de date națională din Inventarul Forestier National

Criterii	Specificatii
Tip de padure/ specii	Rasinoase, Molid, Brad, Predom rasinoase, Amestecuri, Predom foioase, Foioase, Fag, Cvercinee, Salcam
Clase de varsta	1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, 91-100, 101-110, 111-120, 121-130, 131-140, 141-150, 151-160, >160, Unevenaged
Regiuni administrative (NUTS-2)	RO11, RO12, RO21, RO22, RO31, RO32, RO41, RO42
Volum pe picior	Volume annual, m3 y-1
Recolta de masa lemnoasa	Volume annual, m3 y-1
Suprafata	Area, ha
Creserea neta anuala	Net annual growth, m3 y-1 ha-1
Eroarea de eșantionare (in %) pentru toți parametrii de mai sus	Estimation error, %

Parametrii ecuatiilor utilizati la modelare

$$V=a*e^{(-b*A)}*(1-e^{(-b*A)})\hat{}^{(c-1)}$$, *unde*

V- volumul comercial,
A – clasa de varsta de 10 ani,
a,b,c – parametrii ecuatiei specifici ficarei tip de padure

Parametrii ecuatiei pentru estimarea volumului lemnului comercial pe picior

Tip de padure	ConBroad	AA	FS	OB	OC	PA	PredBroad	PredCon	QR	RP
a	2291.41	136381.7553	2019.821	976.8087	3787.497176	2777.876	3696.275	2841.894	1607.577	3541.647
b	0.009851	3.81253E-05	0.005134	0.006911	0.015951353	0.016171	0.01238	0.008661	0.011314	0.002407
c	2.598057	1.949198118	2.137377	2.012281	4.180130563	3.50011	3.635651	2.89859	2.956918	2.413442

Parameteii ecuatiei pentru estimarea cresterii curente cumulate a volumului lemnului comercial pe picior

Tip de padure	ConBroad	AA	FS	OB	OC	PA	PredBroad	PredCon	QR	RP
a	46.67395443	30.53049718	44.82908538	12.60159597	44.91925629	32.29905709	16.71558839	25.99785093	18.19606152	32.28165566
b	0.014718484	0.003007487	3.28696E-05	0.003763308	0.018643759	0.010442337	0.00294835	0.005746935	0.010859768	0.044339613
c	2.33569566	1.542279681	1.349733947	1.264787544	2.574587006	2.109134766	1.388390928	1.474466432	1.659962736	2.806735827

Parametrii ecutiei Boudewyn privind modelarea alocarii de biomasa in compartimetele arborelui functie de volumul lemnului comercial. *P* reprezinta proportia componentei de biomasa din biomasa supraterana integrala (potrivit Boudewyn, P., Song, X., Magnussen, S., Gillis, M.D., 2007. Model-based, Volume-to-Biomass Conversion for Forested and Vegetated Land in Canada. Canadian Forest Service, Victoria, Canada (Inf. Rep. BC-X-411).).

$$(4)\quad p_{stemwood} = \frac{1}{1 + e^{a1+a2\times vol+a3\times lvol} + e^{b1+b2\times vol+b3\times lvol} + e^{c1+c2\times vol+c3\times lvol}}$$

$$(5)\quad p_{bark} = \frac{e^{a1+a2\times vol+a3\times lvol}}{1 + e^{a1+a2\times vol+a3\times lvol} + e^{b1+b2\times vol+b3\times lvol} + e^{c1+c2\times vol+c3\times lvol}}$$

$$(6)\quad p_{branches} = \frac{e^{b1+b2\times vol+b3\times lvol}}{1 + e^{a1+a2\times vol+a3\times lvol} + e^{b1+b2\times vol+b3\times lvol} + e^{c1+c2\times vol+c3\times lvol}}$$

$$(7)\quad p_{foliage} = \frac{e^{c1+c2\times vol+c3\times lvol}}{1 + e^{a1+a2\times vol+a3\times lvol} + e^{b1+b2\times vol+b3\times lvol} + e^{c1+c2\times vol+c3\times lvol}}$$

Valorile parametrilor pentru cele zece tipuri de padure

Tip de padure	a1	a2	a3	b1	b2	b3	c1	c2	c3
ROU_PC	-1.573653143	-0.001653423	-0.043681989	-1.917251538	-0.001318462	-0.067893453	-0.753406708	-0.005322017	-0.854548877
ROU_CB	-1.688343	0.001696	-0.255443	-2.022535	-0.001800	0.128927	-0.722283	0.005140	-1.059489
ROU_AA	-1.426523	-0.000687	-0.083774	-1.822640	-0.000141	-0.056877	-0.522418	-0.000518	-0.500000
ROU_OC	-1.195958	-0.000340	0.044504	-1.588882	-0.002690	-0.172668	-0.888850	-0.004805	-0.407255
ROU_PA	-1.573125306	-0.000498028	-0.022566376	-1.926269813	-0.00016829	-0.011293606	-0.870537754	-0.002046936	-0.443987026
ROU_FS	-1.675509	0.000425	-0.153451	-1.988408	-0.001124	0.070280	-0.796988	0.005713	-1.132685
ROU_PB	-1.716351128	0.000573495	-0.139975714	-2.052043708	-0.001049959	0.055252471	-0.95141123	0.003589983	-0.968666404

ROU_OB	-1.677640	0.000431	-0.104280	-1.990934	-0.002655	0.119850	-0.890889	0.008447	-1.127068
ROU_QR	-1.578718567	-0.002813506	0.057617124	-1.918073416	-0.001676584	0.076810471	-0.756820282	0.008479747	-0.862874224
ROU_RP	-1.631169997	-0.00824022	0.295419876	-1.940141497	-0.015736249	0.303245098	-1.1000358	0.018019029	-0.720251145

Parametrii pentru conversia volmului comercial in biomasa lemnoasa supraterana

Ecuatia $B=A*Vol^B$, unde Vol – volumul comercial pe picior

Tip de padure	A	B
ROU_PC	0.453425409	1.002847289
ROU_CB	0.488376	1.011117
ROU_AA	0.401728	0.997698
ROU_OC	0.414060	0.995031
ROU_PA	0.364690872	1.016230027
ROU_FS	0.649242	0.997663
ROU_PB	0.567652516	1.00460649
ROU_OB	0.638217	0.989001
ROU_QR	0.708919191	0.982355399
ROU_RP	0.605874314	1.014093923

Anexa 2b. Versiune articol asociat sarcina 5.6.

Comparison of two large scale forest scenario modelling approaches for reporting CO_2 removals

Viorel Blujdea, Richard Sikkema, Ioan Dutca, (Mart Jan Schelhaas) and Gert Jan Nabuurs

1. Introduction

Forests strongly influence, and have an important role to play in, global carbon cycles (Masera et al. 2003). Information on forest dynamics at stand- and landscape levels is essential to the understanding of trends in C dynamics. The total C stocks and C fluxes can be changed dramatically according to ecosystem processes such as establishment, growth, mortality, and disturbance. We can also gain insight into global climate changes through such valuable information regarding forest C dynamics. Based on the Kyoto Protocol, aboveground biomass, belowground biomass, litter, dead wood, and soil organic carbon are major components of C stocks to be estimated. Forests store a large amount of C that is absorbed through the photosynthetic process, yet a large amount of C can also be emitted through forest loss and deforestation (Van der Werf et al. 2009). Therefore, information on C stocks and C fluxes related to forest dynamics can be beneficial for forest managers, environmental policy-makers, and governmental agencies who are interested in adapting to climate change (Kim et al 2015).

Over the last decades, many forest model simulators have been developed for the forests of individual European countries, Europe as a whole and some other regions. The underlying growth models are usually based on national datasets of varying size, obtained from National Forest Inventories or from long-term research plots. Many of these models include country- and location-specific predictors, such as site quality indices that may aggregate climate, soil properties and topography effects (Schelhaas et al 2018). However, those individual national-scale studies differ considerably in timing, underlying methodology and scenarios. In the end, a clear demand for consistent projections at European scale still remains (Schelhaas et al, 2017). The European countries most frequently use the forest management models EFISCEN (originally based on forests in the Nordic countries) and the Carbon Budget Modelling or CBM (originally based on Canadian forests).

[to be rewritten – it is mostly a copy paste from reference] [In a review of forest carbon models that use growth yield curves (Kim et al 2015), CBM and EFISCEN are analysed in a qualitative way. As concluded, CBM-CFS3 is expected to give high accuracy in the estimation of forest carbon with diverse inputs and detailed compartments in biomass pools and dead organic matter pools, and handle C dynamics which is related to disturbance and land-use changes deeply in both small-scale and large-scale forests. EFISCEN can project forest carbon dynamics in combination with diverse scenarios driven from multiple models, with matrix structure large-scale forest ecosystem processes described simply and efficiently. In a second more quantitative paper (Jonsson et al, 2017), the maximum wood supply (MWS) in the EU was compiled both via CBM and via EFISCEN. The overall MWS estimated with CBM at EU level is similar to the values obtained with the EFISCEN model. However, there were some differences at country level. In general, CBM estimates of woody biomass potentials are higher than EFISCEN estimates (on average >20%). The main possible reasons are the use of different input data with regards to NFIs, forest area available for wood supply (FAWS) and harvest level. Furthermore, CBM distinguishes between even-aged and uneven-aged forests, while EFISCEN does not. For a few countries, CBM estimates were lower than EFISCEN.]

This paper gives a quantitative comparison of the forest status dynamics and carbon parameters in Romania, as modelled in EFISCEN 4.2 and CBM-CFS3. The aim is to quantify the relative contribution of different sources of uncertainty as originating from two modelling approaches to carbon emissions and removal projections at a national scale. As a case study the Romanian forests were chosen, because the forest is mixed and shows a variety of management regimes

The results for the various pools and fluxes as simulated by the model Carbon Budget Model (CBM-CFS) and EFISCEN were compared. The exercise has value as the two models are conceptually different in running C pools (volume by EFISCEN4.2, C dynamics by CBM-CFS3). Full comparability will be achieved by harmonization of input data on forest inventory and dead organic matter decomposition. The focus is on the ability of both models to represent C stock changes (CSC) in living biomass and transfers to dead organic matter pool (annual production of foliage, branches, bark, etc.) and soil carbon dynamics in comparable circumstances (i.e. forest status, management interventions) at the national scale of Romania. Harvested wood products are not included in any of the models.

2. Methodology / Models description

In assessing the two models we were performing following steps: (i) understanding the two models, harmonization of input data, including transparent presentation of assumptions and procedures involved; (ii) simulation of additional scenarios to assess models behaviour in particular circumstances; (iii) identify corresponding output parameters with regard to forest status and C dynamics; (iv) identification of discrepancies in inputs and outputs, including any feasible calibration; (v) analysis of disagreements between models outputs and validation.

2.1 Understanding the two models, harmonization of input data, including transparent presentation of assumptions and procedures involved

Both CBM-CFS and EFISCEN run on aggregated data, i.e. either derived from forest management planning or statistical sampling-based forest inventories. Datasets on wood volume inventories and yield tables provide a wealth of information that can contribute to analyses of forest C stocks and C stock changes (Stinson et al, 2011).

2.1.1. Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)

The CBM-CFS (Kurz et al. 2009) is an inventory-based, yield- and growth-data driven model that simulates C dynamics of above- and below-ground biomass, litter, dead wood and mineral soil pools (Kurz et al. 2009) at aggregated, i.e. landscape-level. The CBM-CFS runs ten biomass and 11 dead organic matter C pools. CBM-CFS status (e.g. C stocks) and processes (e.g. C fluxes to atmosphere, transfers among pools and to the forest products) are simulated with annual time step following IPCC / UNFCCC reporting requirements for national GHG inventories (i.e. IPCC 2006).

CBM-CFS performs an initialization by attaching steady state stocks to each of 21 C pools to inventory user defined strata at the beginning of the year of the start of the simulation (“0”). Initialization is done based on yield table data, i.e. the standing stock volume curves. Over model run, changes in all other C pools are simulated by propagation of both area and time step dependent standing C stocks derived from cumulated curve of net annual increment of the growing stock (merchantable) volume, i.e. growth curve, and allocation of biomass to other stand biomass compartments, and transfers from living biomass pool to dead organic pool, and transfers from dead organic to mineral soils pool. Any silvicultural practice can be applied by CBM (i.e., thinning, clearcuts, salvage loggings, etc.) defined by as many classifiers as used for forest inventory, e.g. as the minimum are rotation lengths for the final cut and age range for thinning. Any natural disturbance can be simulated assuming adequate data on C transfers among pools is available as a disturbance matrix attached to each type of disturbance.

The model has been applied to 26 EU countries, using National Forest Inventories (NFIs) input data, in order to estimate the EU forest C dynamic from 2000 to 2012, including the effect of natural disturbances and land use change (Pilli et al. 2016a, 2016b). Other countries are using it for scientific explorations or operational purposes (e.g. Kim et., 2016; Zamolodchikov et al. 2013).

2.1.2 European Forest Information SCENario Model (EFISCEN)

The European Forest Information SCENario Model (EFISCEN) is a large-scale forest model that project forest resource development on regional (NUTS2), national, to European scale (Schelhaas 2007; Verkerk et al 2017). The model uses national forest inventory data as a main source of input to describe the current structure and composition of European forest resources. Based on this information, the model can project the development of forest resources, based on different scenarios. These scenarios are mainly determined by management actions, but the model can also take into account changes in forest area, as well as changes in growth e.g. due to climate change. It has been applied to studies concerning impacts of forest management changes (Nabuurs et al. 2007), wood availability, biomass availability, trade-offs with other functions, ad carbon balance. It has been applied to set the Reference level of EU forests under the Kyoto Protocol’s second commitment period (Bottcher et al xx)

EFISCEN simulates volume and volume change in time. EFISCEN is a matrix model, where the state of the forest is represented in matrices as an area distribution over age and volume classes (Salnass

1990). Aging is simulated as the movement of area to higher age classes, while growth is simulated as the movement of area to higher volume classes. Thinning is simulated as movement of area to a lower volume class, while the difference in volume is assumed to be the volume that has been removed by the thinning. Final felling is simulated by moving the area back to the first volume and age class of the matrix from where it can start growing again. The volume originally present at this area is the volume removed during final felling.

Harvest regimes are specified at two levels in the model. First, a basic management regime per forest type and country defines the age range during which thinnings can take place and a minimum age for final fellings. These regimes can be regarded as constraints on the total harvest level. Multiplication of the area available for thinnings and final fellings with the corresponding wood harvest gives the amount of wood that is theoretically available for harvesting. In the second step, the actual demand for wood is specified for thinnings and for final felling separately at the national level. The model calculates which share of the available potential needs to be harvested to satisfy the demand and implements this calculated intensity in the simulation.

EFISCEN is a rather versatile European forest resource model providing detailed insights down to NUTS2 level and up to European scale. It has been applied in studies concerning impacts of management changes [Nabuurs et al 2007], or to include impacts of climate change and its resulting carbon balance [Karjalainen et al 2001; Nabuus et al 2002]. Later on also for upscaling effects of natural disturbances and impacts of adaptive management [Schelhaas et al 2015] or for wood availability and trade-offs with biodiversity [Verkerk 2015]. The model's latest version is documented in [Verkerk et al 2017]. EFISCEN was used to simulate forest management reference level for eleven european countries members of the UE in 2011 ().

2.1.3. Input data into the models

As empiric models, CBM-CFS3 and EFISCEN 4.2 need a limited number of input parameters, which are usually either directly resulted from measurements or pre-processed in a specific way (Table 1).

Table 1. Overview on the input requirements of current versions of the models.

Parameters	**CBM-CFS** (Kurz et al, 2009, Li et al 2003; Boudewyn et al 2007)	**EFISCEN** (Schelhaas et al, 2007; Verkerk et al, 2017)
Land representation	Initialization and simulations are organized in user defined strata resulted from combination of max. ten classifiers. Each classifier may have a non-specified number of strata.	Forest land and land use changes as deforestation and afforestation, further distributed on administrative regions, owner classes, site index and tree species.
Land area at the start of simulation	Input of area on age-class of 5, 10 or 20 years. Initialization assuming a uniform distribution of area within the age-class (i.e. equal area attached to one-year step age).	State of the forest for each forest type is depicted as an area distribution over the age class and equal volume classes (a matrix model). Initial input matrices require pre-processing by specific tool (P-EFSOS).
Land area for land use changes	Deforested area can be subtracted at any time step, randomly or according to pre-defined criteria (e.g. forest type, etc). New forest land can be added at any time step or age of new stands. Conversions from and to forest can be tracked for a period of 20 years.	Deforestation can only occur from bare forest land class (implicit assumption that mature standing stock is harvested). In a symmetric way, afforestation occurs on additional area of bare land moving into the first age class and taking up the growth functions of that forest type.

Standing volume curve	Age-class dependent under-bark standing growing stock (merchantable) volume (i.e. yield table) required. Curve model to fit the available data is chosen by the user. Age-class can be 5, 10 or 20 years.	The actual values of standing merchantable volume over-bark are extracted from forest inventory. Within one age class the inventory volume is split into maximum ten volume classes to represent the natural variation and allowing the thinning effect to be simulated.
Net annual volume increment	Defined as gross increment (of living trees) minus mortality from self-thinning. It is required as age class-dependent cumulated curve of under-bark merchantable volume net increment. Fitting model chosen by the user. Age-class can be 5, 10 or 20 years. A growth multiplier can be applied to account for post-disturbance growth boost.	Growth dynamics are incorporated as five year net annual increment as a percentage of the growing stock (Schelaas et. al, ….). Thinning results in a user defined 'growth boost' (as an additional growth occurring after thinning). The coefficients for the growth functions are derived from inventory data or alternatively from yield tables.
Ingrowth and sub-merchantable trees	Stemwood biomass for non-merchantable and sapling size trees can be added by expansion factors to over-bark merchantable stem wood (e.g. estimated from latest available forest inventory data) via a curve-smoothing algorithm.	Ingrowth is not included. Volume of sub-merchantable trees can be thinned.
Specification of management interventions	Thinning at any intensity of intervention, final cut(s) may include shelter-wood systems (2-3 interventions).	Very detailed management regimes per forest type, country, owner, and age class.
Wood removals/ harvest/management interventions	Management interventions defined by targets, eventually constrained by one to multiple combined criteria. Target can include collecting dead wood. The targets are defined as C amount in over-bark standing merchantable volume, or area, or proportion from available volume subject to an intervention (or combination amongst). It applies merchantability criteria associated to administrative boundaries classifier, i.e. proportion of non-commercial components (tops and stump in total stemwood left on site). CBM allows tracking separately the volume from deforestation or afforestation.	The total amount of roundwood to be removed (demanded) from the forest is specified. Removals can be defined for the total country, or by region, owner, site class and, or tree species for each time step and age class, separately for thinning and final felling. Units are 1,000 m3 overbark per 5 years. This total demand is then met by the harvest as allowed by the management regimes per forest type.
Volume to biomass conversion and expansion procedures	Conversion of merchantable volume-to-stemwood biomass requires the two parameters of their exponential relation. Bark, branches and foliage biomass are derived as relative to stemwood biomass from merchantable volume (see Boudewyn et al., 2007). C stock in fine and coarse roots according to general equations for softwood and hardwood species (Li et al. (2003).	Age-class dependent Biomass Expansion Factors (BEFs) are required per tree species, to compile the non-commercial biomass compartments and to allocate them over living biomass or litter layers in the forest. After harvest, removal of (part of the) slash and pre-commercial wood can be defined to supply biomass for bioenergy. This has impacts on the soils C
Natural disturbances	Any type of natural disturbance (no matter the intensity*) can be implemented via user specified disturbance matrix attached to concerned time step and type. Disturbance matrix allows disturbance-specific transfers among the pools. No multiple disturbances are implemented in a year unless their cumulated effect is accounted in the disturbance matrix.	Natural disturbances are not included in current version (although a separate version has been developed).
Representation of natural processes	Turnovers are defined for five biomass pools run individually by the model (merchantable stemwood, otherwood, foliage, coarse and fine roots). Harvesting residues defined by merchantability criteria. Annual mortality rate is defined on climatic zones for merchantable	Mortality rate is defined as part of standing volume of living biomass, depending on management, density). Part of the thinned parcels are not subject to natural mortality.

	stemwood and branches, by a constant value along the simulation.	
Forests composition dynamics	Transitions between various tree species, e.g. species composition change, or growth patterns as post-disturbance events, i.e. increment shift, can be implemented at any age of the stands.	Transitions between tree species can be simulated via conversion after final felling.
Information needed for initialization of standing volume	Initial standing biomass attached user defined strata is derived from yield curve assuming one year age distribution.	Estimates directly derived from National Forest Inventory per forest type on diameter (classes), standing volume, increment, age class division both in ha and in m^3 standing volume per time step 5 years.
Soil (submodule)	Own decomposition model. Dead organic matter and mineral soils pools are initialized (time step "0") assuming non-equilibrium conditions, i.e. considering historical natural disturbance over past 2000 years (by default fire) and most-recent stand-replacing disturbance until less than 1% change of the aggregate amount of litter, dead wood and soil organic matter occurs in successive iterations. Temperature-dependent decay rates are defined on climatic zones.	Incorporates Yasso07 model (Liski et al., 2005) which simulates four C pools in the mineral soils. Yasso implies an equilibrium of carbon in mineral soil without management or natural disturbances. Natural mortality (as share of standing volume), felling rate of standing dead trees, remaining felling residues and litter fall rates are used as input into the soil module.
Time management	Runs 1-year time step. A "delay" until regeneration start is possible for initialization consistent with post-harvest regeneration delay.	Runs 5-year time step.
* CBM own database provides some 300 disturbance matrixes in its AIDB which can be used as a proxy for running various natural and anthropogenic disturbance events, that can be tailored by local/national data		

2.1.4 Romanian National Forest Inventory (NFI) data

Data on state of the forest attached to initial year 2010, the mid-year of the first cycle of the statistical sampling based national forest inventory (NFI1, www.roifn.ro), is used as input into the models. User defined strata consist in ten major forest types distributed on across seven NUTS-2 administrative units and five climatic regions. Association of forest types to climatic regions is based on Pilli (2012). Forest state parameters (Table 2) are available for age-class of 10 years (e.g. age-class 1 is 0 to 9 years old, age-class 2 is 10 to 19 years old, etc.).

Table 2. Overview of forest state parameters attached to initial year of the simulation 2010, as mid-year NFI1 (aggregated values at national level, with sampling error for 95% confidence interval of the mean)

Forest state parameter and unit	***Nationally aggregated value***	***Comments***
Forest type area (ha)	6072260±2.199%, split on ten forest types: Other broadleaved (2303052); Beech (914359); Spruce (composition >90% spruce, 674483); Coniferous and broadleaved mixed forests (< 70% coniferous or broadleaves, 527284); Oaks (505508); Predominantly coniferous (70-90% coniferous, 364980); Predominantly broadleaved (70-90% broadleaves, 330923); Other coniferous (318365); black locust (123069); Fir (10245)	Only "forest available for wood supply (FAWS)"
Standing stock volume (m3)	NFI1: 2,051,190,828 ±2.772% NFI2:	Volume of entire aboveground woody biomass
Annual net volume increment (m3/ha/yr)	8,17 ±1.236%, split on forest type: …..	Annual volume increment of entire aboveground woody biomass, excluding mortality

Dead wood stock (mil. m3)	Standing DW (53,5 ±5.862%), laying DW (68,2 ±5.377%)	Standing (snags) and laying dead wood
Annual mortality rate (m3/ha/yr)	0.96 ±4.681%	Preliminary, according to 2nd cycle of IFN
Harvest (m3/year)	Fellings (11979242 ±10.121%); Thinnings (16236703); Total harvest (28215945)	Average annual extraction of living trees. Amounts resulted from raw split on thinning and felling based on age from technical norms (e.g. early fellings may be misallocated as thinning)

2.1.5 Harmonization of input data

Effort was focussed to ensure input data is as consistent as possible. Expert assumptions are involved substantially. NFI's aboveground woody volume was first converted to merchantable volume (for EFISCEN) and to under-bark stemwood biomass (for CBM-CFS2). Conversions involved exclusion of the bark and branches volume based on their proportion from Giurgiu et al. (1972) and wood density (Mos et al., 1972). Under missing national data, foliage share was assumed equal to values of corresponding genus in CBM-CFS library (namely, numerator of $p_{foliage}$ ratio incorporated in CBM-CFS's original AIDB). Harmonization of share of biomass compartments in the standing biomass consisting in averaging percentages within each age class (for EFISCEN) and fit Boudewyn et al.(2007) equation (for CBM-CFS3). Other parameters were harmonized as well (Table 3):

Table 3. Harmonization of other parameters on forest status used as inputs

Parameter	**CBM-CFS3**	**EFISCEN** (* - expert estimation)
Regeneration (i.e. post-harvesting period when no biomass growth was applied)	Two years delay	Regeneration is modelled via a 'young forest coefficient': 0.75: about 75% of the forest is immediately regenerated, while 25% remains bare land, thus two 95% is regenerated in years' time.
Regrowth after thinning, extra boost (gamma)	Not applied	Growth boost coefficient defining the proportion of thinned area that is moved up one extra volume-class. Default is 0.4, which means that 40% of the thinned area is moving up one extra volume class, while 60% remains in the same volume class.
Avoid matrix diversion (beta)	Not applicable	Transition chances, and thus increment, in high volume classes are changing, together with the thinning boost in thinned stands. With a beta factor Default of 0.4, i.e., increment increases only for the lower volume classes (40%), while the absolute increment remains constant in the upper volume classes (60%).
Deforestation	570 ha per year	Defined per time step of 5 years, i.e. five times 570 ha
Annual national harvest (23.2 million m^3 merchantable volume, over-bark). Assumed constant in time.	Annually, disaggregated on intervention type and forest types according to NFI1 reported shares.	Distributed over total thinning and total final felling per time step of 5 years, i.e. 116 million m^3 per time step. No distinction on forest types.
Thinning history	Minimum 5 years since last intervention	EFISCEN default: 20% of area in a year. 20 % proportion of area is not available for thinning in the initial year (2010), assuming recent thinning.
Annual turnover for merchantable stemwood, i.e. results in the transfer from standing merchantable wood to standing dead wood, incl. bark), (% of standing biomass yr−1)	0.3%	0.149% per time step of 5 years (assuming a cumulative effect of 0.3% per annum)
Annual dead wood decay rate, i.e. litterfall transfer of	27.5%	80% per time step of 5 years (assuming a cumulative effect of 27.5% per annum)

standing dead wood to litter pool (% mortality yr−1)		
Annual turnover for branches (% of branch biomass yr−1)	1.15%	As of CBM-CFS default values for softwood and hardwood species
Annual dead wood decay rate, i.e. litterfall transfer of branch snags to litter pool (% of dead wood snags yr−1)	10%	As of CBM-CFS default values for softwood and hardwood species

2.2 Simulation of additional scenarios to assess models' behaviour in particular circumstances

Additional to reference scenario which is running business as usual (BAU) assumptions (defined in Table 2 and 3, i.e. exclude natural disturbances and include deforestation), three additional scenarios are selected to highlight model behaviour under circumstances where models are known as implying different approaches (as highlighted in table 1), as follows:

- **A.** Detailed harvest to EFISCEN (using multiple criteria: target amount, time step, forest type, intervention intensity and age range when it is applied) and aggregated harvest to CBM (the same as for EFISCEN with exception of forest type);
- **B.** **No deforestation** in order to assess the underestimation of annual sink, i.e. assuming only land from age class zero is subject to deforestation by CBM and how area is managed in time;
- **C.** **Natural disturbance regime scenario** running windfall as the most prominent natural disturbance in Romanian forest (additional to deforestation). Available windblown volume over time series 1988-2010 is repeatedly implemented in the same sequence until the end of simulated period. Features of windblown are: a) there was an event every single year; b) minimum annual amount blown down was 73 th.m3, 85 times less than the maximum amount recorded; c) there were two years with amounts higher than 6 000 th.m3 (i.e. 22 % of annual harvest reported for 2010). The assumption is 55% of merchantable is salvaged (experts elicitation).
- **D.** CBM-CFS3's **sensitivity to initialization of standing merchantable volume in the initial year of the simulation (**±15% variation of standing stock volume vs. reference).

2.3 Identify corresponding output parameters and ensure comparability of outputs

To ensure comparability between models ouput, e.g. on pools, a post-processing toward harmonization of outputs was achieved. On top of this, because of predefined queries in the CBM result explorer user-interface (i.e. query limited to one combination of classifiers at once), we performed some post-processing by querying in the "results" database to extract simultaneous results across any combinations of classifiers, rather than using the interface. Own queries were confirmed against corresponding SQL clauses in the standard interface. This consisted in weighting and averaging data at the user defined strata. Further on, a the back-conversion from C amount to volume was done by the inverse of volume-to-biomass equations (Roberto, is there any reference here?). For enhanced comparability of the outputs, CBM-CFS3 results were averaged over 5 years, e.g. assuming average of steps 1 to 5 from CBM to correspond step 5 from EFISCEN.

2.4 Identification of discrepancies in inputs and outputs, including any feasible calibration

Two models have different approaches of data aggregation and processing. In CBM initialization of 2010 is based on empirical standing volume curves generated from NFI1 data averaged at regional scale on forest types and age-class (as far as plot data is not available). Purpose of the calibration was to simulate an initial standing stock volume within the NFI1 confidence interval of 2.2% at aggregated level and ± 15% on forest types (error assumed by Romanian Yield tables ????). This was achieved by fitting Chapman-Richards model to area-weighted data (originally un-weighted). Furthermore, biomass turnover for dead wood (mortality rate) and dead wood decay (litterfall rate) were calibrated against NFI data by trial and error. Allocation of biomass in relation to merchantable volume was re-checked based on Boudewyn dynamic model.

2.5 Analysis of (dis)agreements between models' outputs and validation.

Checks regarded: a) simulated values for initialization against NFI1 data; b) Basic indicators are used to test whether the models can be considered calibrated, like: relative difference between simulated data (having CBM-CFS as reference, in alphabetical order), and Bland Altman agreement (Bland, J.M. and Altman, D., 1986. Statistical methods for assessing agreement between two methods of clinical measurement. The lancet, 327(8476), pp.307-310) as well as correlations (e.g. between percent difference in predicted biomass (2010-2060) vs. percent differences between harvesting/mortality (2010-2060), Simulated values of forest status or C stock parameters for future years, i.e. 2060, are compared against original input data (for 2010). Mean Bias Error (MBE) and the Coefficient of variation of the Root Mean Square Error (Cv(RMSE)) can be used, despite small pool.) and c) conservation of area (e.g. accounting deforestation) in time.

5. Results

5.1 Simulation of forest status dynamics for reference scenario.

A1.1 Dynamics of age class distribution on area.

Total area and area on forest types dynamics, considering deforested area, is consistent by both models over the simulated period. Both models simulate a skewed distribution of area in older age-class compared to initial state when skewed toward younger ones (Figure 1), i.e. 15% more area is allocated by CBM-CFS in the oldest age-class.

For the start year of the simulation, i.e. 2010, simulated age class distribution on areas by CBM appears to be slightly different from the input data, i.e. between 6% underestimation for 1st age class of 20 years (i.e. 0-19 years) and 11% overestimation of age class 7th age class (120-139 years).

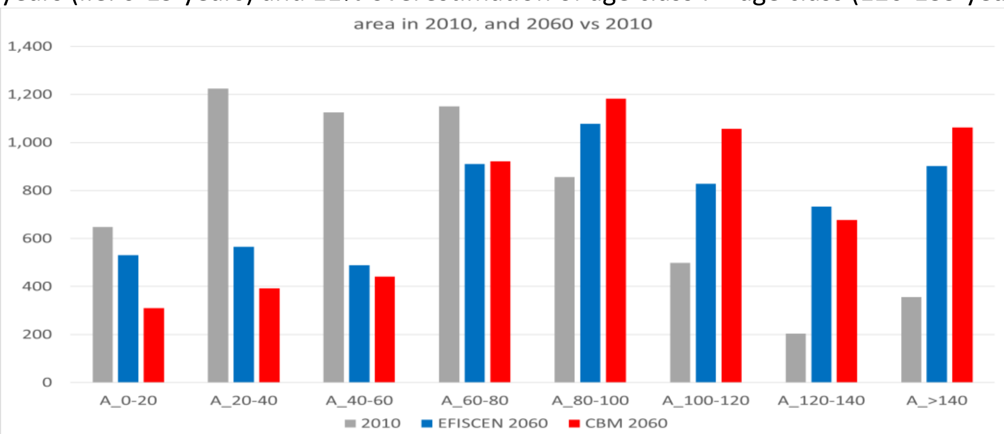


Figure 1. Distribution of area on age classes (for all forest types) in 2010 and for 2060 as simulated by CBM-CFS (red) and EFISCEN (blue), in 1,000 ha

The two models run quite similar area on age class in time (figure 2).

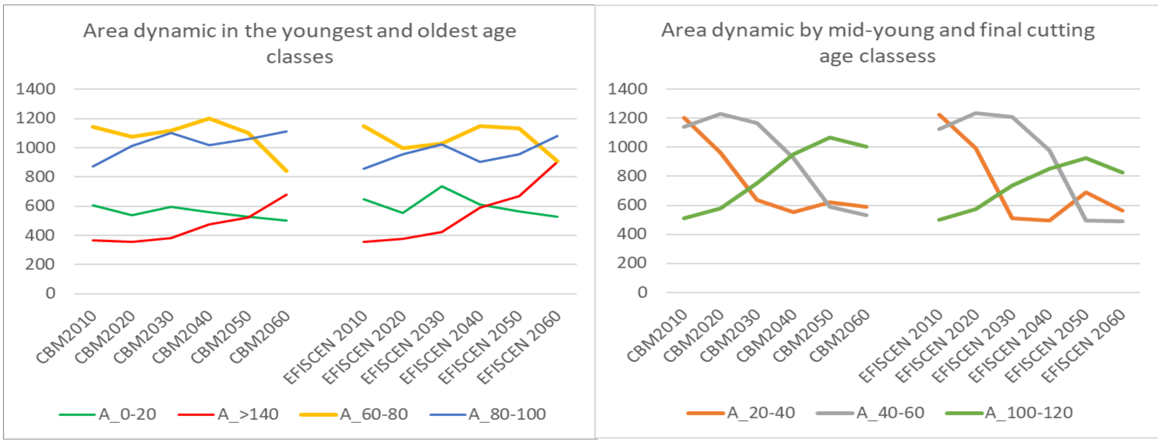


Figure 2. Simulated total area dynamics on age-class: left side for youngest and oldest age classes, and right side for mid-young and final fellings corresponding age-class

A1.2 Dynamics of the volume of standing stock. CBM-CFS3 allows estimation of growing stock volume (including merchantable and its bark) on user defined strata based on time step, and not on age-class. Simulations by two models are quite consistent (Figure 3).

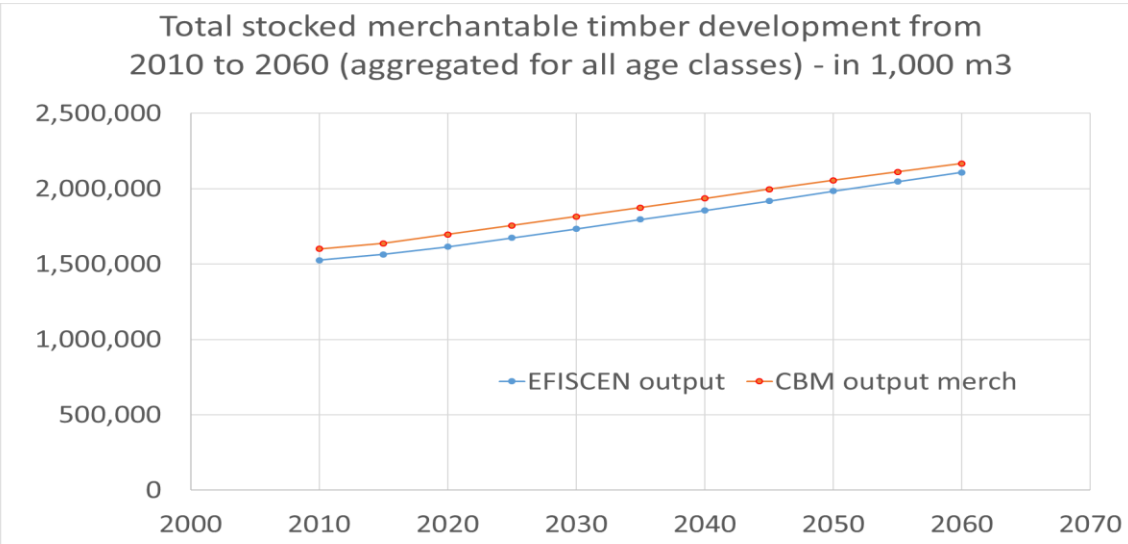


Figure 3. Total standing stock of merchantable timber development from 2010 to 2060 (aggregated) - in 1,000 m3

The apparent systematic difference seems linked to CBM-CFS3 initialization which resulted in 4.9% higher estimate for 2010 than the input values provided from NFI1 and EFISCEN (which uses exactly the NFI1 estimates for each user defined strata as initial values). On forest types, initial value resulted from the CBM-CFS initialization ranges from 17% overestimation for mixed forests to 25% underestimation for black locust forest. Nevertheless, initial values for major forest types were initialized within a range of ± 20% of NFI input data.

A3. Annual net increment of volume of the merchantable standing stock. CBM allows a derivation of the net increment of the merchantable volume as the net change between consecutive years of the C stocks in the standing merchantable pool to which the annual amount of harvest was added. Annual mortality is implicitly taken into consideration by the difference living biomass stocks of consecutive years. Question: Net change between consecutive years is correct since area is changing every year with deforestation -this may create some underestimation of actual increment – is it better to extract NAI from fluxes in the year (where for CBM BEF should be applied to extract only merh.?). On time steps, EFISCEN simulates values within a range from +4.6% to +16.9% higher compared to CBM-CFS

(Figure 6) while both show decrease toward the end of simulated period (rather consistent with increasing share of old-age stands area).

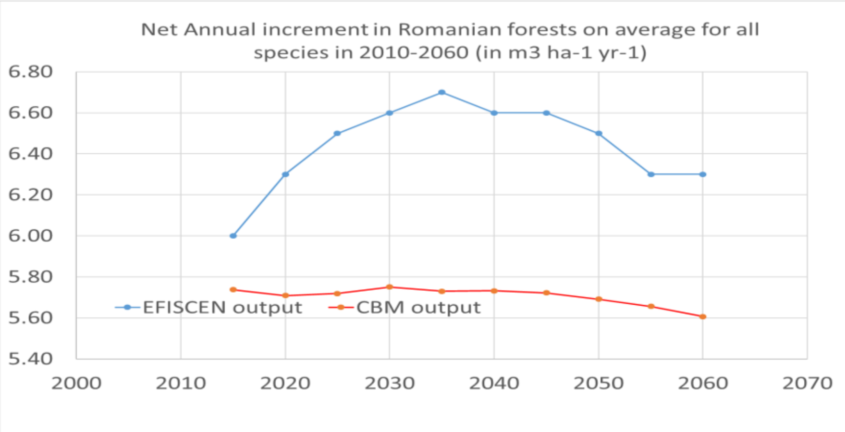


Figure 6. Net Annual increment dynamics, as average for all forest types (in m3 ha-1 yr-1)

Data pre-processing procedure attached to CBM-CFS3 approach lead to an overestimation of the annual net increment for initial year by 77% for black-locust and an underestimation by 35 % for Fagus sylvatica. For major forest types, CBM-CFS3 estimates it within ±22%.

A4. Harvest allocation. Under reference scenario, a constant harvest equal to NFI1 representing around 57% of the annual growth is applied along 2010-2060. Both models satisfy harvest better in the first half of the simulated period (>98% of demand). CBM excludes harvest associated to deforestation which explains slightly smaller total amounts achieved. Performance on long term is most likely explained by larger area available under older age class, e.g. CBM performs better due to a better achievement of fellings related amount, while volume extracted by thinning is fully achieved by both models. EFISCEN goes to almost 28% underachievement of final fellings in 2060. Thus, underachievement is first caused by availability of biomass to be harvested defined by the constraints as harvesting criteria, less criteria better (Figure 7).

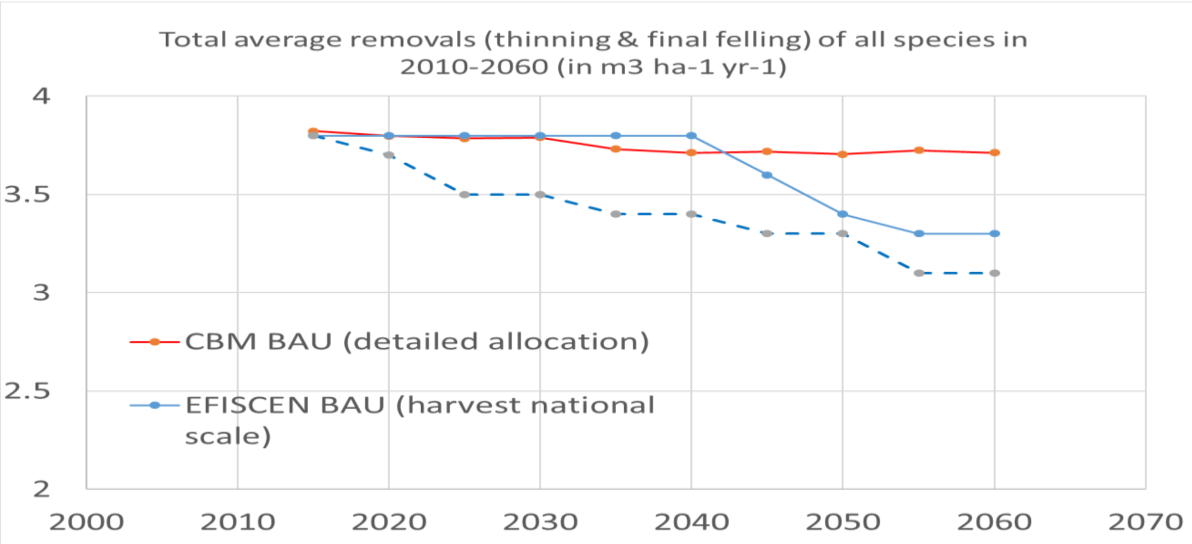


Figure 7. Merchantable wood harvesting achievement

A1.3 ***Dynamics of annual mortality and standing dead wood stock***. Both models consistently report both an increasing trend of mortality rate (i.e. equal to turnover of the merchantable standing stock) and increasing stock of standing dead wood (CBM also provides branch mortality, should I include it here ?) (Figure 4). Difference between simulations stays rather constant in time, as linked to dynamic of an increasing growing stock. In average, annual mortality rate for other woody components of the growing stock (e.g. branches, tops) simulated by CBM is around 80% of the mortality rate of merchantable wood for broadleaved based forest types and as high as some 150% for coniferous. For initial year CBM predicts values sensibly equal to measured ones (Table 4), unlike EFISCEN which simulates mortality rates of one order of magnitude higher. There are notable differences regarding standing dead wood amount for the base year (or it is a step issue?).

Table 4. Mortality rates and amount of dead wood

Indicator	CBM-CFS	EFISCEN	IFN1
Annual mortality rate (m3 ha-1 yr-1)	1.12	2.49	1.12
Standing dead wood amount (m3)	3.12	3.11	8.81???

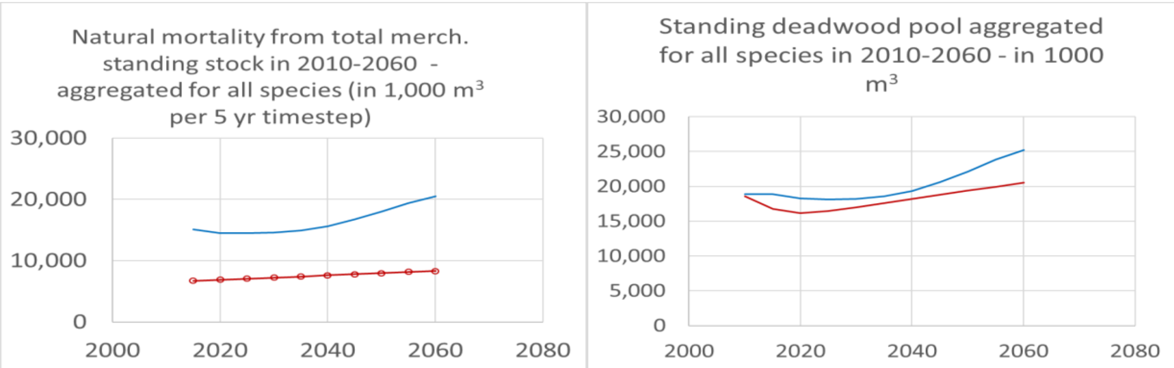


Figure 4. Dynamics of annual mortality rate (left side, in 1,000 m^3 per 5 year timestep) and standing deadwood pool (right side, in 1000 m3), aggregated for all species at national level

5.2 Simulation of Carbon dynamics for reference scenario

B1. C stock in standing living biomass pool, i.e. including all biomass components: stem, leaves, branches, coarse roots and fine roots, is initially 10 % and increasing to 14% higher in CBM than EFISCEN, consistent with volume estimates along 2010-2050. Annual change of C stock in time stays sensibly constant to around 3-4% for both models, with a total increase in 2050 vs. 2010 of some 38% (Figure 8). The difference between CBM and EFISCEN is very likely the explained by inherent un-match of BEFs and root biomass.

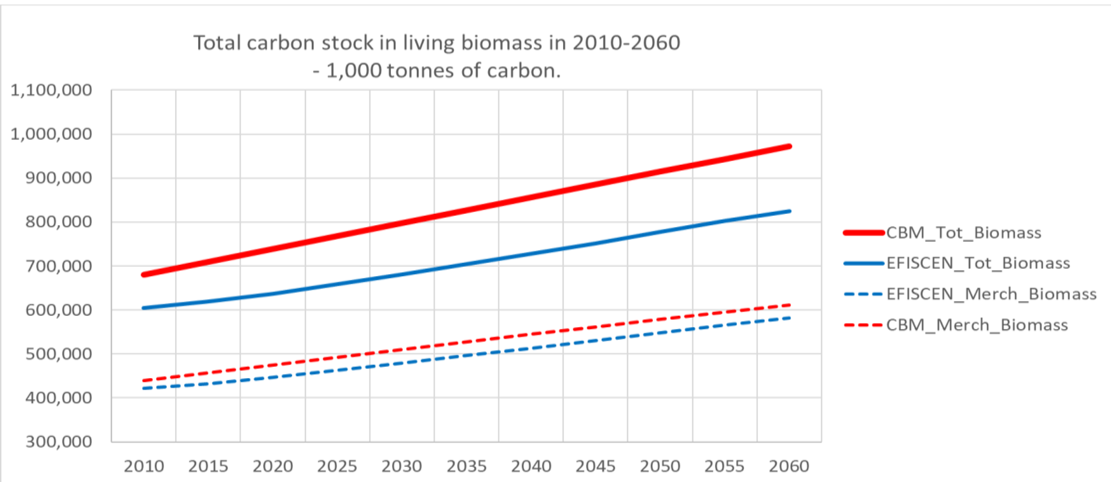


Figure 8. C stocks in standing living biomass and merchantable pool

Share of merchantable stock in total standing living biomass is in average 66% for CBM and 70% for EFISCEN. Share of various biomass components slightly increases or decreases from the initialization. (Table 5).

Table 5 Share of C stocks in various components of total Living biomass pool (aggregated for all species)

Model	Time step	Merchantable (over- bark)	Other Wood	Foliage	Roots
CBM	0	66%	16%	1%	17%
	50	65%	20%	1%	15%
EFISCEN	0				
	50				

B2.1 Annual net change in C stock of the standing merchantable biomass
Both models implement consistent solutions to account deforested area in time, i.e. considering area changes in time?. Change follows general pattern of the net annual increment (see figure 6). Under assumption of constant harvest level, it is significantly different in the early stages of the simulation while there is a converges later (i.e. Figure 10).

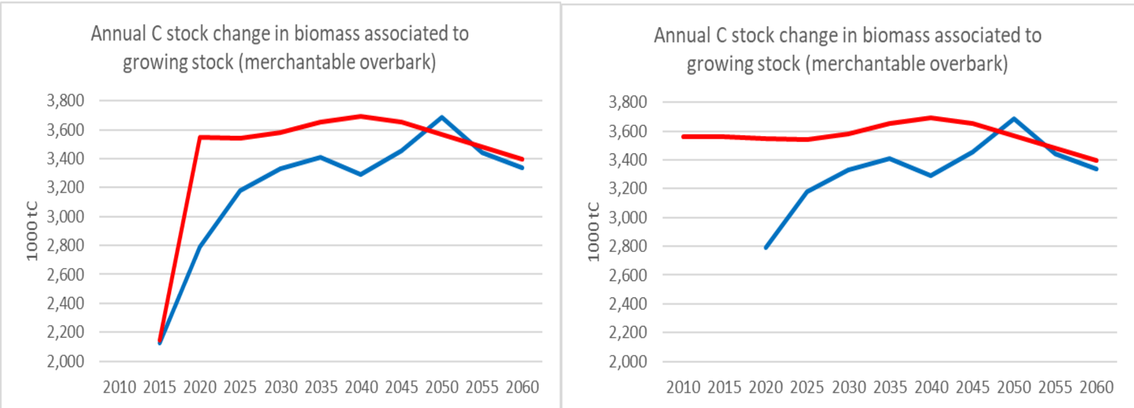


Figure 10. Annual C stock change aggregated for all species across

B3. CO2 removals by total standing living biomass pool including all biomass components: stem, leaves, branches, coarse roots and fine roots. In average, EFISCEN simulates an average of 17. Mil t CO2 per year, while CBM of 21. Mil. tCO2 per year (Figure 11). CBM apparently projects larger contribution of non-merchantable components, e.g. from branches, foliage and roots biomass. In CBM branches share increase from 16% in 2010 to 21% in 2050 which may explain the difference (Table 5).

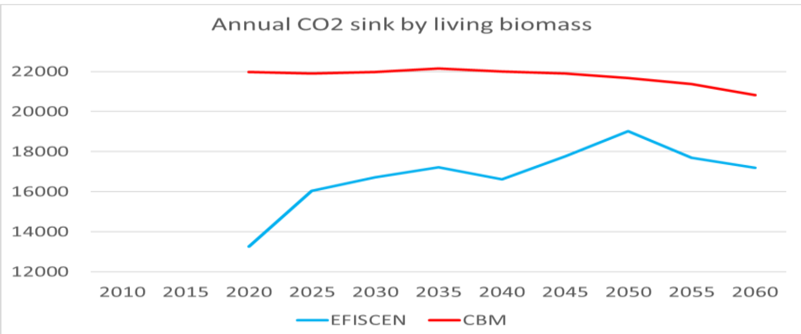


Figure 11. CO2 removals by CBM (right side axis) and EFISCEN (lest side axis)

B2. C stock in dead wood pool shows maximum ±10% difference between two models, also showing a consistent trend, i.e. slightly increasing in time from 5 to 7 mil. tC (Figure 12). Both models show a drop in the first simulated decade, in CBM there is a post-initialization drop of some 10% of the initialized stock which is apparently caused by an overestimation of initialized value.

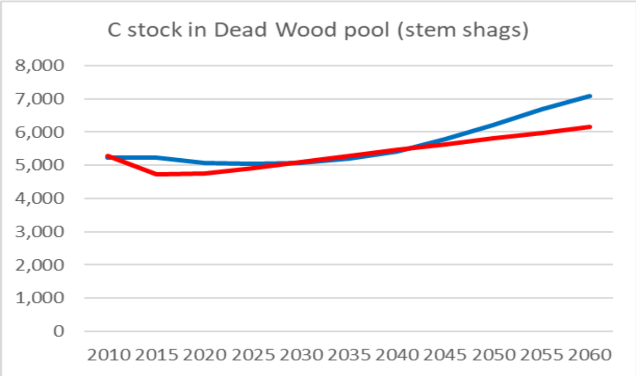


Figure 12. Dynamic of C stock in dead wood pool by the two models

In the initial year, EFISCEN reports no C while CBM-CFS apparently overestimates this pool what explains significant loss for the first 10 years immediately after simulation starts (Figure 13).

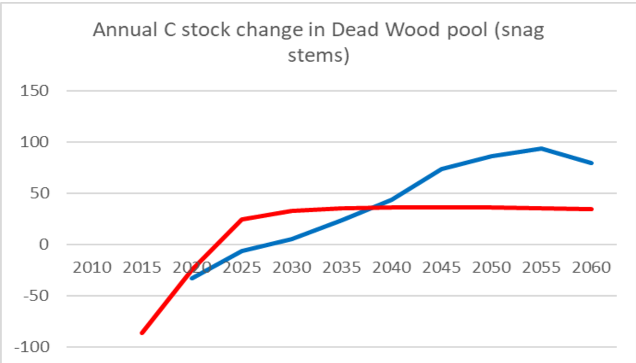


Figure 13. Dynamic of annual C stock change in dead wood pool by the two models.

Results of other scenarios

Land use changes: simulation of deforestation. Both models perform consistent decrease of total forest area following scheduled deforestation. In the spirit of LULUCF GHG reporting, CBM reports detailed information on deforestation, e.g. both area, C stock changes and non-CO2 emissions, unlike EFISCEN which assumes deforestation takes place on bare land (i.e. with no carbon stocks in any pool). CBM distributes deforestation on forest types approximatively proportionally with area of forest types, i.e. less represented forest types may not suffer any area loss by deforestation (i.e. if forest type area < 2% of total area). EFISCEN applies proportional loss of area across all forest types in any year.

Degree of detail of harvesting criteria. Free allocation of harvest (i.e. only defining the annual amount on intervention type) resulted in achieving the required amount only from some type of forests in case of CBM in the early period simulated.

CBM-CFS3's sensitivity to initialization. A sensitivity of CBM to ± 15% variation of standing volume curves used for initialization results in shifts of the area distribution in 2060, affecting both youngest and oldest age-classes, i.e. under constant final felling harvest in time, a smaller initial standing stock (-15 % of BAU) reduces the area of older age class and increases it over youngest ones (Figure 14).

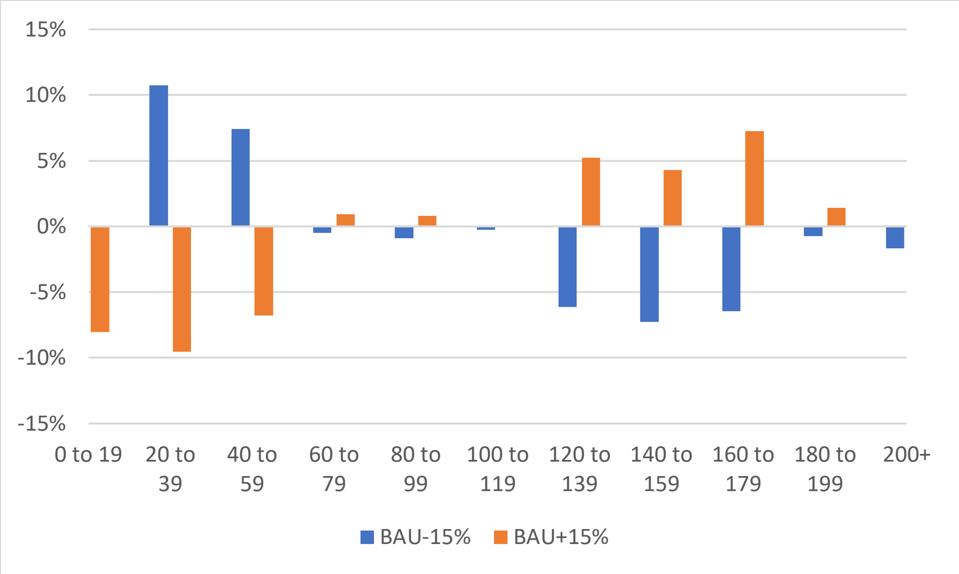


Figure 14. Deviation of area on age class in 2060 caused by deviation of ± 15% of the initial standing volume compared to exact initial value

Simulation by CBM of realistic pattern and intensity of major natural disturbance resulted in significant impact on age-class distribution over 50 simulated years, i.e. 16% more land in first two age classes in 2060. Aggregated DW stock is always higher under ND scenario, i.e. higher for forest types affected by windfall. Annual change in DW stock varies within ± 33 % for no disturbance scenario and ± 462% when natural disturbance are accounted for. Largest annual changes simulated are 0.8 mil. mc input into, and 0.4 mil. mc output from DW pool (they are both half under no disturbance scenario).

Table 6 Dry test runs to check the applicability of different scenarios for CBM and EFISCEN

	Reference		**No deforestation**		**Natural disturbances regime**		**Free harvest allocation**	
	CBM	**EFISCEN**	**CBM**	EFISCEN	CBM	EFISCEN	CBM	EFISCEN
Total standing volume in mln m^3								
2010	1601	**1526**	1601		1601		1601	
2060	2166	**2108**	2170		2134		2121	
Increment per ha								
2015	5.74	**6.00**	5.74		5.70		5.76	
2060	5.61	**6.30**	5.61		5.58		5.54	
Annual sink estimate (mil. tCO2)								
2015	21979		21980		21336		21966	
2060	20833		20912		19929		19577	

6. Discussions & consistency check

Both models give plausible results for run period of 50 years for stock, increment, mortality, thinning, final felling, regeneration.

Current version of CBM only allows exploring the results on age classes of 20 years, while EFISCEN is versatile.

The two models follow different concepts: EFISCEN focusses on typical forest parameters (e.g. standing volume, annual net increment, areas) with additional outputs on C stocks and changes, while CBM-CFS focuses on the dynamic of C stocks and changes on time steps. Current CBM version owns a minimal flexibility in the management of age class distribution in the output. Its “result” output is inflexibly organized on age-class of 20 years, so any try to split on age class of 10 years may be very approximate based on some age-averaged indicators provided as default output (i.e. this may result in a counter-factual inconsistency in the CBM output files area for the initial year 2010). For this reason, this analysis is mostly organized on time steps (corresponding to calendar years, i.e. GHG inventory reporting approach), rather than on age-class (i.e. forestry data approach).

Calibration of LB and DW in the base year 2010. While areas seem about right, there is large difference in standing merchantable volume in 2010, which seems to become systematic across entire simulated period (figure 2). While EFISCEN uses exactly the point estimates of standing volume from forest inventory database as initial value, CBM performs an initialization based on user-defined standing merchantable volume curve associated to each user defined strata. This leads to different value than the actual estimate provided from forest inventory pool. Zamolodchikov et al. (2013) found a larger 6% CBM-CFS3 estimate for the pool of phytomass and 10% smaller for soil. Kim et al. (2016) apparently has a perfect match of the initial value for standing biomass. Deviation from measured value occur when statistical models used to fit measured data and input data are different or raw estimates are combined with fitted curve.

[Is there any bias in the initialization? Is initialization of EFISCEN a unique solution? Coherence of tree biomass components between input and output to be checked [output volume on age class of 20 years vs. input].

[Measurements show significant amount of C is stored as DOM (i.e in initial year some 5.8% of the total growing stock) and also large amounts of woody biomass are annual transferred from living woody biomass pools (1.7% of the total growing stock)]

Comparison of forest status parameters simulated requires post-processing of CBM results. For this C stock and fluxes estimates were converted back to volume in a way consistent with conversions from biomass to volume (e.g. using the same two parameters of the exponential equation after conversion of the result to 1ha), on most detailed user defined strata (so to weighted effect of area contribution).

Consistency of growth and yield curves are the responsibility of inputs procedure in CBM, while for EFISCEN are linked. Increment in thinning vs. no-thinned stands.

While parameters related to C stock dynamics in total biomass pool and emissions/removals to atm are available, the net annual increment of merchantable biomass needs post-processing of CBM output. For all forest types there is lower value resulted by CBM quite consistent with less build-up of the standing C stock for merchantable wood (figure 6).

Rigorous allocation of final harvest distorts long term area dynamics on age class and projected harvest may be unsatisfied. IN CBM, a free allocation by only mentioning the disturbance type and age when that applies without mentioning the forest types results in unrealistic allocation (e.g. some forest types may not be harvested at all) and overharvesting some forest types, although the total harvest demand is observed. Harvest calibration…..

Method used here to estimate the NAI is affected by the harvest uncertainty of 10.2% (Table 3)

National strategy of forest management. Both models signal accumulation of old stands assuming current harvesting of rate of ….. % of annual increment, i.e. 15% of forest are over 14-years old and 41% of stands are above 100 years old. …. annual increment national forest production fund.

Different concept of allocation of deforestation may not have practical effects when small D areas. In EFISCEN deforestation always occur on bare land from clear cut available in post-harvesting, which may affect the projection on long run especially in areas with high deforestation (e.g. at regional scale due to development).

Gross growth derived from latest NFI is provided as a proxy for "yield table", i.e. cumulated increment throughout the stand life. This reflects the actual standing stock volume rather than an actual table (assuming pure species and full stocked volume which is not the case of shelterwood systems, e.g. applied in case of all broadleaved based forest in Romania).

Annual increment is difficult to validate?

While transparency on methods incorporated is ensured by numerous publications and direct assistance and training programs, actual pre-processing of input data need specific knowledge and skills (e.g. in CBM parametrization with local data of biomass allocation requires advanced statistical knowledge). Same for EFISCEN for volume allocation in initial year. For example, EFISCEN implements a "correction procedure" for "increment" based on its proportion to "standing stock", CBM-CFS assumes these two parameters are independent leaving their consistency in hands of pre-processing operation. Note RS: what do you mean with this statement?

Consistency checks are done before actual calibration of some parameters. Fact is that both models can be feed with consistent data. Reddy et al. [17] claims that "calibration is highly dependent on the personal judgment of the analyst doing the calibration". Statistical indices are the most used criteria for evaluating the accuracy of calibration and whether a model should be considered calibrated.

Model's sensitivity to parametrization was assessed for mortality rate and dead wood snags decay rate (transfer to litter). Validation vs. actual data from NFI was used as benchmark.

In CBM mortality is not age dependent but one global value for any age. Also in EFSCEN the mortality is assumed to be age independent share of living biomass stock (see table XX).

7. Conclusions and recommendations

Fit of original data may create need for further calibration (based on comparison of input and output for start year), which is not the case in EFISCEN which uses point estimates as input. Any inconsistent input generates over/underestimation of C stock and a long term impact in simulation by CBM.

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Anexa 3. Title: Assessing carbon stock changes matched to land use and land-use change under climate frameworks (Draft)

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Keywords: National forest inventory, sampling design, carbon stocks, model-dependent inference, UNFCCC, LULUCF , KP

Introduction

Land is a limited resource and knowledge about land use and land-use change is important. For example, land-use change is assumed correlated with large GHG emissions (e.g. Houghton et Hackler 2001, Foley et al. 2005, Le Quéré et al. 2011).Under climate frameworks for Annex I Parties (e.g. (UNFCCC 2013; IPCC 2006), changes in carbon pools (living biomass, dead wood, litter, soil organic carbon and harvested wood products) should be matched to land use and land-use change and traced back in time. The United Nations Framework Convention on Climate Change (UNFCCC) requires such reporting for at least 36 land-use categories (IPCC 2006). The KP uses a similar approach but is an accounting model that accumulates land use categories into activities (Höhne, Niklas, et al. 2007). The EU-regulation is built on the same models [6]. For all three reporting frameworks, a land-use change matrix is required that could trace both gross and net land use changes. Specific climate policy requirements focus on data quality and "Annex I Parties shall quantitatively estimate the uncertainty of the data used" (24/CP.19).

Land cover probably correlates with land use but the land cover may change without changing the land use. On the other hand, land use may change if the predominant land use changes without major changes in land cover. A young forest may look very different from an old one, but the land use is "Forest land". Sometimes agroforestry combines different land uses at the same time on the same land or land use may change during the year. Thus, FAO and the climate frameworks have introduced the concept of "predominant land use". The purpose is to report land into one land use category only –without double counting or excluding land from the reporting. A land use category has a definition sometimes including a minimum area. Activities that are built on land use categories seldom have a defined minimum area.

It's probably more challenging to estimate and delineate land use from land cover using remote sensing techniques than by direct measurements in the field (REF?). Few available parallel assessments show good agreement at aggregated national scale (REF). A spatial assessment unit is used for monitoring land use or activities and it often refers to the resolution of a remote sensing pixel or the resolution of underlying data for a map. Generally, the spatial assessment unit should be the same over the period assessed and to have a higher resolution than the minimum area for defining a land use category. It should be noted that the resolution of chosen spatial assessment unit may influence on the results. One example is when a land use category encompasses small patches of other land use categories. Then given resolution, the smaller land use category may incorrectly be included and reported under the larger land use category. If a field-sampling plot that can be delineated into more than one land use category is used for estimating land use and land-use change, then a land use conversion down to zero can be detected. And if the land use is correctly measured on the sampling plots, the estimates will be unbiased.

Figure.1 describes the concepts of land use (UNFCCC), activity (KP) and spatial assessment unit. At t1 for a periodical inventory using permanent ground sampling plots, the land use consist of Forest land (FL) and the activity Forest management (FM) is reported under the KP. The circular sample plot (here sampling unit) represents the total area (the rectangle) and in this specific case the estimated area of FL/FM is 100% and the same as the true for the total area. At t2, 64% of the total area of FL has been converted to Settlements (S) and is reported as Deforestation (D) under the KP. The remaining area is reported as FL remaining FL or FM. Observe that, using the circular sampling plot as spatial assessment unit, the estimated D is 63% and that only the emission of one harvested tree is reported under D. Delineation of land uses and the geographic positioning of trees on the plots are required to report changes in living biomass matched to land use and land-use change on delineated plots.

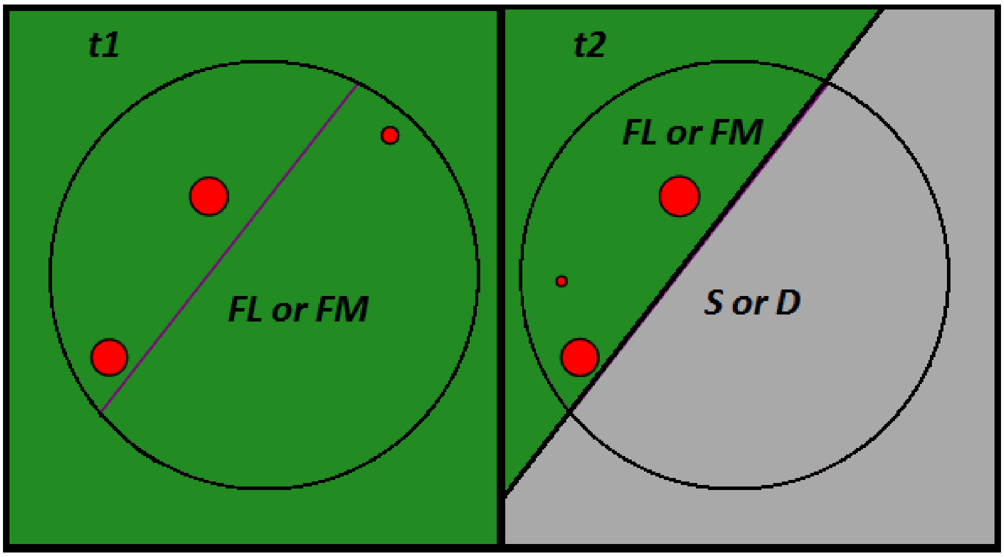

Figure 1) The true area is 100% FL/FM at t1 and a sampling unit is by using area based sampling estimating that 100% of the area is FL/FM. At t2, 64% of the area has been converted to S/D and the estimated area of S/D is 63%. The positioning of trees on delineated plots is central for matching changes in carbon pools (living biomass) to land use and land-use change. Red dots refer to living trees and the size of each dot is proposal to its size. Using the stock change method between t1 and t2, one small harvested tree is reported as an emission under S/D while a new small tree and the difference in size of two larger trees are reported as a removal under FL/FM

The occurrence/total area, size, shape of land use categories may influence on the accuracy of estimates. Most monitoring systems will estimate common land use categories more precise than uncommon. The minimum area for defining a land use category may introduce another monitoring problem. If, for example, the minimum area for defining Forest land is 0.5 ha, and an area of Forest land of exactly 0.5 ha is partly deforested or naturally downgraded by say 0.0001 ha, then the whole 0.5 ha is assumed converted to another land use category –this because the definition do not longer hold. Independently of monitoring system used, the major difficulty is to identify land use and borders between such. The general problem is to implement a continuous accurate assessment design for monitoring land-use changes (and corresponding changes in carbon pools).

The reporting under climate frameworks is annual but the data may reflect a trend. A commonly used approach is the stock change method that estimates changes in carbon pools as the difference between two consecutive measurements (another approach is to monitor flows through gains and losses). A permanent periodic design (the same sample units are revisited) is encouraged (compared with a temporary) since it improves the accuracy of estimates and it's also possible to obtain estimates of both gross and net land use conversions (required under the UNFCCC). A five-year inventory cycle is suggested but almost any cycle is accepted. A long inventory cycle may miss detecting multiple land use changes and thereby miss reporting emissions connected to the not-identified land use changes, as well as increasing uncertainty on when such conversions have occurred.

The inventory designs for reporting changes in carbon pools matched to land use may be sample based or a total inventory (or combined). The idea with using a sample based approach is to measure the variable of interest on the sample units and thereby most of the uncertainty will arise from that a sample and not the entire population was measured. A total wall-to-wall inventory does not introduce a sampling error but maybe systematic errors because it is difficult to (without bias) measure carbon stock changes on all land. In practice, it's likely that only wall-to-wall methods based on RS-data can generate unbiased estimates (REF). The RS-designs are usually combined with "ground truth" from field measurements or by models to match land use and land-use change to changes in carbon pools.

Most Annex I Parties under the UNFCCC/ KP base their monitoring of land use and land-use change on remote sensing (RS) data (as annual Landsat assessment, e.g. Australia) or on data from their national forest inventory (e.g. Finland). This is often challenging and the estimates are usually combining multiple data sources, e.g. Australia (ground truth complemented by RS-data and by, models; FullCAM;), data from national forest inventories or by other supporting material as ancillary statistics from agencies. A second general approach is to use cadastral (Czech R), vector maps (Denmark) or land cover maps for at least two occasions in time to estimate land use and land-use change (Netherlands). At least one country builds its reporting on a complete field survey (wall-to-wall;Japan) and one country builds the reporting on field sample plots only (Sweden).

"Although many authors (McRoberts 2011; Tomppo et al.2011) point it out that remote sensing alone will not be viable option, it remains to be clarified what combinations of remote sensing and field surveying are appropriate, as well what estimation techniques should be applied when combining the two sources." This far no country has introduced relatively new techniques as model-based approaches for improving their estimates of land use and land-use change. For example, a model based approach may model land use from RS-data that is calibrated by "ground truth". However, the techniques have been introduced for improving estimates of changes in e.g. living biomass.

In the present study we will estimate land use and land-use change (and for a few examples changes in carbon pools) given a field based approach and using a sampling design for a case country. We have selected Sweden as case country and the Swedish LULUCF reporting under climate frameworks are based on the Swedish National forest Inventory (NFI). We will estimate the accuracy of estimates given sampling intensity and properties of the land use categories. In addition, we will imitate an ongoing approach in Romania. The Romanian NFI combines field sampling plots with aerial photos. Finally, we will introduce a model based approach (post-stratification) to study if this approach improves the estimates /***Check New Zealand***/. From a climate reporting approach, we will discuss advantages and disadvantages using different approaches.

Material and methods

*Swedish LULUCF data

Under the climate framework, Sweden has adapted 15 national land use categories to IPCCs six broad land use categories (Forest land (FL), Cropland (CL), Grassland (GL), Settlements (S), Wetlands (W) and Other land (OL). Changes in carbon pools and areas are reported for FL, CL, GL and S that are assumed managed while only areas are reported for the unmanaged land use categories (OL and W). Details about definitions of land use categories are found in the National Inventory Report. Activities under the KP are built on these land use categories. Deforestation (D) is defined as a land use conversion from FL to another managed land use category and the areas are accumulated from 1990. Land cannot leave this activity. The activity Afforestation/Reforestation (AR) is the opposite (managed land to Forest land) and is also accumulated from 1990 and can only leave this category for D. The activity Forest management (FM) refers to FL remaining FL but also FL converted to unmanaged land and unmanaged land converted to FL are considered FM. Cropland management (CM) is an activity on CL that is not reported under D. Finally Grazingland management (GM) is an activity on GL that is not reported under D or CM (CL converted to GL stays as CM).

Changes in carbon pools are matched to land use and land-use change based on estimates from the National Forest Inventory (NFI). The NFI is quite unique in the sense that it covers all land (not only Forest land), was established before the base year (1990) and has a permanent sampling design. A permanent sampling design is required to monitor both gross and net land use transfers to produce a land use matrix.

The NFI is an annual, systematic cluster-sample inventory of Sweden. Each year roughly 870 sample clusters are inventoried. The square shaped clusters are distributed all over the country in a pattern that, due to autocorrelation, is denser in the southern part than in the northern part of the country. Each cluster, that constitutes one sampling unit, consists of four to eight sampling plots. A sampling plot has a radius of 10 m and can be delineated into more than one land use category. Each year around 6000 sample plots are inventoried and a five-year inventory cycle is used for five different cycles (established 1983, 1984, 1985, 1986 and 1987, respectively. Data for years between consecutive inventories are interpolated (REF to NIR or figures?). The biomass is estimated for singular living trees using allometric models (Marklund, Petersson and Ståhl)

**Romanian LULUCF data

*** One land use grid cover whole country (500x500 m2) using aerial photos, land use estimates based on aerial photo interpretation and ground truth ***.

Case 1: Monitoring carbon pools changes matched to land use and land-use change using field sampling plots only

Change in living biomass (2012-2013), total biomass (2013) and area (2013) were estimated for activities under the KP. The estimator and variance estimator used are found in Appendix 1. Data from the Swedish NFI was used and the stock change method was applied (REF NIR). In total 4344 tracts (or around 30000 permanent sample plots) covering all land were used. For areas, the influence of different sample intensity (number of tracts used) on SE was assessed by assuming simple random sampling.

Case 2: Combining land use from aerial photo interpretation with ground truth

Twenty tracts were subjectively selected from permanent sample plots from the Swedish NFI. Ten of these tracts included at least one plot/plot part of AR and another ten of D. The tracts consisted of 15x8 plus 5x4 = 140 plots but one plot was removed for technical reasons. To imitate the inventory design of the Romanian NFI, each plot was matched to an aerial orthophoto at two consecutive inventories (t1 and t2). Sometimes, t1 and t2 didn't exactly correspond between the two data sets. Uncertainty in geographically matching the two data sets may also arise from the identification of plot centers using GPS. The orthophotos were viewed on a display via ArcMap. When needed, land was delineated by a line into different land use classes. Areas per plot intersection were automatically measured.

Results

Case1

Based on ground measured field plots and given design for 2013, the change in living biomass under FM in Sweden was estimated 31.5 Mton CO2/yr. The corresponding estimated accuracy of this estimate was 3.32 MtonCO2/yr. The relative error (SE/gross growth) is approximately 2% (Skogsdata 2015; Table 1). The area under FM was estimated to 27.4 Mha with an estimated SE of 0.27 Mha or an uncertainty of around 1% (Table 2). Changing from around 1000 to 30000 sampling units will probably reduce the uncertainty from around 2.0 to 0.4 %, respectively. The relative uncertainty for area is much higher for more uncommon activities – around 7% for AR, D and GM and around 3% for CM. If using 10000 sample units, the relative uncertainty for area would approximately be around 5% or lower (Table 1).

Table.1) Change in living biomass (2012-2013) and total biomass (2013) per KP-activity. Biomass refers to living trees dbh>99 mm at breast height. Minus=emission

2013	FM		D		AR		CM		GM	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE

Diff AGB	[Mton CO2/yr]	23.8	2.50	-1.01	0.43	0.91	0.14	0.19	0.08	0.26	0.06
Diff BGB	[Mton CO2/yr]	7.68	0.82	-0.34	0.15	0.30	0.05	0.07	0.03	0.11	0.02
Diff total B	[Mton CO2/yr]	31.5	3.32	-1.35	0.58	1.21	0.18	0.25	0.11	0.37	0.08
Total AGB	[Mton CO2]	3176	19.9	2.55	0.27	11.1	0.71	5.88	0.48	13.4	0.31
Total BGB	[Mton CO2]	1065	6.70	0.91	0.10	3.74	0.24	2.13	0.18	5.36	0.31
Total B	[Mton CO2]	4241	26.7	3.46	0.37	14.8	0.95	8.02	0.66	18.8	0.61

Table.2) Areas (2013) per KP-activity. SE in italics are extrapolated assuming SRS

2013		FM		D		AR		CM		GM		
		Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	n
Area	[kha]	27382*	269	266	17.8	281	19.0	2877	93.3	462	26.0	4344
			560		*37.1*		*39.6*		*194*		*54.1*	*1000*
			396		*26.2*		*28.0*		*137*		*38.3*	*2000*
			250		*16.6*		*17.7*		*86.9*		*24.2*	*5000*
			177		*11.7*		*12.5*		*61.5*		*17.1*	*10000*
			102		*6.77*		*7.22*		*35.5*		*9.88*	*30000*

*=not corrected for FL in the mountain area

Case 2

Land use was assessed from aerial photo interpretation and matched to ground truth (measurements on NFI sample plots) and the ground truth land use was assumed to be correct (Table 3). Around 93% of FL remaining FL was correctly interpreted from aerial photo images. The incorrect assessments consisted of WL (four plots) and OL (1 plot). GL remaining GL was incorrectly assessed on one plot as CL. Part of two plots were incorrectly identified as S on CL remaining CL. Three plots/plot parts were incorrectly classified as FL or CL for S remaining S. Deforestation was incorrectly classified for 3 of the plots. For two plots the S was assumed already at t1 and only a part of the plots was actually D. For one plot a thinning was observed. The suspected reason for the observed thinning was either forestry or a land use conversion to GL (new land pastures), but the land use was not change from FL to GL (so incorrect). Few AR plots were correctly classified. One type was abandoned GL or CL that by definition are considered FL and small plants are hard to identify using an aerial photo. The second type of incorrect AR, was when plots that constituted FL and with a small proportion of S at t1, were converted to FL. Almost every plot identified as "no change" was correctly assessed while about every second in the category "change". The latter class was quite uncommon with only minor changes in land use.

Table.3) Correspondence between aerial photo interpretation and ground truth (n=139).

Grount truth					Aerial photos
t1	t1	t2	t2	n	Correct at t1 and t2
FL	100%	FL	100%	72	93%
GL	100%	GL	100%	4	75%
CL	100%	CL	100%	15	87%
WL	100%	WL	100%	3	100%
S	100%	S	100%	10	67%

FL	100%	CL,GL,S	0-100%	9	67%
CL,GL,S	0-100%	FL	100%	12	25%
FL+CL,GL or S	No change			7	86%
FL,CL,S	Change			2	50%
WL	100%	WL	100%	3	100%
Other combination	100%	Other combination	100%	2	100%

Discussion

- Model self-regulating –the relative accuracy increases for larger areas. Problem D (that is accounted differently) that is quite uncertain and varies al lot between years (large fluxes small area)
- CM I more accurate than GM (probably reason is that GM is smaller, more spread while CM larger homogenous patches)
- General pros and cons compare to other approaches (consistency, match carbon to land, design)
- Suggest an appropriate sampling intensity –compare with Romania,+another country
- We cannot do anything about the population but probably more variation in Romania
- Sample intensity (Romania 30000 compare to 4000 is ok)
- Design (Romania has improved the accuracy by matching aerial photo to NFI plot)
- Other pools (only living biomass) and mention the estimation and monitoring of dead wood. RO NFI monitors all pools (SOM and LT were collected in 2012)

***Benefits of increasing inventory cycles and intensity advantages and disadvantages and how this can influence the accuracy of estimating changes in area and carbon stocks, later on GHG emissions associated.

***Different land uses have different carbon stocks, during changes from land use to another land use it is assumed that the carbon stocks over time will reach the average carbon of the new land use, and later on emissions and removals of CO2, can be estimated on this basis, benefits of increasing inventory cycles and intensity

*** When rare events/small areas as Deforestation or even Afforestation, age dependent/duration since conversion started allowing better assessment of CSC?

***Advantages for using NFI data offers a strong positioning being able to provide sample complete information on land use categories, but there will be a need to extend information from different sources.

***Forest definitions:

Using different data set for land use and land cover sample based with remote sensing information, may have an important influence because can causes inconsistent definitions among land use classes.

Land use and management is quite different between countries.

*** Trends during land use changes can be cyclical, meaning emission from land use can occur more regular because and they are associated with timber harvesting

** How many rare events / conversions) can occur and how can we include them in the right category if we increase by changing inventory cycle from 5 years to 10, 15,30 and if uncertainty for area will increase or decrease. Following the results mentioned above creating a tree decision can be relatively helpful. (explanations if is there any change between an inventory 5 cycle and we have a change which will last 1 or 2 year, do we consider land use change? And if the inventory cycle will increase at 10 years and we have a temporary change which can last longer then 2 year and then returns as the main category, we will not consider a change at all because of the length of the inventory. Establishing thresholds can improve decisions.

Appendix 1

Estimators and estimators of variance for case 1

We suggest a ratio estimator where A is the measured area, $\hat{A}$ is the estimated area and $\hat{Y}$ is the estimated variable of interest for a region/stratum. $\hat{A}$ And $\hat{Y}$ can be estimated separately using the Horvitz-Thompson estimator.

$\tilde{Y} = A \cdot \frac{\hat{Y}}{\hat{A}} = A \cdot \hat{R}$ [Formula 1]

The variance and an estimator of the variance may be expressed as:

$$V(\tilde{Y}) = A^2 \cdot V(\hat{R}) = V(\hat{Y} - \hat{R} \cdot \hat{A})$$

$$\hat{V}(\tilde{Y}) = \hat{V}(\hat{Y} - \hat{R} \cdot \hat{A})$$

Alternatively:

$$\hat{V}(\tilde{Y}) = \frac{A^2}{\hat{A}^2} \cdot \hat{V}(\hat{Y} - \hat{R} \cdot \hat{A})$$

Assuming SRS, wtr:

$$\hat{V}(\tilde{Y}) = N^2 \cdot \frac{1}{n} \cdot \left(1 - \frac{n}{N}\right) \cdot s^2_{y-\hat{R}\cdot a}$$

$$\hat{V}(\tilde{Y}) = \frac{(\bar{A} \cdot N)^2}{(\bar{a}^2 \cdot n)} \cdot \left(1 - \frac{n}{N}\right) \cdot s^2_{y-\hat{R}\cdot a}$$

The estimator is quite robust when$\bar{A} = \bar{a}$, but if not:

$$\hat{V}(\tilde{Y}) = \frac{\left(\frac{A}{N} \cdot N\right)^2}{(\bar{a}^2 \cdot n)} \cdot \left(1 - \frac{n}{N}\right) \cdot s^2_{y-\hat{R}\cdot a}$$

$\hat{V}(\tilde{Y}) = \frac{A^2}{\bar{a}^2} \cdot \frac{1}{n} \cdot \left(1 - \frac{n}{N}\right) \cdot s^2_{y-\hat{R}\cdot a}$

$\hat{V}(\tilde{Y}) = \frac{A^2}{(\sum a)^2} \cdot n \cdot s^2_{y-\hat{R}\cdot a}$ [Formula 2]

Explaining the last term:

$s^2_{y-\hat{R}\cdot a} = \frac{1}{(n-1)} \cdot \sum_{i=1}^{n}(y_i - r \cdot a_i)^2$

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Anexa 4. Versiune curenta a articolului „How efficient is D^2H as predictor in biomass allometric models?”