Validatie C-Simulator

Algemene opmerking: de rotaties en/of behandelingen worden zelden of nooit volledig consistent aangehouden, daarom werden waar nodig gemiddelde waarden toegepast voor toedieningen en werden 'equivalente' rotaties gebruikt (zie figuren in bijlage)

BDB GFT proef Boutersem (1997-2008)

- Rotatie: suikerbiet, wintertarwe, aardappelen, wortelen
- Leembodem
- Initieel C-gehalte 1%
- Reële ploegdiepte varieert tussen 23 en 30 cm (niet exact gekend, daarom gesimuleerd op zowel 23 als 30 cm)

Behandeling: geen toediening organische stof

Gemeten C-gehalte tot 2008: fluctuerend tussen 0,9 en 1 %

Gesimuleerd C-gehalte in 2008:

- Ploegdiepte 23 cm: 0,95 %

Behandeling 15 T GFT compost jaarlijks

Gemeten C-gehalte in 2008: 1,4 %

Gesimuleerd C-gehalte in 2008:

- Ploegdiepte 23 cm: 1,4 %
- Ploegdiepte 30 cm: 1,23 %

Behandeling 45 T GFT compost jaarlijks

Gemeten C-gehalte in 2008: 2.0 %

Gesimuleerd C-gehalte in 2008:

- Ploegdiepte 23 cm: 2.3 %
- Ploegdiepte 30 cm: 2.0 %

Behandeling 45 T GFT compost driejaarlijks

Gemeten C-gehalte in 2008: 1.1 %

Gesimuleerd C-gehalte in 2008:

- Ploegdiepte 23 cm: 1.4 %
- Ploegdiepte 30 cm: 1.2 %

GFT proef VLACO Gent (1997-2008)

Gewassen: aardappel, suikerbiet, wintertarwe, kuilmaïs, wintergerst al dan niet met groenbemester op zandleem

Ploegdiepte 30 cm

Behandelingen: divers (soms met toepassing van dierlijke mest) maar steeds met/zonder GFT

Dierlijke mest en groenbemester zonder GFT

Initieel C%: 0,757

- Gemeten C % na 11 jaar: 0,747
- Gesimuleerd C% na 11 jaar zonder groenbemester: 0,75
- Gesimuleerd C% na 11 jaar met groenbemesters 2 jaren op 3: 0,82

Idem met GFT

Initieel C%: 0,822

- Gemeten C % na 11 jaar: 0,869
- Gesimuleerd C% na 11 jaar + groenbemester 1 jaar op 3 : 1,1

ILVO Proef (Data Greet Ruysschaert)

Bodem zandleem

Ploegdiepte 23 cm (?)

Initieel C gehalte 1,56 %

Monocultuur korrelmaïs zonder organische bemesting (12 jaar)

- Gemeten C% na 12 jaar: 1,48
- Gesimuleerd C% na 12 jaar: 1,45

Monocultuur korrelmaïs + 22,5 T GFT per jaar (12 jaar)

- Gemeten C% na 12 jaar: 1,97
- Gesimuleerd C% na 12 jaar: 2,2

Monocultuur korrelmaïs + 22,5 T GFT + 45 T drijfmest (12 jaar)

- Gemeten C% na 12 jaar: 2
- Gesimuleerd C% na 12 jaar: 2,3

Rotatie voederbieten snijmaïs, spruitkool aardappelen + 50 T GFT/jaar

Initieel C% Gehalte 1%

- Gemeten na 4 jaar: 1,3 %
- Gesimuleerd na 4 jaar: 1,8 %

Liroux (1959-1994)

- Zie ook artikel van Wesemael et al. 2005 (bijlage)
- Rotatie 3 à 4 jaar Suikerbieten + Wintertarwe, Wintergerst, Rogge, veldbonen
- Belangrijke jaarlijkse fluctuaties in gemeten koolstofcijfers die niet onmiddellijk verklaarbaar zijn (zie grafiek)
- Juiste samenstelling dierlijke mest niet gekend (in simulatie wordt runderstalmest toegepast)
- Bepalingsmethode C = W+B (correctie door te voeren om totaal C-gehalte te berekenen ?)
- In de simulatie worden gewasaanvoercijfers gebruikt berekend op basis van huidige opbrengsten. Waarschijnlijk lagen de werkelijke waarden in de beginperiode van de proef merkelijk lager

Behandeling 1: afvoer van alle gewasresten

- Lineaire regressie op gemeten waarden: zeer licht dalende trend (-0,0008/jaar)
- Simulatie: geleidelijk dalende trend (± - 0,004/jaar)

Behandeling 4: 40 ton stalmest 1x per rotatie + inwerken resten bieten

- Lineaire regressie op gemeten waarden: licht stijgende trend (+ 0,004/jaar)
- Simulatie: licht stijgende trend (± + 0,0017/jaar)

Behandeling 5: Inwerken stro

- Lineaire regressie op gemeten waarden: licht dalende trend (- 0,0003/jaar)
- Simulatie: licht stijgende trend (± + 0,0046/jaar)

Behandeling 6: Inwerken teeltresten + groenbemester

- Lineaire regressie op gemeten waarden: zeer licht stijgende trend (+ 0,0007/jaar)
- Simulatie: licht stijgende trend (± + 0,0074/jaar)

Conclusies:

- Er zijn geen perfecte meerjarige meetreeksen met rotaties beschikbaar, daarom zijn de simulaties per definitie als benaderend te beschouwen
- Stijgende of dalende trends worden in vrijwel alle gevallen correct gesimuleerd
- De afwijking tussen gemeten waarde - gesimuleerde waarde in het algemeen beperkt en liggen lager dan de 20% afwijking die voor dergelijke modellen aanvaardbaar worden geacht
- Belang van de juiste ploegdiepte dient onderstreept te worden
- Werking GFT-compost wordt blijkbaar nog steeds enigszins overschat en dit vooral bij toepassing van hoge dosissen (momenteel geen gegevens beschikbaar om aanpassingen te maken, maar op termijn zeker in het oog te houden)

- Simulatie GFT -proef Gent geeft stijgende trend aan voor behandeling met compost daar waar in werkelijkheid zo goed als geen verandering wordt vastgesteld, in andere gevallen kan de ploegdiepte de overschatting van de GFT compostwerking deels verklaren

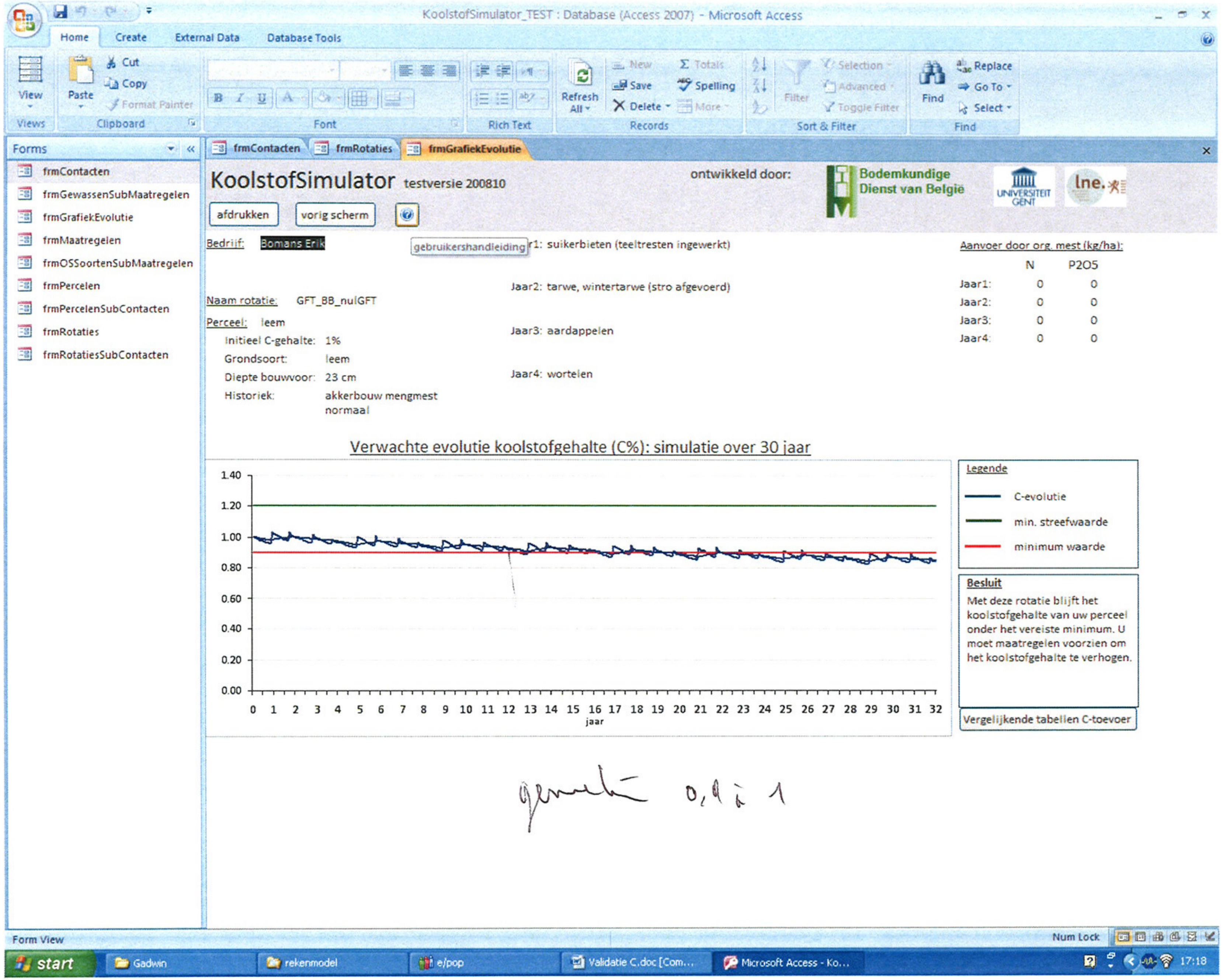
- Bij de vergelijking tussen gemeten waarden en gesimuleerde waarden is het aangeraden te vergelijken met de onderste waarden van de grafiek eerder dan met de gemiddelde waarden, zeker bij sterk fluctuerende C-gehalten (bv ten gevolge van hoge jaarlijkse toedieningen van organische stof). De onderkant geeft immers beter het gehalte aan stabiele vormen van BOS weer (te vergelijken met de situatie die zou ontstaan een jaar nadat de toedieningen worden stopgezet).

- Resultaten simulaties Liroux zijn vergelijkbaar met deze van de simulaties die werden uitgevoerd door Bas van Wesemael

E. Bomans

17 oktober 2008

GFT proef Boutersem



gemeten 0,9 à 1

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- frmGrafiekEvolutie
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- frmOSSoortenSubMaatregelen
- frmPercelen
- frmPercelenSubContacten
- frmRotaties
- frmRotatiesSubContacten

frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België — Universiteit Gent — lne.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Naam rotatie: GFT15PERJ

Perceel: leem

Initieel C-gehalte: 1%

Grondsoort: leem

Diepte bouwvoor: 23 cm

Historiek: akkerbouw mengmest normaal

Rotatie:

Jaar1: suikerbieten (teeltresten ingewerkt)
GFT-compost 15t/ha in maart + GFT-compost 15t/ha in oktober

Jaar2: tarwe, wintertarwe (stro afgevoerd)

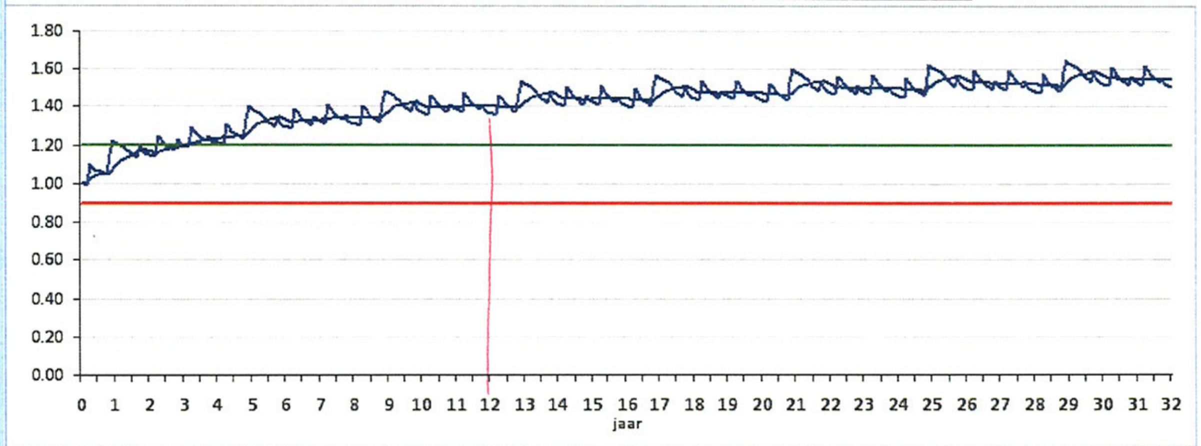
Jaar3: aardappelen
GFT-compost 15t/ha in maart

Jaar4: wortelen
GFT-compost 15t/ha in maart

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	294	213
Jaar2:	0	0
Jaar3:	147	107
Jaar4:	147	107

Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende

- C-evolutie
- min. streefwaarde
- minimum waarde

Besluit

Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

1 -> 1,4

KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access

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Forms: frmContacten, frmGewassenSubMaatregelen, frmGrafiekEvolutie, frmMaatregelen, frmOSSoortenSubMaatregelen, frmPercelen, frmPercelenSubContacten, frmRotaties, frmRotatiesSubContacten

frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België | Universiteit Gent | lne.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Naam rotatie: VLACO_BB_GFT15perj

Perceel: leem
- Initieel C-gehalte: 1%
- Grondsoort: leem
- Diepte bouwvoor: 30 cm
- Historiek: akkerbouw mengmest normaal

Rotatie:
- Jaar1: suikerbieten (teeltresten ingewerkt)
  GFT-compost 15t/ha in maart + GFT-compost 15t/ha in oktober
- Jaar2: tarwe, wintertarwe (stro afgevoerd)
- Jaar3: aardappelen
  GFT-compost 15t/ha in maart
- Jaar4: wortelen
  GFT-compost 15t/ha in maart

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	294	213
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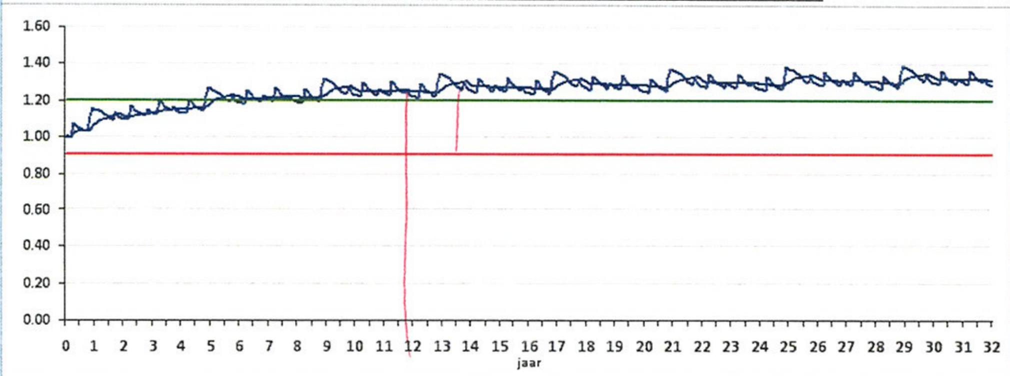
Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende
- C-evolutie
- min. streefwaarde
- minimum waarde

Besluit

Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

1 -> 1,4

Form View | Num Lock

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KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access

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- frmPercelenSubContacten
- frmRotaties
- frmRotatiesSubContacten

frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België, Universiteit Gent, lne.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Naam rotatie: GFT45PERJ

Perceel: leem

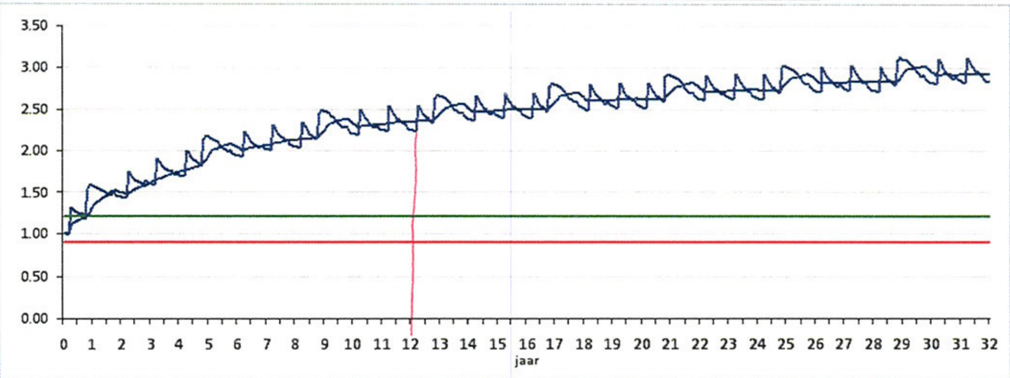
Initieel C-gehalte: 1%
Grondsoort: leem
Diepte bouwvoor: 23 cm
Historiek: akkerbouw mengmest normaal

Rotatie:
Jaar1: suikerbieten (teeltresten ingewerkt)
GFT-compost 45t/ha in maart + GFT-compost 45t/ha in oktober
Jaar2: tarwe, wintertarwe (stro afgevoerd)
Jaar3: aardappelen
GFT-compost 45t/ha in maart
Jaar4: wortelen
GFT-compost 45t/ha in maart

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	882	639
Jaar2:	0	0
Jaar3:	441	320
Jaar4:	441	320

Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende
- C-evolutie
- min. streefwaarde
- minimum waarde

Besluit
Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

1 -> 2

Form View | Num Lock

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Views | Clipboard | Font | Rich Text | Records | Sort & Filter | Find

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- frmPercelenSubContacten
- frmRotaties
- frmRotatiesSubContacten

frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België | Universiteit Gent | lne.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Naam rotatie: GFT45PERJ

Perceel: leem

Initieel C-gehalte: 1%

Grondsoort: leem

Diepte bouwvoor: 30 cm

Historiek: akkerbouw mengmest normaal

Rotatie: Jaar1: suikerbieten (teeltresten ingewerkt)
GFT-compost 45t/ha in maart + GFT-compost 45t/ha in oktober

Jaar2: tarwe, wintertarwe (stro afgevoerd)

Jaar3: aardappelen
GFT-compost 45t/ha in maart

Jaar4: wortelen
GFT-compost 45t/ha in maart

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	882	639
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Jaar3:	441	320
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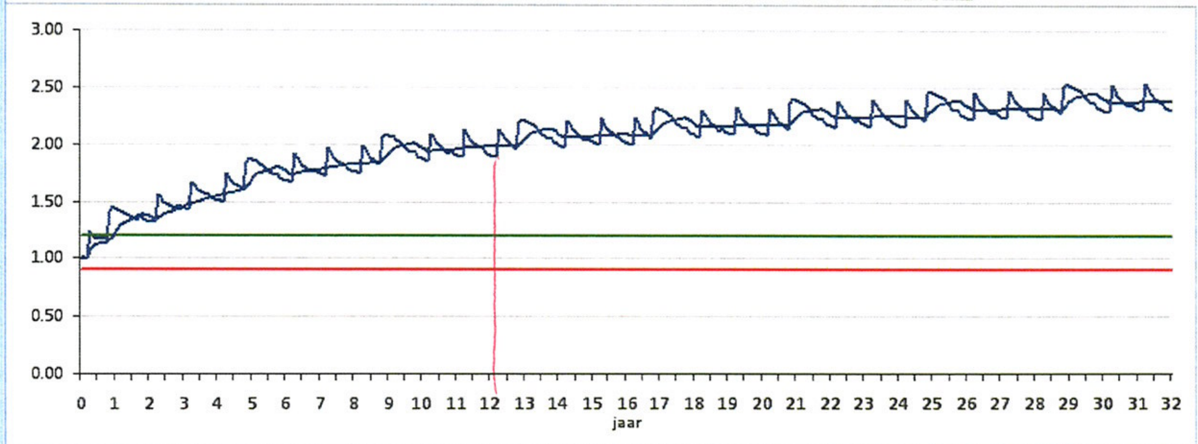
Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende

- C-evolutie
- min. streefwaarde
- minimum waarde

Besluit

Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

1 -> 2

KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access

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Forms: frmContacten, frmGewassenSubMaatregelen, frmGrafiekEvolutie, frmMaatregelen, frmOSSoortenSubMaatregelen, frmPercelen, frmPercelenSubContacten, frmRotaties, frmRotatiesSubContacten

frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België, Universiteit Gent, lne.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Naam rotatie: GFT45T/3J

Perceel: leem

Initieel C-gehalte: 1%

Grondsoort: leem

Diepte bouwvoor: 23 cm

Historiek: akkerbouw mengmest normaal

Rotatie:

Jaar1: suikerbieten (teeltresten ingewerkt)
GFT-compost 45t/ha in maart

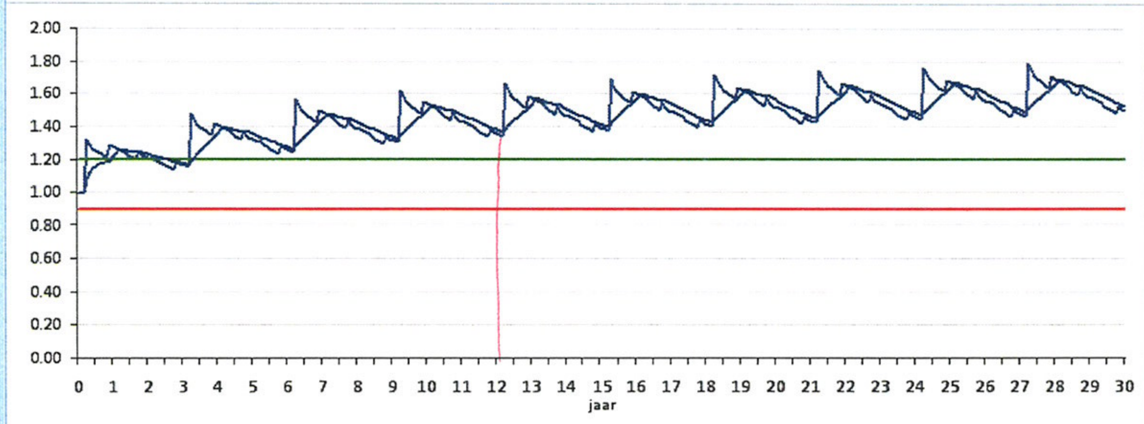
Jaar2: tarwe, wintertarwe (stro afgevoerd)

Jaar3: aardappelen

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	441	320
Jaar2:	0	0
Jaar3:	0	0

Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende
- C-evolutie
- min. streefwaarde
- minimum waarde

Besluit

Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

1 → 1,1

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KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access

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frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België, Universiteit Gent, Ine.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Naam rotatie: GFT45T/3J

Perceel: leem

Initieel C-gehalte: 1%

Grondsoort: leem

Diepte bouwvoor: 30 cm

Historiek: akkerbouw mengmest normaal

Rotatie:

Jaar1: suikerbieten (teeltresten ingewerkt)
GFT-compost 45t/ha in maart

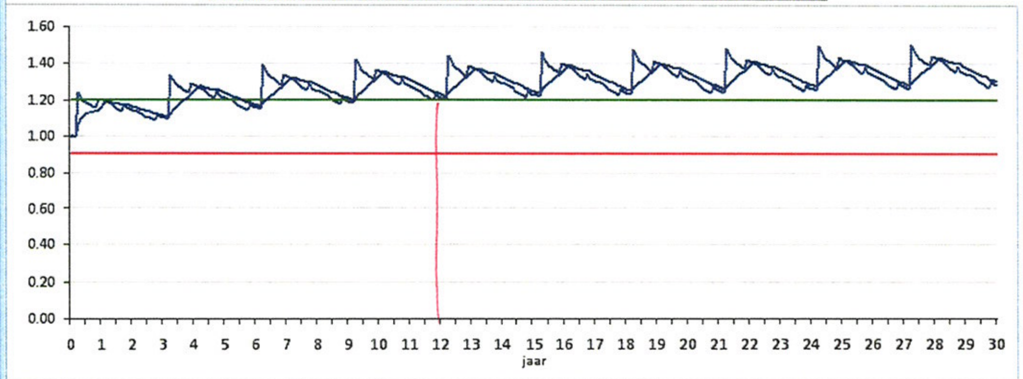
Jaar2: tarwe, wintertarwe (stro afgevoerd)

Jaar3: aardappelen

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	441	320
Jaar2:	0	0
Jaar3:	0	0

Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende

C-evolutie

min. streefwaarde

minimum waarde

Besluit

Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

1 -> 1.1

Form View | Num Lock

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GFT proef Gent

Textuur: zandleem (exact gehalte klei: 8,7%), bouwvoordiepte 30cm, dichtheid 1,5 g cm^{-3}

Initieel OC gehalte (0,75%OC aan begin jaar 0)

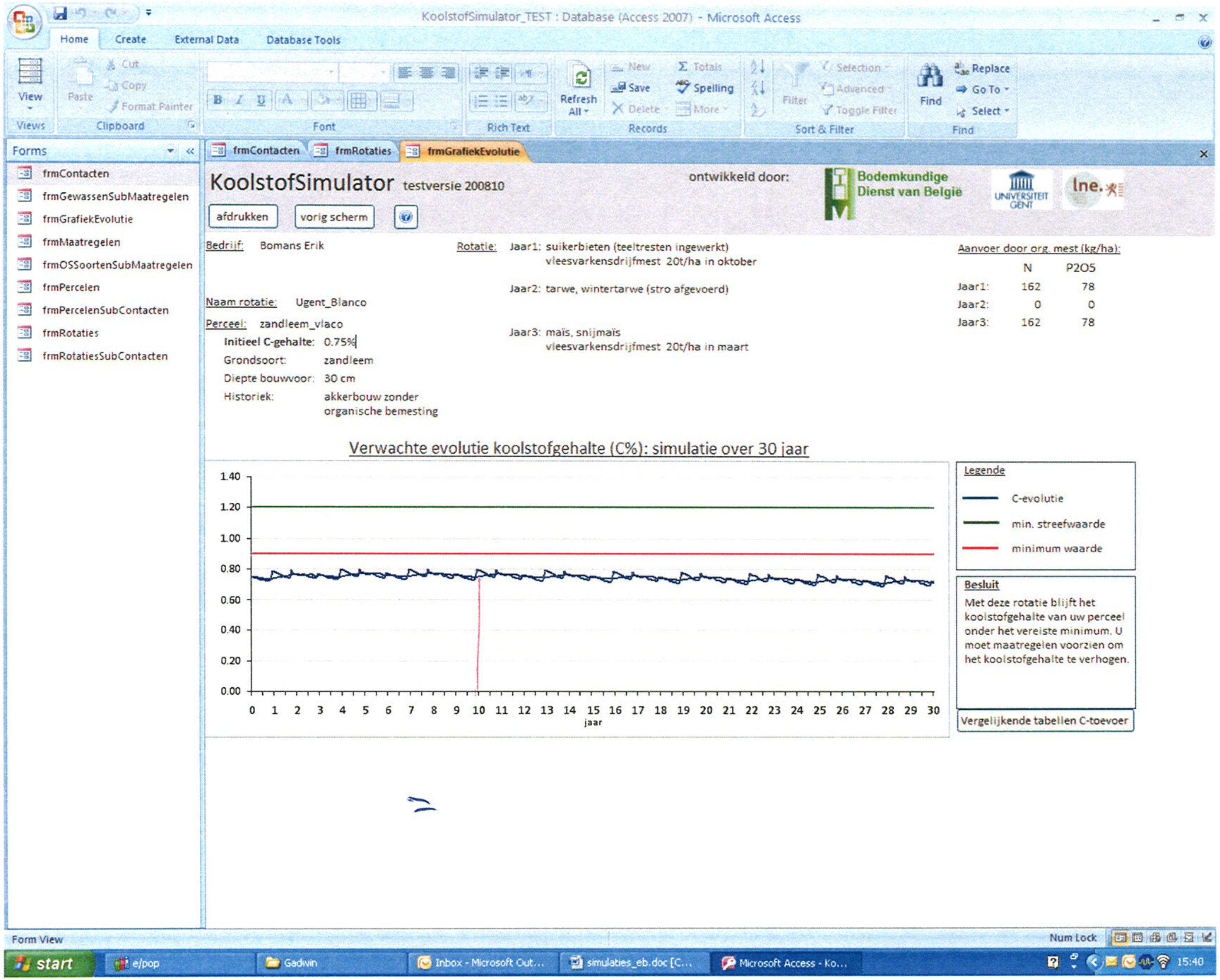
Gewasrotatie + OC gehalte (0-30cm laag op het einde van het jaar):

jaar	**Gewas**	**Blanco %OC**	**Blanco Organische Bemesting**	**GFT %OC**	**GFT Organische Bemesting**
0 (1997)	Aardappel	0,757	-	0,822	40t GFT
1 (1998)	Suikerbiet	-	-	-	-
2 (1999)	Wintertarwe	0,727	-	0,828	-
3 (2000)	Kuilmaïs	-	Groenbemester (gele mosterd) 40t runderstalmest	-	Groenbemester (gele mosterd) 40t runderstalmest 40t GFT
4 (2001)	Wintertarwe	0,667	30t varkensmengmest	0,81	30t varkensmengmest
5 (2002)	Suikerbiet	-	Groenbemester (gele mosterd)	-	Groenbemester (gele mosterd)
6 (2003)	aardappel	0,609	-	0,742	-
7 (2004)	wintergerst	0,674	30t varkensmengmest	0,767	30t varkensmengmest
8 (2005)	Suikerbiet	0,73	Groenbemester (Gele mosterd)	0,855	50t GFT Groenbemester (Gele mosterd)
9 (2006)	Kuilmaïs	0,72	30t varkensmengmest	0,86	30t varkensmengmest
10 (2007)	Wintertarwe	0,747	30t varkensmengmest	0,869	30t varkensmengmest
11 (2008)	Suikerbiet	-	-	-	-

Alle gewasresten worden ingeploegd behalve het stro van tarwe en gerst. Groenbemesters worden aangegeven in het jaar waarin ze geoogst werden.

4x Gr = 1/3
4x SB = 1/3
2x AA
2x KM } = 1/3

160 T /
2AT / ha j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Forms
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frmOSSoortenSubMaatregelen
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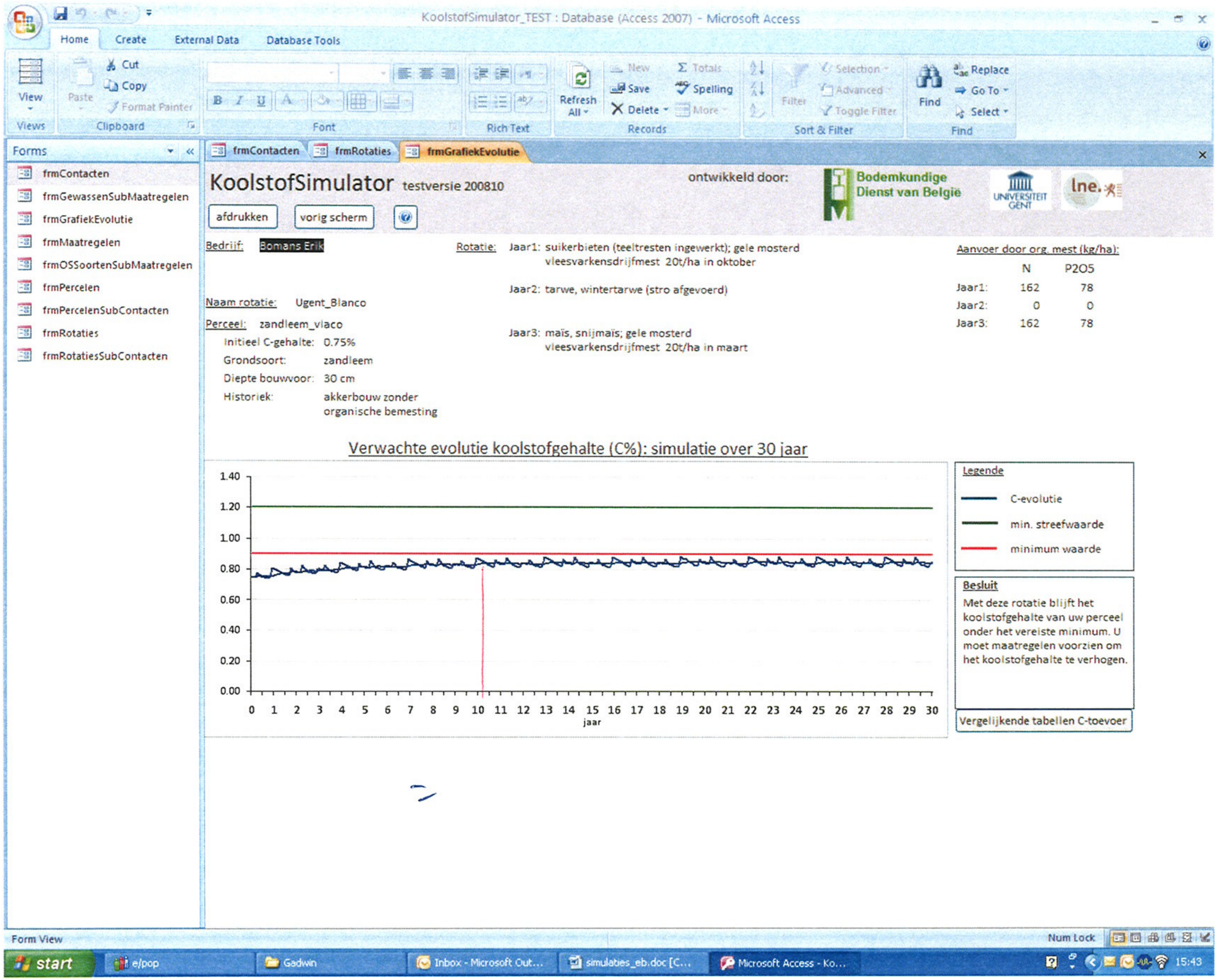
frmPercelenSubContacten
frmRotaties
frmRotatiesSubContacten
frmContacten
frmRotaties
frmGrafiekEvolutie
KoolstofSimulator testversie 200810
ontwikkeld door:
Bodemkundige Dienst van België
UNIVERSITEIT GENT
afdrukken
vorig scherm
Bedrijf: Bomans Erik
Naam rotatie: Ugent_Blanco
Perceel: zandleem_vlaco
Initieel C-gehalte: 0.75%
Grondsoort: zandleem
Diepte bouwvoor: 30 cm
Historiek: akkerbouw zonder organische bemesting
Rotatie: Jaar1: suikerbieten (teeltresten ingewerkt) vleesvarkensdrijfmest 20t/ha in oktober
Jaar2: tarwe, wintertarwe (stro afgevoerd)
Jaar3: maïs, snijmaïs vleesvarkensdrijfmest 20t/ha in maart
Aanvoer door org. mest (kg/ha):
N P2O5
Jaar1: 162 78
Jaar2: 0 0
Jaar3: 162 78
Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
jaar
Legende
C-evolutie
min. streefwaarde
minimum waarde
Besluit
Met deze rotatie blijft het koolstofgehalte van uw perceel onder het vereiste minimum. U moet maatregelen voorzien om het koolstofgehalte te verhogen.
Vergelijkende tabellen C-toevoer
Form View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frmPercelen
frmPercelenSubContacten
frmRotaties
frmRotatiesSubContacten
KoolstofSimulator testversie 200810
ontwikkeld door:
Bodemkundige Dienst van België
afdrukken
vorig scherm
Bedrijf: Bomans Erik
Rotatie: Jaar1: suikerbieten (teeltresten ingewerkt); gele mosterd vleesvarkensdrijfmest 20t/ha in oktober
Jaar2: tarwe, wintertarwe (stro afgevoerd)
Jaar3: maïs, snijmaïs; gele mosterd vleesvarkensdrijfmest 20t/ha in maart
Aanvoer door org. mest (kg/ha):
N P2O5
Jaar1: 162 78
Jaar2: 0 0
Jaar3: 162 78
Naam rotatie: Ugent_Blanco
Perceel: zandleem_viaco
Initieel C-gehalte: 0.75%
Grondsoort: zandleem
Diepte bouwvoor: 30 cm
Historiek: akkerbouw zonder organische bemesting
Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar
jaar
Legende
C-evolutie
min. streefwaarde
minimum waarde
Besluit
Met deze rotatie blijft het koolstofgehalte van uw perceel onder het vereiste minimum. U moet maatregelen voorzien om het koolstofgehalte te verhogen.
Vergelijkende tabellen C-toevoer
Form View
Num Lock
start
15:43

KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access

frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België — Universiteit Gent — lne.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Naam rotatie: Ugent_GFT

Perceel: zandleem_vlaco

- Initieel C-gehalte: 0.75%
- Grondsoort: zandleem
- Diepte bouwvoor: 30 cm
- Historiek: akkerbouw mengmest normaal

Rotatie:

Jaar1: suikerbieten (teeltresten ingewerkt); gele mosterd
vleesvarkensdrijfmest 20t/ha in oktober

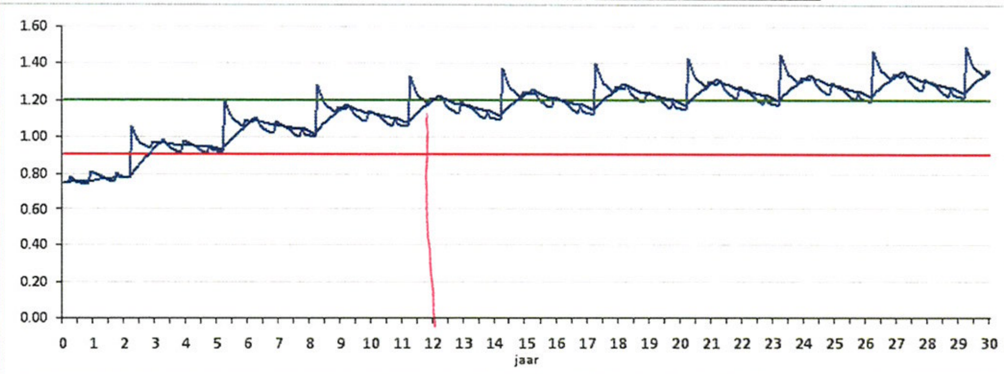
Jaar2: tarwe, wintertarwe (stro afgevoerd)

Jaar3: maïs, snijmaïs; gele mosterd
vleesvarkensdrijfmest 20t/ha in maart + GFT-compost 40t/ha in maart

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	162	78
Jaar2:	0	0
Jaar3:	554	362

Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende

- C-evolutie
- min. streefwaarde
- minimum waarde

Besluit

Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

0,75 → 0,87

ILVO proeven

ILVO (Greet Ruysschaert)

-heel gebruiksvriendelijke programma

-duidelijke handleiding. paar kleine opmerkingen:
p2. 'Opgelet: bemestingsdosissen dienen steeds ingegeven te worden als kg of liter product per hectare'. Hoort dit bij de paragraaf waar het nu bij staat, dwz %C vs humuss. Ik begrijp de link tussen beide delen van de paragraaf immers niet goed.
p2. Derde punt onder 1.3. '...uitspraken te doen over veranderingen op de korte of zeer korte termijn'. Wat is kort of zeer kort? Ik begrijp dat veranderingen binnen een jaar niet zinvol zijn, maar wat met een termijn van 4-5 jaar, wordt dit als kort aanzien?
p11. Bij 'akkerbouw stalmest normaal' moet in de zin die erop volgt 'mengmest' vervangen worden door 'stalmest'
-p16. Figuur 7. Is het mogelijk de kolom 'koolstof aanvoer' en de kolom 'DPM/RPM' op een of andere manier te combineren zodat er kan gesorteerd worden op de hoeveelheid aangebrachte stabiele koolstof?

- Kan het informatiescherm 'verhogen van het koolstofgehalte' alleen geraadpleegd worden als men onder de streefzone komt? Dit is een beetje jammer. Het zou goed zijn als de gebruiker altijd toegang tot dit scherm zou kunnen krijgen.

-X-as van de grafieken: waarom in maanden en niet in jaren? Zou dit niet duidelijker zijn?
- Na het bewaren van de rotatie zou het handig zijn een bevesting te krijgen dat het is bewaard
- Engels raaigr**aa**s moet Engels raaigras worden
- Er zit ergens een fout in het programma waardoor de hoeveelheden N en P2O5 door bemesting steeds op nul komen te staan in jaar 4

We hebben het programma eens losgelaten op de data van enkele proeven en over het algemeen is het programma te optimistisch wat koolstofopbouw betreft. De gemeten waarden zijn meestal lager dan de gesimuleerde waarden, vooral bij toediening van organische bemesting. Enkele voorbeelden:
- Monocultuur korrelmaïs met jaarlijkse toediening van 22.5 ton/ha GFT-compost. Begin %C: 1.56%, na 12 jaar is 1.97% gemeten, het programma simuleert na die periode bija 2.50%
- Monocultuur korrelmaïs zonder organische bemesting. Begin %C: 1.56%. Gemeten na 12 jaar 1.48%. In de simulatie is een lichte stijging waar te nemen. Rekening houdend met mogelijke meetfouten zit deze voorspelling echter vrij goed
-Monocultuur korrelmais met 22.5 ton/ha GFT-compost en 45ton/ha drijfmest. Begin %C: 1.56%, na 12 jaar 2%, simulatie: 2.6%
- 4 jarige rotatie met voederbieten, snijmaïs, spruitkool en aardappelen en een jaarlijkse GFT toediening van 50ton/ha. Begin %C: 1.00%, na 4jaar 1.3%, simulatie: +/-1.8%

met vriendelijke groeten,

Greet

Greet Ruysschaert
Instituut voor Landbouw- en Visserijonderzoek (ILVO)
Eenheid Plant - Teelt en Omgeving
Burgemeester Van Gansberghelaan 109
9820 Merelbeke
Tel: +32 (0) 9 272 26 98
www.ilvo.vlaanderen.be

KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access

Home | Create | External Data | Database Tools

View | Paste | Cut | Copy | Format Painter | Refresh All | New | Save | Delete | Totals | Spelling | More | Filter | Selection | Advanced | Toggle Filter | Find | Replace | Go To | Select

Views | Clipboard | Font | Rich Text | Records | Sort & Filter | Find

Forms

- frmContacten
- frmGewassenSubMaatregelen
- frmGrafiekEvolutie
- frmMaatregelen
- frmOSSoortenSubMaatregelen
- frmPercelen
- frmPercelenSubContacten
- frmRotaties
- frmRotatiesSubContacten

frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België | Universiteit Gent | Ine.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Rotatie: Jaar1: mais, korrelmaïs

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	0	0

Naam rotatie: ILVO2

Perceel: ILVO

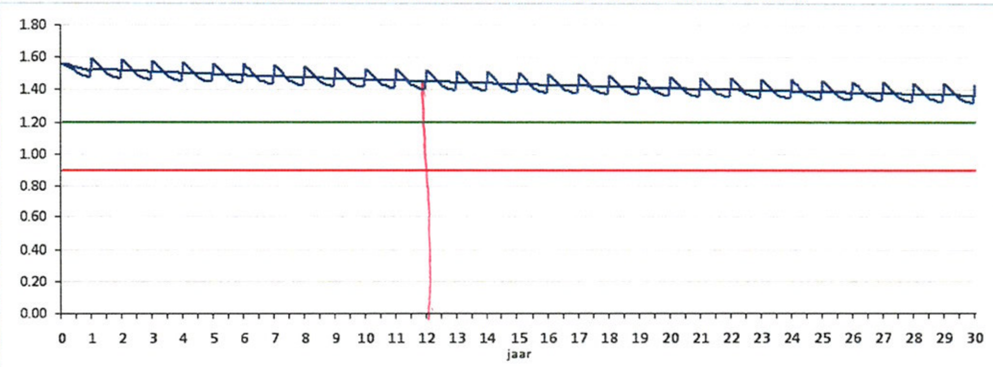
Initieel C-gehalte: 1.56%

Grondsoort: zandleem

Diepte bouwvoor: 23 cm

Historiek: akkerbouw stalmest normaal

Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende

- C-evolutie
- min. streefwaarde
- minimum waarde

Besluit

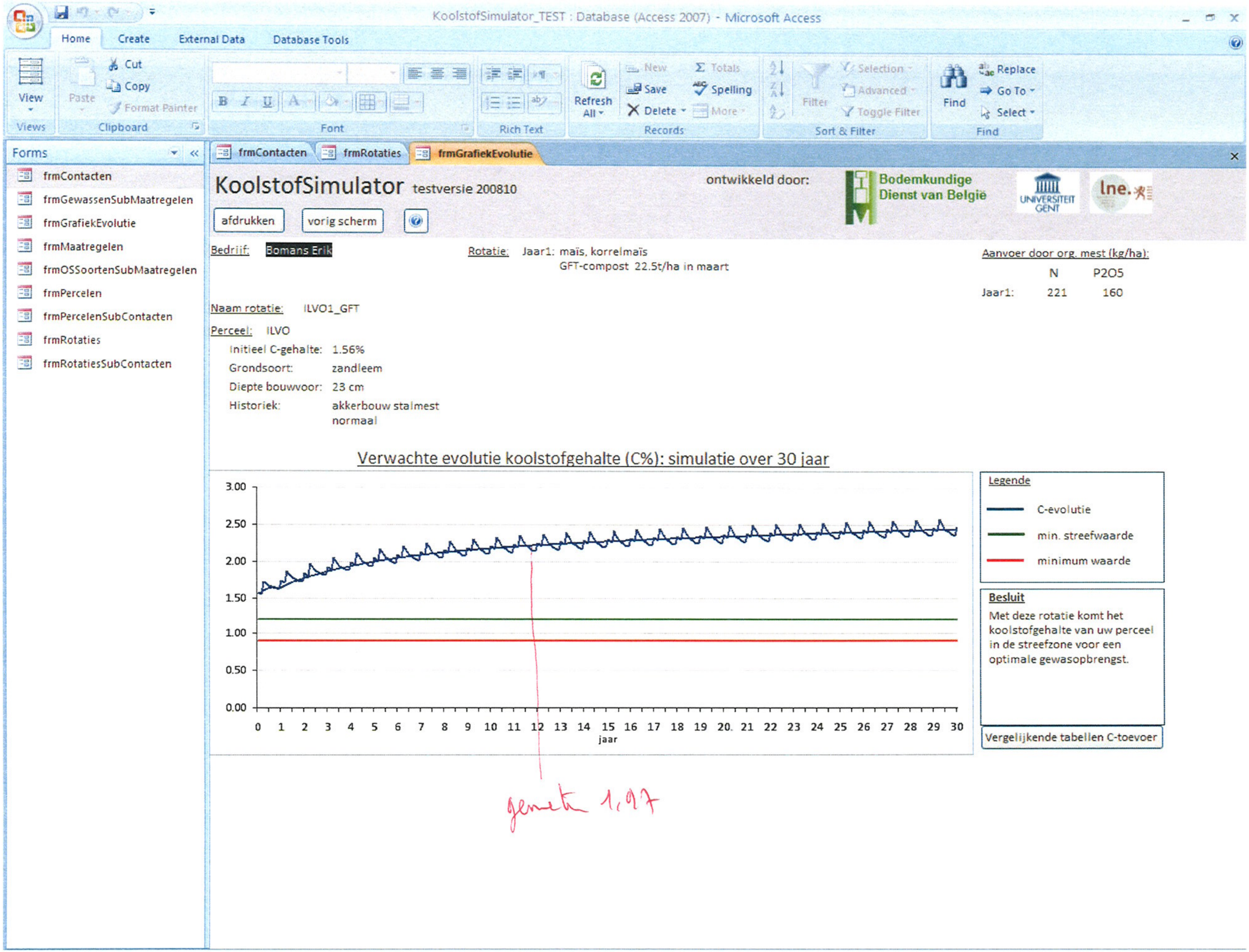
Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

gemeten ~~m~~ 1,48

Form View | Num Lock

start | bordau | Gadwin | My Documents | e/pop | Inbox - Microsoft ... | Microsoft Access ... | simulaties_ILVO.d... | 9:47


KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access
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frmGewassenSubMaatregelen
frmGrafiekEvolutie
frmMaatregelen
frmOSSoortenSubMaatregelen
frmPercelen
frmPercelenSubContacten
frmRotaties
frmRotatiesSubContacten
KoolstofSimulator testversie 200810
ontwikkeld door:
Bodemkundige Dienst van België
afdrukken
vorig scherm
Bedrijf: Bomans Erik
Rotatie: Jaar1: maïs, korrelmaïs
GFT-compost 22.5t/ha in maart
Aanvoer door org. mest (kg/ha):
N P2O5
Jaar1: 221 160
Naam rotatie: ILVO1_GFT
Perceel: ILVO
Initieel C-gehalte: 1.56%
Grondsoort: zandleem
Diepte bouwvoor: 23 cm
Historiek: akkerbouw stalmest normaal
Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar
jaar
Legende
C-evolutie
min. streefwaarde
minimum waarde
Besluit
Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.
Vergelijkende tabellen C-toevoer

gemeten 1,97

KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access

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Forms
- frmContacten
- frmGewassenSubMaatregelen
- frmGrafiekEvolutie
- frmMaatregelen
- frmOSSoortenSubMaatregelen
- frmPercelen
- frmPercelenSubContacten
- frmRotaties
- frmRotatiesSubContacten

frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België — Universiteit Gent — lne.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Rotatie: Jaar1: maïs, korrelmaïs
GFT-compost 22.5t/ha in maart + vleesvarkensdrijfmest 45t/ha in maart

Aanvoer door org. mest (kg/ha):

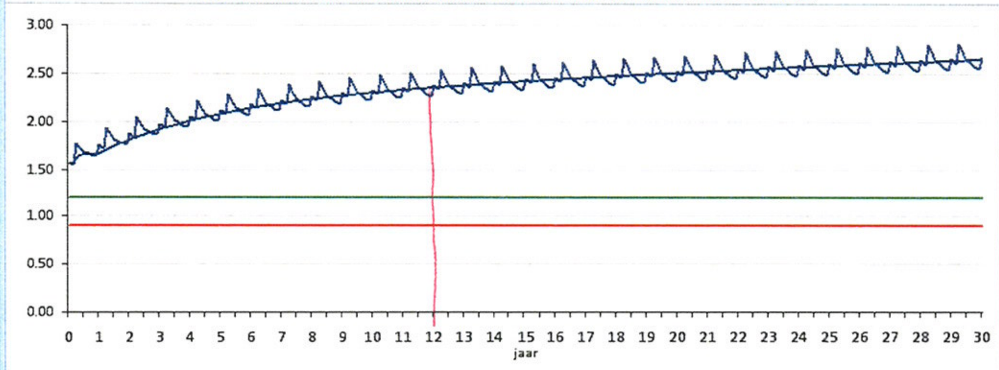
	N	P2O5
Jaar1:	585	335

Naam rotatie: ILVO3

Perceel: ILVO

Initieel C-gehalte:	1.56%
Grondsoort:	zandleem
Diepte bouwvoor:	23 cm
Historiek:	akkerbouw stalmest normaal

Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende
- C-evolutie
- min. streefwaarde
- minimum waarde

Besluit
Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

gemeten: 2 %

Form View — Num Lock

start | bordau | Gadwin | My Documents | e/pop | Inbox - Microsoft ... | Microsoft Access ... | simulaties_ILVO.d... | 9:49

KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access

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Forms
- frmContacten
- frmGewassenSubMaatregelen
- frmGrafiekEvolutie
- frmMaatregelen
- frmOSSoortenSubMaatregelen
- frmPercelen
- frmPercelenSubContacten
- frmRotaties
- frmRotatiesSubContacten

frmContacten | frmRotaties | frmGrafiekEvolutie

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België

http://www.ugent.be/nl/departments?ugentid=LA12

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Naam rotatie: ILVO4

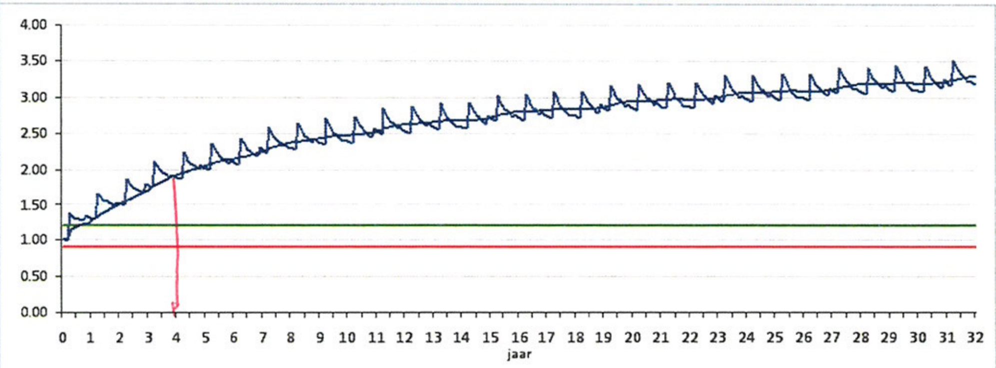
Perceel: ILVO2
- Initieel C-gehalte: 1%
- Grondsoort: zandleem
- Diepte bouwvoor: 23 cm
- Historiek: akkerbouw stalmest normaal

Rotatie:
- Jaar1: voederbieten (teeltresten ingewerkt) GFT-compost 50t/ha in maart
- Jaar2: maïs, snijmaïs GFT-compost 50t/ha in maart
- Jaar3: spruitkolen GFT-compost 50t/ha in maart
- Jaar4: aardappelen GFT-compost 50t/ha in maart

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	490	355
Jaar2:	490	355
Jaar3:	490	355
Jaar4:	490	355

Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar



Legende
- C-evolutie
- min. streefwaarde
- minimum waarde

Besluit

Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.

Vergelijkende tabellen C-toevoer

gemeten 1,8

Form View | Num Lock

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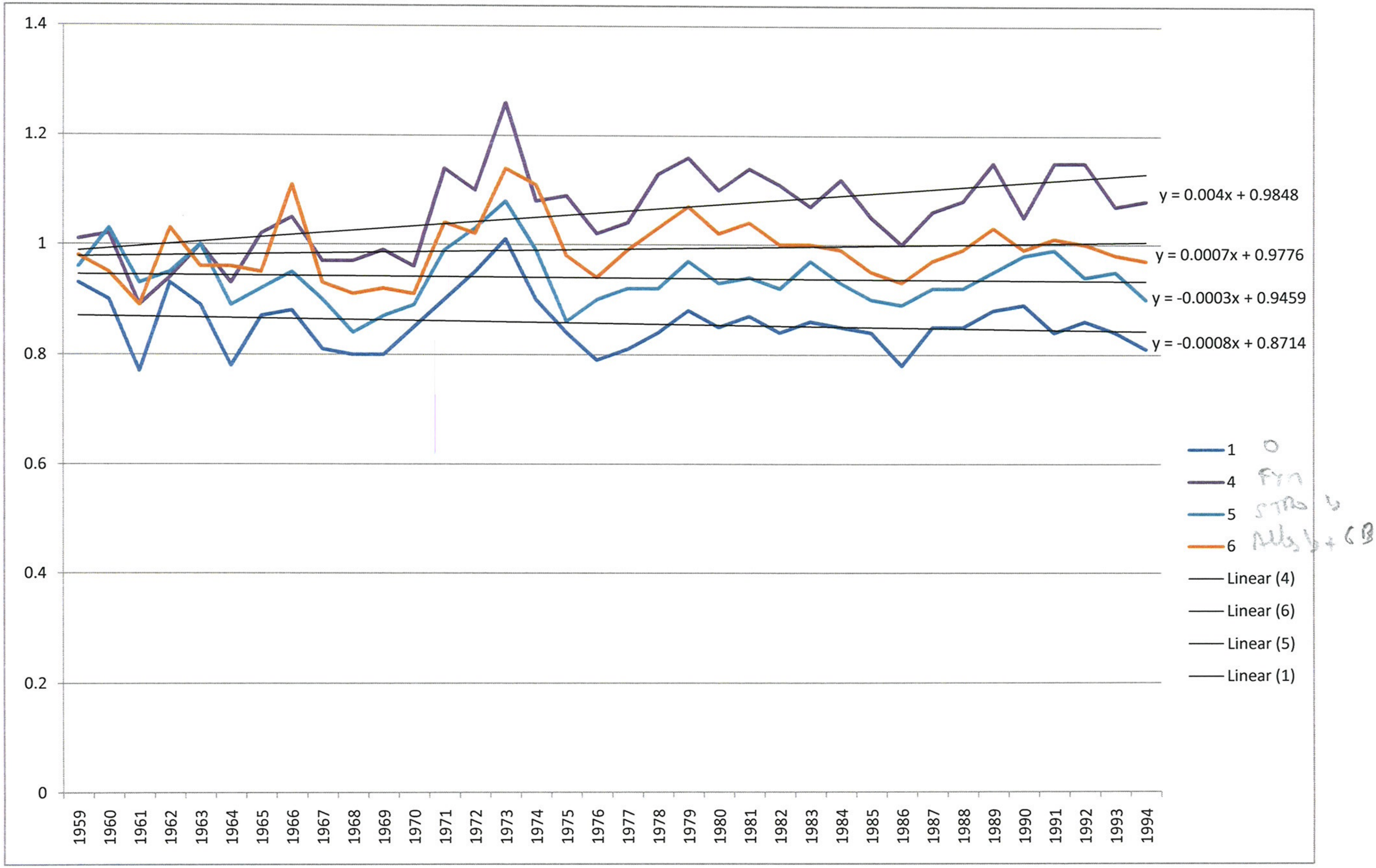
Liroux


1.4
1.2
1
0.8
0.6
0.4
0.2
0
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
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1971
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1975
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1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
y = 0.004x + 0.9848
y = 0.0007x + 0.9776
y = -0.0003x + 0.9459
y = -0.0008x + 0.8714
1
4
5
6
Linear (4)
Linear (6)
Linear (5)
Linear (1)

1

KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access

Forms: frmContacten, frmGewassenSubMaatregelen, frmGrafiekEvolutie, frmMaatregelen, frmOSSoortenSubMaatregelen, frmPercelen, frmPercelenSubContacten, frmRotaties, frmRotatiesSubContacten

KoolstofSimulator testversie 200810

ontwikkeld door: Bodemkundige Dienst van België, Universiteit Gent, Ine.

afdrukken | vorig scherm

Bedrijf: Bomans Erik

Naam rotatie: liroux58_75_1

Perceel: Liroux

- Initieel C-gehalte: 0.94%
- Grondsoort: leem
- Diepte bouwvoor: 23 cm
- Historiek: akkerbouw zonder organische bemesting

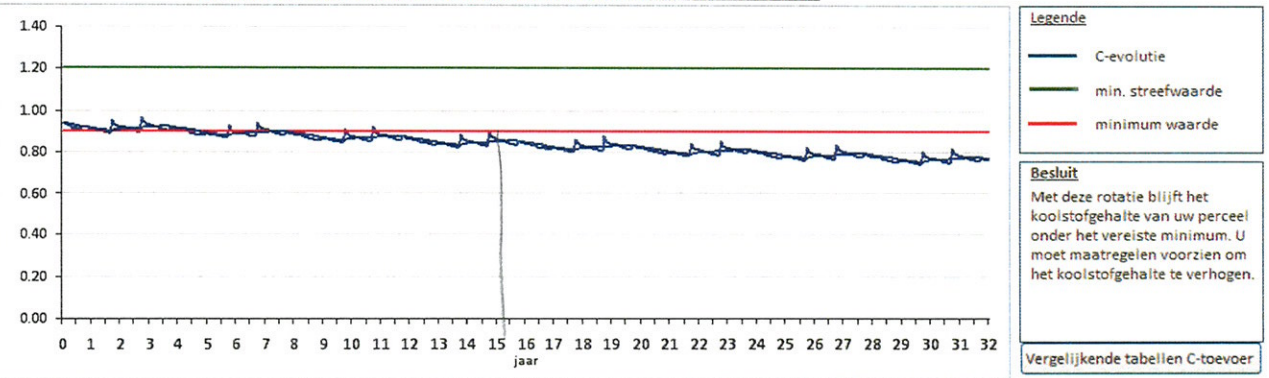
Rotatie:

- Jaar1: suikerbieten (teeltresten afgevoerd)
- Jaar2: tarwe, wintertarwe (stro afgevoerd)
- Jaar3: tarwe, zomertarwe (stro afgevoerd)
- Jaar4: veldbonen

Aanvoer door org. mest (kg/ha):

	N	P2O5
Jaar1:	0	0
Jaar2:	0	0
Jaar3:	0	0
Jaar4:	0	0

Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar

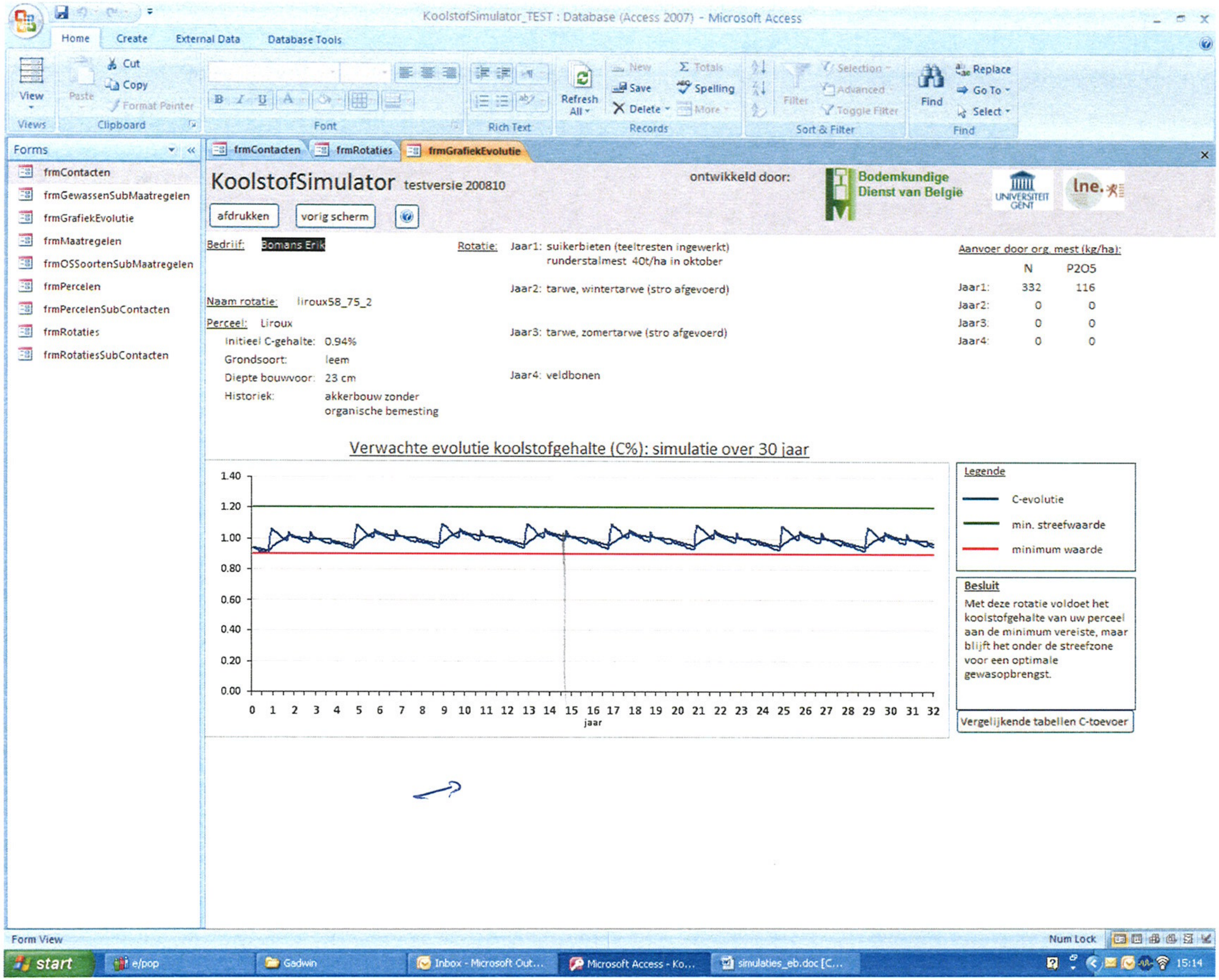


Besluit

Met deze rotatie blijft het koolstofgehalte van uw perceel onder het vereiste minimum. U moet maatregelen voorzien om het koolstofgehalte te verhogen.

Vergelijkende tabellen C-toevoer

Form View | Num Lock | start | e/pop | Gadwin | Inbox - Microsoft Out... | simulaties_eb.doc [C... | Microsoft Access - Ko... | 16:07


KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access
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frmGrafiekEvolutie
frmMaatregelen
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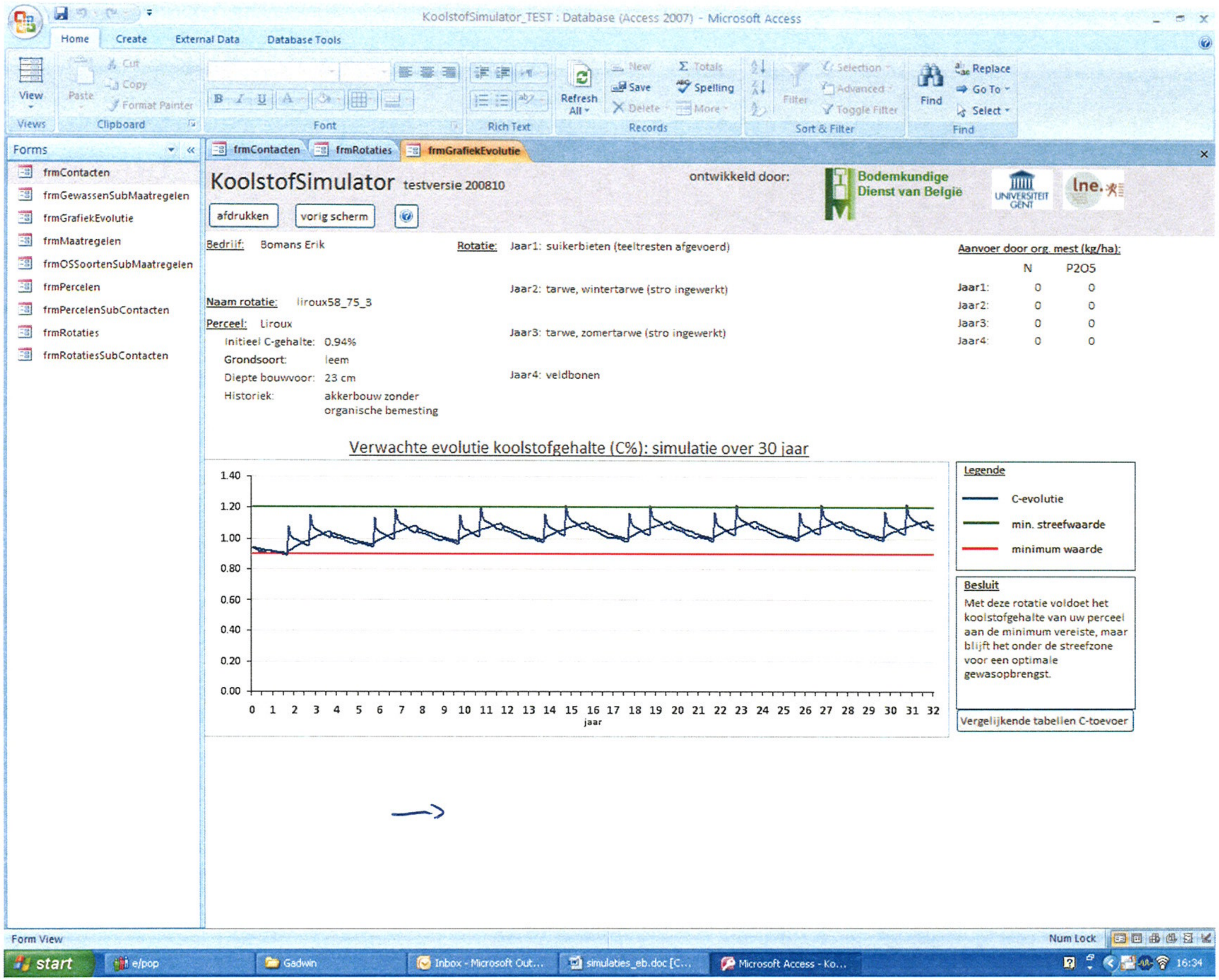
frmPercelen
frmPercelenSubContacten
frmRotaties
frmRotatiesSubContacten
KoolstofSimulator testversie 200810
ontwikkeld door:
Bodemkundige Dienst van Belgie
afdrukken
vorig scherm
Bedrijf: Bomans Erik
Rotatie: Jaar1: suikerbieten (teeltresten ingewerkt) runderstalmest 40t/ha in oktober
Jaar2: tarwe, wintertarwe (stro afgevoerd)
Jaar3: tarwe, zomertarwe (stro afgevoerd)
Jaar4: veldbonen
Naam rotatie: liroux58_75_2
Perceel: Liroux
Initieel C-gehalte: 0.94%
Grondsoort: leem
Diepte bouwvoor: 23 cm
Historiek: akkerbouw zonder organische bemesting
Aanvoer door org. mest (kg/ha):
N P2O5
Jaar1: 332 116
Jaar2: 0 0
Jaar3: 0 0
Jaar4: 0 0
Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar
jaar
Legende
C-evolutie
min. streefwaarde
minimum waarde
Besluit
Met deze rotatie voldoet het koolstofgehalte van uw perceel aan de minimum vereiste, maar blijft het onder de streefzone voor een optimale gewasopbrengst.
Vergelijkende tabellen C-toevoer
Form View
Num Lock
15:14



KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access
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frmGrafiekEvolutie
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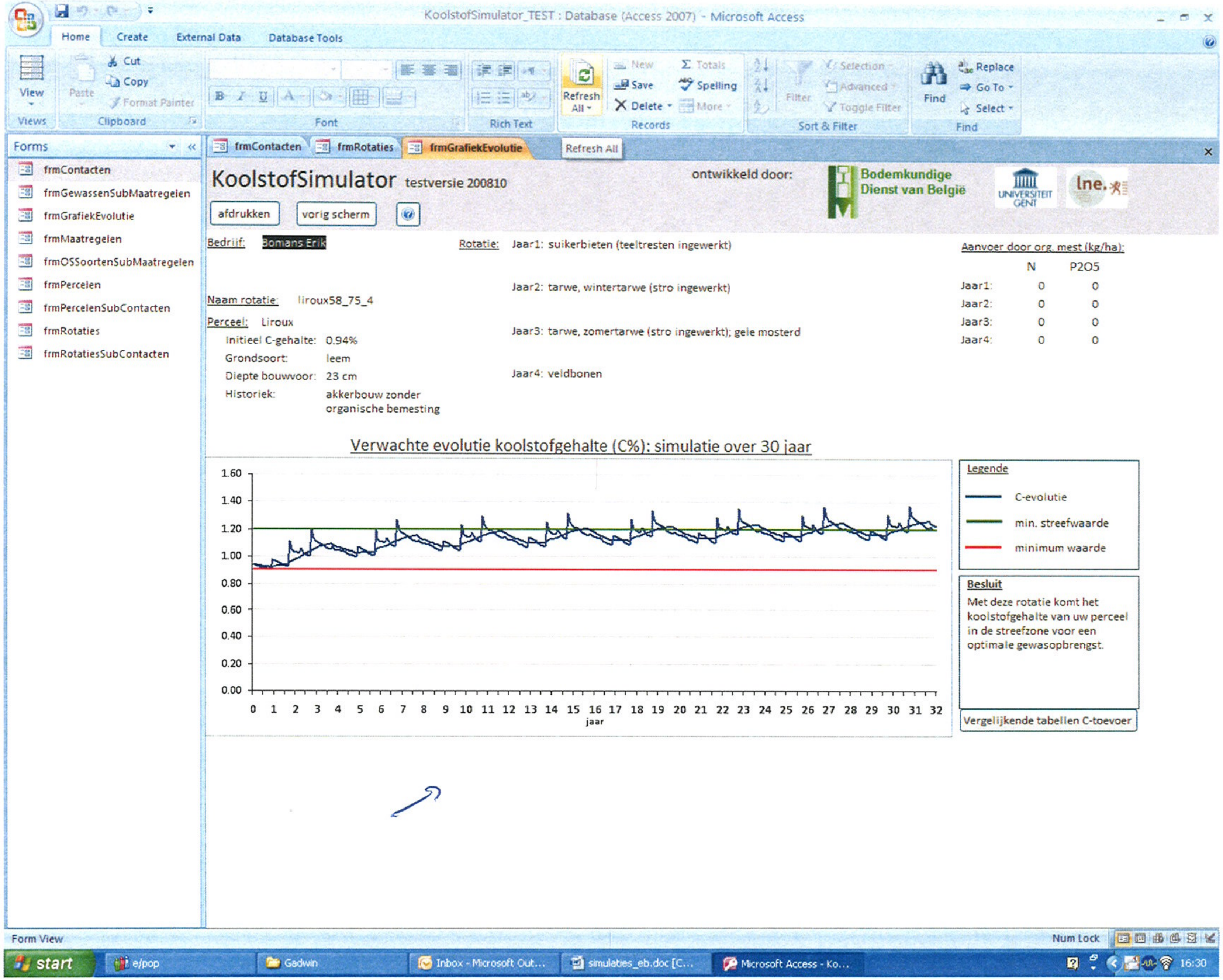
frmOSSoortenSubMaatregelen
frmPercelen
frmPercelenSubContacten
frmRotaties
frmRotatiesSubContacten
KoolstofSimulator testversie 200810
ontwikkeld door:
Bodemkundige Dienst van België
afdrukken
vorig scherm
Bedrijf: Bomans Erik
Naam rotatie: liroux58_75_3
Perceel: Liroux
Initieel C-gehalte: 0.94%
Grondsoort: leem
Diepte bouwvoor: 23 cm
Historiek: akkerbouw zonder organische bemesting
Rotatie: Jaar1: suikerbieten (teeltresten afgevoerd)
Jaar2: tarwe, wintertarwe (stro ingewerkt)
Jaar3: tarwe, zomertarwe (stro ingewerkt)
Jaar4: veldbonen
Aanvoer door org. mest (kg/ha):
N P2O5
Jaar1: 0 0
Jaar2: 0 0
Jaar3: 0 0
Jaar4: 0 0
Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar
jaar
Legende
C-evolutie
min. streefwaarde
minimum waarde
Besluit
Met deze rotatie voldoet het koolstofgehalte van uw perceel aan de minimum vereiste, maar blijft het onder de streefzone voor een optimale gewasopbrengst.
Vergelijkende tabellen C-toevoer


KoolstofSimulator_TEST : Database (Access 2007) - Microsoft Access
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frmGewassenSubMaatregelen
frmGrafiekEvolutie
frmMaatregelen
frmOSSoortenSubMaatregelen
frmPercelen
frmPercelenSubContacten
frmRotaties
frmRotatiesSubContacten
KoolstofSimulator testversie 200810
ontwikkeld door:
Bodemkundige Dienst van Belgie
afdrukken
vorig scherm
Bedrijf: Bomans Erik
Naam rotatie: liroux58_75_4
Perceel: Liroux
Initieel C-gehalte: 0.94%
Grondsoort: leem
Diepte bouwvoor: 23 cm
Historiek: akkerbouw zonder organische bemesting
Rotatie: Jaar1: suikerbieten (teeltresten ingewerkt)
Jaar2: tarwe, wintertarwe (stro ingewerkt)
Jaar3: tarwe, zomertarwe (stro ingewerkt); gele mosterd
Jaar4: veldbonen
Aanvoer door org. mest (kg/ha):
N P2O5
Jaar1: 0 0
Jaar2: 0 0
Jaar3: 0 0
Jaar4: 0 0
Verwachte evolutie koolstofgehalte (C%): simulatie over 30 jaar
jaar
Legende
C-evolutie
min. streefwaarde
minimum waarde
Besluit
Met deze rotatie komt het koolstofgehalte van uw perceel in de streefzone voor een optimale gewasopbrengst.
Vergelijkende tabellen C-toevoer
Form View
Num Lock

UCL

Ik heb het expertsysteem geprobeerd. Ik moet zeggen dat het er goed uitziet. Ik had aanvankelijk een probleem om het opgestart te krijgen. Ik kwam niet voorbij het eerste blad waar de naaam en contact gegevens meoten worden ingevuld. Later maakte het programma wel een bestand aan en kon ik de simulaties uitvoeren. Voor het invoeren van de rotaties zou ik het gemakkelijk vinden als er bij de menu lijsten ook een mogelijkheid is om te herstellen (een gewas of bemesting ongedaan te maken). Ik begrijp dat je natuurlijk een nieuwe rotatie kunt invoeren, maar een foutje is snel gemaakt en het zou handig zijn om dit te kunnen herstellen. Ik heb eens snel de simulatie getest op het lange termijn experiment in Gembloux (zonder mest en met export van gewas residus). De uitkomsten kwamen goed overeen met de waarnemingen. Toen ik gemiddelde waardes voor de leemstreek gebruikte uit het werk van Esther Goidts kwam ik minder goed uit. Dit hangt echter samen met andere factoren.

Samenvattend: kleine verbeteringen zouden het product verbeteren, maar het is zeker te gebruiken en voor zover ik het heb getest geeft het ook realistische uitkomsten.

Groeten

Bas

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phone: +32 10 472056
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Modelling the evolution of regional carbon stocks in Belgian cropland soils

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van Wesemael, B., Lettens, S., Roelandt, C. and Van Orshoven, J. 2005. **Modelling the evolution of regional carbon stocks in Belgian cropland soils.** Can. J. Soil. Sci. **85**: 511–521. In long-term experiments, it has been demonstrated that management of cropland influences the evolution of soil organic carbon (SOC) stocks. National inventories of SOC stocks in Belgium have recently been compiled, and show an evolution of SOC stocks of arable land from 1960 to 1990 and 2000. In order to analyse the driving forces of these changes, we concentrate on the SOC evolution in the soil associations of three of the 13 Belgian agricultural regions (Dunes–Polders, Loam belt and Condroz). The small confidence limits around the mean SOC values within some soil associations (0.4–12.7 t C ha^{-1}) allow us to compare the observed values with the results of the RothC soil carbon model and hence quantify the most important driving forces. After estimating the local parameters by fitting the model to SOC values from a long-term experiment in central Belgium, the model was run from 1960 to 2000 for typical soil profiles of soil associations in the three agricultural regions. The main factors inducing changes in SOC stocks are the increase in plough depth as a result of continued mechanisation in the 1960s and the sustained input of organic amendments in the form of farmyard manure and slurry. In contrast to earlier publications on CO_2 emissions from agricultural soils, the model did not predict a decrease in SOC stocks for the period 1990–2000. A slight increase was observed, although this increase is not significant for most soil associations. The comparison between modelled and observed SOC data at two time slices allows the uncertainty of the model results to be estimated. This uncertainty ranges from 7.5 to 14.4% of the SOC stock and is in the same order of magnitude as the uncertainty around SOC modelling for the long-term experiments both in Belgium and elsewhere in Europe. The organic matter concentration in the topsoil, an indicator for soil quality, was in the range of 1.5 to 3.3%. Organic matter content increased in the Dunes–Polders and decreased in the Loam belt and the Condroz from 1960 to 2000. Many soils in the Loam belt are now close to the critical level of 2% under which the soils are vulnerable to compaction and erosion.

Key words: Soil organic carbon, regional modelling, soil-land-unit, Belgium

van Wesemael, B., Lettens, S., Roelandt, C. et Van Orshoven, J. 2005. **Modélisation de l'évolution des stocks de carbone dans les sols agricoles belges.** Can. J. Soil. Sci. **85**: 511–521. Il est démontré, sur base d'essais permanents, que les techniques culturales influencent l'évolution des réserves de carbone organique des sols agricoles (COS). En Belgique, des inventaires nationaux récents montrent une évolution des réserves de carbone du sol durant la période 1960 à 1990 et 2000. Dans le but d'analyser les principaux acteurs de ces changements, notre étude se concentre sur l'évolution des réserves de COS des associations de sols présentes dans trois des treize régions agricoles de Belgique: les Dunes–Polders, la région limoneuse et le Condroz. Les limites de confiance, cernant étroitement les valeurs moyennes de COS de la plupart des associations, nous permettent de comparer les valeurs observées aux simulations obtenues à l'aide du modèle RothC. Cette démarche permet de quantifier les facteurs les plus actifs dans l'évolution des réserves de COS. Après estimation des paramètres locaux par ajustement des paramètres du modèle à l'évolution des réserves de COS observées, RothC simula l'évolution des stocks de carbone pour les associations de sols typiques des trois régions agricoles sur la période allant de 1960 à 2000. Les principaux facteurs induisant des variations de la teneur en carbone organique du sol sont l'augmentation de la profondeur de labour et l'accroissement des apports d'effluents d'élevage sous forme de fumier et de lisier. Contrairement aux résultats publiés précédemment dans la littérature, le modèle ne prédit pas de diminution du contenu en carbone des sols durant la période 1990-2000. Une augmentation mineure et non-significative fut observée. L'incertitude des résultats de la modélisation a été évaluée en faisant la comparaison avec des valeurs observées en 1990 et 2000. Cette incertitude s'élève à 7.5–14.4 % du stock de COS et elle est du même ordre de grandeur que l'incertitude liée à la modélisation d'expérience à long terme. La concentration en matière organique de la couche superficielle du sol, témoin de la stabilité structurale, se situe entre 1.5 et 3.3%. Durant la période étudiée, cette quantité est en augmentation dans la région des Dunes–Polders, elle décroît dans la région limoneuse et dans le Condroz. De nombreux sols de la région limoneuse sont maintenant proches du seuil critique des 2% sous lequel les sols sont sensibles à l'érosion, la compaction et la battance.

Mots clés: Carbone organique du sol, modélisation à l'échelle régionale, unité paysagère, Belgique

Abbreviations: **BIO**, microbial biomass; **DPM**, decomposable plant material; **FYM**, farmyard manure; **HUM**, humified organic matter; **IOM**, inert organic matter; **LSU**, landscape unit; **PET**, potential evapotranspiration; **RPM**, resistent plant material; **SAU**, total area in production; **SOC**, Soil organic carbon; **SOM**, soil organic matter

Estimates of soil carbon stocks are currently available at rather coarse scales. Global soil data bases such as WISE and SOTER have been used to estimate the SOC stocks for the major soil units at the global and continental scale (Batjes 1996; Batjes and Dijkshoorn 1999; Bernoux et al. 2002). Examples of studies at regional scale also exist. Howard et al. (1995) demonstrated the large variation in SOC stocks for the United Kingdom with the bulk of the carbon stored in Scottish peat. Arrouays et al. (2001) reported spatial variation in SOC stocks induced by soil type, land use and climate in France. The influence of soil type, land use and climate on SOC stocks at the national scale implies that sequestration of carbon in the soil is limited to a local maximum, and that the carbon sequestration potential is spatially variable. Therefore, explicit account needs to be taken of the impact of soil type and local climate on SOC accumulation rates, and on suitability of land for different land management options (Smith, P. et al. 2000). The most appropriate way to study SOC content is on a unit area basis for a specified depth interval. In the literature two depth intervals are commonly used: 0–30 cm is considered to reflect the SOC stock, which reacts quickly to changes in climate, land use and management, 0–100 cm represents the total carbon stocks and the depth to which soil data are available for most soils (e.g., Batjes 1996).

Given the labour intensity of soil sampling and SOC analyses, specific programmes for determining SOC stocks covering the territory of an entire country to our knowledge do not exist. Instead data bases containing soil profiles described and analysed during the compilation of national soil maps are the most common source of SOC data. However, when using these data it should be realised that they were not specifically collected to compile SOC inventories. The data cover a time span of often more than 20 yr and the sampling points are not randomly distributed. Therefore, the data bases are not ideal instruments for deriving information for sites in between profile pits. Instead, the profile pits should be linked to the soil series of digitised soil maps and they should be used to represent the SOC content of these soil units (Van Orshoven et al. 1993). Routine analyses of the topsoil are carried out frequently for arable lands and grasslands (Vanongeval et al., 2000). Although the carbon content is one of the parameters analysed, the carbon distribution with depth cannot be inferred and, at least in Belgium, the location of the sample points is only known at the municipality level.

A GIS framework has been developed to estimate SOC stocks in Belgian terrestrial ecosystems (Lettens et al. 2004). The basic units have uniform soil, climate and land use and are referred to as landscape units (LSU). The LSUs are a topological intersection of the 1990 version of the Corine Land Cover dataset (European Commission 1993) and the digitised soil association map of Belgium (1:500 000; Tavernier and Maréchal 1962). For 1960, the soil carbon density expressed in tonne ha^{-1} can be computed directly from the profiles in the "Aardewerk" data base (Van Orshoven et al. 1993; Lettens et al. 2004). Carbon stocks are calculated for specified depth intervals using the carbon content, the horizon thickness, the bulk density and the stone content. For 1990 and 2000, the carbon content of arable soils is derived from several data bases containing the results of routine fertility analyses of the 0–23 cm topsoil. These inventories show that the SOC stock in the upper 30 cm of cropland soils increased from 51.0 ± 0.58 t C ha^{-1} in 1960 to 57.5 ± 0.17 t C ha^{-1} in 1990 and decreased again to 54.3 ± 0.14 t C ha^{-1} in 2000 (Lettens et al., 2004, 2005). The decrease in SOC stock for Belgian croplands of 0.3 t C ha^{-1} yr^{-1} from 1990 to 2000 is slightly lower than the decrease of 0.90 t C ha^{-1} yr^{-1} in Flemish croplands reported by Sleutel et al. (2003) and the decrease under the business as usual scenario in European croplands of 0.84 t C ha^{-1} yr^{-1} reported by Vleeshouwers and Verhagen (2002). However, the drivers of these changes in SOC stocks are difficult to determine from either inventories aggregated at the regional scale or from modelling exercises at the European scale with gridcells of c. 3000 km^2. Examples of regional scale modelling of SOC stocks exist for Iowa (Paustian et al. 2002) and Hungary (Falloon et al. 1998a). However, these exercises do not offer the possibility to validate model results against observations at different time slices. Alternatively, uncertainty analysis of model predictions is restricted to long-term experiments and hence the spatial variability of soil, climate and management data is not addressed (Falloon and Smith 2003). The spatially explicit inventories available for different time slices in Belgium consist of LSUs with a single soil association under a specified land use (Lettens et al. 2004, 2005). These LSUs of c. 50 km^2 provide an excellent starting point for research into the drivers of the SOC stock change in arable soils and their observed SOC stocks can be used to evaluate the uncertainty of model predictions.

This paper combines regional-scale SOC modelling with spatially explicit inventories of three different time slices i.e., 1960, 1990 and 2000 (Lettens et al. 2004, 2005). The objective of this paper is to investigate the uncertainty of modelling the SOC dynamics from 1960 to 2000 at the regional scale by comparing the model results to the SOC stocks of the landscape units distinguished by Lettens et al. (2004, 2005). Furthermore, the paper briefly highlights the risk of decrease in soil organic matter leading to a decrease in topsoil stability.

MATERIALS AND METHODS

Calibration of the RothC Model

The RothC-26.3 model was developed to simulate the turnover of organic carbon in non-waterlogged agricultural soils (Coleman and Jenkinson 1996). The model spilts soil organic carbon into four active pools and a small amount of inert organic matter (IOM). The active pools consist of decomposable plant material (DPM), resistant plant material (RPM), microbial biomass (BIO) and humified organic matter (HUM). Input of carbon from plant material is divided between DPM and RPM. The DPM/RPM ratio equals 1.44. These pools in turn decompose exponentially to produce CO_2, which is lost to the atmosphere, and BIO + HUM. The proportions between the quantity of CO_2 and BIO + HUM produced is determined by the clay content. The decomposition rate constants, in years^{-1}, of the different pools are: DPM: 10, RPM: 0.3, BIO: 0.66 and HUM: 0.02. The decomposition rate is modified as a function of temperature, soil moisture deficit and the presence of a plant cover. The model has been tested against SOC stocks in long-term experiments under a range of climate and soil conditions (Coleman et al. 1997; Smith et al. 1997). The internal structure and internal parameters were unaltered. Further details of the RothC model and the model itself can be obtained from the GCTE SOMNET website (http://www.rothamsted.bbsrc.ac.uk/aen/somnet/).

In this paper, the model was first used to simulate the evolution of SOC stocks for long-term experiments representing the dominant crop rotation in Belgium. Once confidence was obtained in the model's performance to simulate the SOC evolution in function of carbon input from a growing crop, for which experimental data do not exist, addition of farmyard manure (FYM) or plant residues, the model was used at the regional level to simulate carbon stocks of the LSUs.

The long-term experiments have been conducted by the Centre de Recherche Agronomique de Gembloux since 1959 and are one of the GCTE SOMNET sites (Frankinet et al. 1993). The soil was classified as a Eutric Cambisol according to the FAO system or a Hapludalf according to the USDA soil taxonomy. The site has a cool temperate climate (Cbf in the Köppen classification) with a annual minimum temperature of 6.4°C, an annual maximum temperature of 14.4°C and a mean annual precipitation of 767 mm. The precipitation is evenly distributed throughout the year. The silty soil with a clay percentage of 15.4% and an initial SOC stock of 38.28 t C ha^{-1} (0–22 cm) was ploughed to a depth of 22 cm and occasionally 35 cm. The rotation consists of sugar beet followed by 2 or 3 yr of cereals, mainly winter wheat, winter barley, pigeon beans, oats and fallow. There are six treatments with six replicates each receiving 106–128 kg N yr^{-1} of synthetic fertiliser. All treatments have been modelled, but only the ones with export of crop residues and no additions of animal manure (control), export of crop residues and application of animal manure (FYM) and turning under of crop residues and green manure without animal manure (residue) will be discussed. The control treatment only received 1.92 t C ha^{-1} yr^{-1} crop residue in 1959. The FYM treatment received 1.92 t C ha^{-1} yr^{-1} crop residue and 4.6 t C ha^{-1} yr^{-1} FYM in 1959 and 1.23 t C ha^{-1} yr^{-1} FYM from 1960 to 1994. The residue treatment received crop residues and green manure at a rate of 1.75 t C ha^{-1} yr^{-1} from 1959 to 1994. The monthly precipitation and average temperature recorded at the meteorological station of Gembloux (at 3 km) were averaged for the 1959–1994 period. Potential evapotranspiration (PET) was calculated from the monthly temperature by means of the Thornthwaite equation (Shaw 1994, p. 260). PET was converted to open pan evaporation, required as input by the RothC model by dividing the PET by 0.75 (Coleman and Jenkinson 1996). Amendments of FYM, slurry, crop residues and green manure were converted to carbon input and averaged over the measurement period.

The IOM pool was estimated from the initial SOC stock using the equation proposed by Falloon et al. (1998b). RothC was then run to equilibrium, iteratively fitting carbon inputs to match the initial SOC stock and thus the distribution in compartments with different decomposition rates (DPM, RPM, BIO and HUM; Coleman and Jenkinson 1996). The plant C input to the soil was estimated by optimising the total SOC stock predicted by the model to the measured data of the control experiment. The same plant C input was then used adding FYM and or crop residue as specified for the other experiments. The plant C input that fitted both the control experiment and those with amendments was retained. The performance of the model was evaluated on the root mean square error (RMSE) used by Smith et al. (1997):

$$RMSE = \frac{100}{\bar{O}} \sqrt{\sum_{i=1}^{n} (P_i - O_i)^2 / n} \qquad (1)$$

Where O is observed, $\bar{O}$ is the mean of the observed values, P is predicted and n is the number of samples.

Regional Application of the RothC model

Once the plant input for a typical rotation in Belgian cropland (see above) was determined, the model was run for the soil associations under cropland (LSUs). The Belgian soil association map distinguishes 65 soil associations, which represent broad zones with similar texture and drainage class (Tavernier and Maréchal, 1962). A brief description of the soil associations to which the model was applied is given in Table 1. The clay content of the topsoils of those profiles located within each soil association was extracted from a geo-referenced soil profile database, "Aardewerk", and an average value was calculated for each soil association (Van Orshoven et al. 1993). The RothC model was run to equilibrium to reproduce the initial SOC stocks for these LSUs given by Lettens et al. (2004) as a starting value. The predicted SOC stock for the upper 22 cm in 1990 and 2000 was then compared to the observed stocks in the LSUs from the inventories by Lettens et al. (2005).

One of the problems in running soil carbon models at the regional scale is to ensure that the agricultural statistics are aggregated for the same spatial units as the biophysical data on soil and climate. The agricultural regions were selected as aggregation level for the land management data. Thirteen agricultural regions are distinguished in Belgium with relatively homogenous soils, climate and dominant type of agriculture. The boundaries of these regions coincide with those of a group of soil associations. Since the 1950s farmers have been requested each year to declare a large number of variables to the National Institute for Statistics (INS 1958–2002). Three mainly arable agricultural regions were selected coinciding with the main climate gradient in Belgium (Fig. 1). In particular, the average temperature of the coldest month (from 1960 to 2000) decreases from the coast (3.71°C) to the centre (2.14°C) and the plateau of the Condroz (1.94°C). The average annual precipitation increases along the same gradient from

Table 1. Observed SOC stocks and change in stocks over time in the upper 22 cm of soil for the arable LSUs in three agricultural regions. The number of samples, the 95% confidence interval and a brief description of the soil associations are given

Agricultural region	Association number[z]	1960[y] (t C ha^{-1})	*n*	1990[x] (t C ha^{-1})	*n*	2000[x] (t C ha^{-1})	*n*	Delta 1960–1990 (t C ha^{-1}yr^{-1})	Delta 1990–2000 (t C ha^{-1}yr^{-1})	Association description	
Dunes–Polders	3	47.2 ± 6.9	18	43.7 ± 0.9	216	41.4 ± 1.4	135	−0.1	−0.2	Sand-sandloam soils	
	4	45.5 ± 4.3	33	48.6 ± 1.2	142	47.0 ± 3.0	40	0.1	−0.2	Clay soils	
	5	36.5 ± 6.6	27	54.2 ± 2.5	344	52.1 ± 2.5	332	0.6	−0.2	Soils with a clay cover	
	6	47.2 ± 9.5	15	52.7 ± 2.2	141	52.9 ± 2.6	130	0.2	0.0	Soils in covered depressions	
	7	26.7 ± 3.9	18	48.0 ± 2.2	34	46.8 ± 2.4	46	0.7	−0.1	Soils prone to sealing	
	8	34.8 ± 2.3	56	51.8 ± 1.5	346	49.3 ± 1.6	342	0.6	−0.3	Soils in former channels	
	9	60.7 ± 12.7	22	47.6 ± 1.3	316	43.7 ± 1.1	370	−0.4	−0.4	Soils in depressions	
	10	41.2 ± 4.8	26	53.0 ± 2.6	94	49.6 ± 2.6	87	0.4	−0.3	Soils of former mudflats	
	11	39.1 ± 6.2	30	58.1 ± 3.3	61	52.1 ± 2.3	67	0.6	−0.6	Soils of marshes	
	12	42.5 ± 4.1	30	46.0 ± 0.7	481	42.3 ± 0.9	344	0.1	−0.4	Covered Pleistocene soils	
Loam belt	30	43.3 ± 2.1	195	37.9 ± 0.8	1582	36.2 ± 0.5	1091	−0.2	−0.2	Silt loam soils with textural	Excessively drained
	31	42.8 ± 1.3	524	35.1 ± 0.4	2358	32.8 ± 0.4	1407	−0.3	−0.2	or stuctural B horizon	Well-drained
	32	35.4 ± 1.2	440	35.0 ± 0.5	1306	31.9 ± 0.5	1495	0.0	−0.3		Moderately well drained
	33	38.6 ± 1.4	450	35.3 ± 1.1	605	35.4 ± 0.7	980	−0.1	0.0		Imperfectly drained
	34	47.2 ± 9.1	31	46.9 ± 5.1	39	44.0 ± 4.6	69	0.0	−0.3		Poorly drained
	35	35.7 ± 1.3	398	35.7 ± 1.0	85	32.9 ± 0.5	1077	0.0	−0.3	Silt loam soils with broken textural	
	36	29.8 ± 2.8	4	31.1 ± 1.8	2	24.3 ± 1.0	3	0.0	−0.7	or stuctural B horizon	
Condroz	41	50.6 ± 5.6	55	42.5 ± 3.6	128	40.4 ± 1.6	133	−0.3	−0.2	Stony loam soils with textural	Chalk or flint
	42	40.2 ± 4.8	32	32.9 ± 2.5	56	35.8 ± 2.4	77	−0.2	0.3	or stuctural B horizon containing:	Schist or sandstone
	43	37.9 ± 3.2	106	32.8 ± 2	76	35.1 ± 1.8	140	−0.2	0.2		Psammite
	44	39.1 ± 1.7	247	36.8 ± 1.4	208	37.7 ± 1.1	255	−0.1	0.1		Limestone
	46	54.0 ± 4	126	40.6 ± 1.8	186	45.3 ± 2.3	328	−0.4	0.5		Schist
	47	43.5 ± 3.8	78	41.1 ± 5.7	62	39.7 ± 2.3	103	−0.1	−0.1		Schist and limestone
	48	41.8 ± 3.3	64	40.4 ± 2.9	20	37.4 ± 2.7	75	0	−0.3		Schist and psammite

[z]After Tavernier and Maréchal (1962).
[y]Observed SOC stocks from Lettens et al. (2004)
[x]Observed SOC stocks from Lettens et al. (2005).

Fig. 1. Location of the long-term experiments (Gembloux) and the three agricultural regions: (1) Dunes-Polders, (2) Loam belt and (3) Condroz.

740 mm to 846 mm and 885 mm. The regions are characterised by poorly developed sand, clay to clay loam soils in marine and estuarial sediments (Dunes–Polders, associations 3–12 in Table 1), well-developed silt to silt loam soils with a cambic or argillic B horizon in the middle of Belgium (Loam belt, associations 30–36) and well developed stony loam soils with a cambic or argillic B horizon on the transition to the semi-continental plateaus (Condroz, associations 41–48). Time slices of approximately 5 yr from 1958 onwards were selected from the agricultural statistics (INS 1958–2002) with the following variables extracted: the total area in production (SAU), the areas under cropland and grassland, and the number of each type of livestock subdivided into age classes (Table 2).

Farmyard manure and slurry production were calculated according to the methodology proposed by Dendoncker et al. (2004). These authors estimate the annual production of either FYM or slurry using the livestock in age classes, the type of housing, the time spent in the housing and excretion coefficients published by the Walloon Government (Moniteur belge 2002). FYM and slurry inputs were then converted into carbon stocks using a dry matter content of 25% for FYM and 12% for slurry (Vlaamse Landmaatschappij 2004) and a carbon content of 41% for both (Brady and Weil 1996, p. 374). Smith, K.A. et al (2000, 2001) performed a series of surveys on the production and use of animal manure and found that both slurry and FYM were spread on grassland, maize and cereals. Since no data are available for Belgium, we assume that FYM and slurry were spread from July to November on both arable and grassland soils within the agricultural region.

For all simulations, the tillage depth was considered to be 22 cm. This corresponds to the tillage depth of the long-term experiments in Gembloux and to the sampling depth of the 1960, 1990 and 2000 SOC data. However, tillage depth has not remained constant over the 1960–2000 period. Mouldboard ploughs are the most frequently tillage implements in Belgium. In the long run, the overturning of the topsoil results in a plough layer with a uniform SOC content. An increase in tillage depth results in a decrease of SOC concentrations in the topsoil, since a dilution over a larger volume of soil of the same plant input occurs (Van Meirvenne et al. 1996). A tillage depth of 21 cm is reported in 1960 for the Loam belt (Van Oost et al., 2000) and for western Flanders (Van Meirvenne et al. 1996). As a result of mechanisation, the tillage depth in the Loam belt increased to 25 cm in 1970 and remained constant thereafter (Van Oost et al. 2000). This is confirmed by local farmers who state that the main constraint to deeper tillage is ploughing up the less fertile B horizon. In western Flanders a mean tillage depth of 36 cm is reported for 1990 by Van Meirvenne et al. (1996). We assume tillage depth to have increased from 21 cm in 1960 to 25 cm in 1970. Hence the modelled SOC stocks are multiplied by a factor decreasing from 1.0 in 1960 to 0.84 from 1970 to 2000.

Monthly precipitation and temperature for the centre of the three agricultural regions were extracted from a spatial

Table 2. Evolution of agricultural land use and livestock density for three agricultural regions in Belgium (INS 1958–2002)

Year	SAU[z] (ha)	Arable	Grassland	Horses	Cows	Pigs
		(%)			(number of animals per 100 ha)	
Dunes-Polders						
1958	77 009	57.2	41.9	11.7	167.1	95.7
1959	76 270	57.3	41.7	11.4	169.4	91.2
1965	75 536	58.5	39.7	7.8	166.4	121.3
1970	74 831	58.0	40.6	4.1	176.1	273.4
1975	71 809	58.6	40.7	2.9	196.1	356.3
1980	68 509	62.2	37.2	2.1	200.0	412.8
1985	67 365	64.3	35.1	1.8	203.9	480.2
1990	66 607	70.5	28.9	1.2	208.4	710.3
1995	67 529	74.0	25.2	1.5	210.0	788.4
2000	68 253	74.9	24.3	2.0	186.9	837.9
2002	67 896	72.7	26.4	2.0	175.4	778.3
Loam belt						
1958	363 688	65.1	32.4	11.2	123.4	55.6
1959	363 930	65.1	31.7	10.3	122.8	42.9
1965	362 459	66.2	30.2	4.6	126.5	75.2
1970	350 938	66.6	29.4	2.1	131.7	144.6
1975	343 329	71.6	26.9	1.2	138.2	142.3
1980	334 723	74.6	24.3	1.0	140.6	131.7
1985	331 972	76.4	22.5	0.7	143.4	119.5
1990	328 961	79.2	19.5	0.7	154.8	125.0
1995	329 398	81.3	17.1	0.8	158.3	119.3
2000	331 490	79.0	19.3	1.0	143.7	120.6
2002	330 505	78.5	19.7	1.1	137.1	121.0
Condroz						
1958	148 331	44.2	54.5	5.7	134.3	30.6
1959	147 688	43.5	54.8	4.8	136.8	31.8
1965	147 022	44.4	53.9	1.6	145.8	34.3
1970	145 113	46.6	51.3	1.5	154.3	52.3
1975	141 651	52.4	47.2	1.3	157.3	38.2
1980	137 482	56.3	43.5	1.4	157.8	23.1
1985	135 045	59.0	40.8	1.0	156.7	17.4
1990	134 553	61.5	38.3	1.0	170.6	14.2
1995	133 977	66.7	33.2	1.2	175.6	12.1
2000	134 462	64.1	35.8	1.4	168.5	21.6
2002	136 373	63.3	36.6	1.4	159.4	24.7

[z]SAU = total area in production.

climate database (ATEAM climatology) divided into 10′ × 10′ grid cells covering Europe (New et al. 2002). These were aggregated to average monthly precipitation and temperature for the period 1960–2000. PET was calculated from the temperature using the empirical formula of Thornthwaite and was converted to open pan evaporation using the same factor (OPE = PET/0.75) as for the long-term experiments (Shaw 1994, p. 260).

RESULTS AND DISCUSSION

Calibration of the RothC Model for Belgian Arable Cropping Systems

The RothC-26.3 model was run to represent three of the treatments of the long-term experiments in Gembloux (Fig. 1). The experiments were run under typical agricultural management i.e., including a sugar beet, winter wheat, winter barley, spring oats and pigeon beans rotation of varying length (Frankinet et al. 1993). Crop residues were exported from the control plot, which did not receive any organic amendments. This treatment was selected to iteratively adjust the plant input parameter to 1.7 t C ha^{-1} yr^{-1} (Fig. 2). The other two treatments were simulated using the same plant input (Fig. 2). However, slurry and FYM or plant residues were applied as specified in the experimental protocol. Organic amendments were expressed in carbon input and were averaged over the duration of the experiment (in t C ha^{-1} yr^{-1}). The amendments were applied from July to November weighted according to the frequency of application in each month. After calibrating the plant input, the model reasonably represents the observed SOC stocks with uncertainties ranging from 5.8% RMSE (Eq. 1) for the control to 6.9% for the FYM and 8.4% for the residue treatment. The RMSEs are in the same order of magnitude as the ones reported by Falloon and Smith (2003) for long-term experiments in the United Kingdom, Hungary and Sweden. A remarkable peak in observed SOC stocks of all treatments in 1973 cannot be explained. One factor might be the interannual variation in bulk density, which is not taken into account. As such, equivalent soil mass is a far better measure when determining soil carbon than is equivalent soil depth.

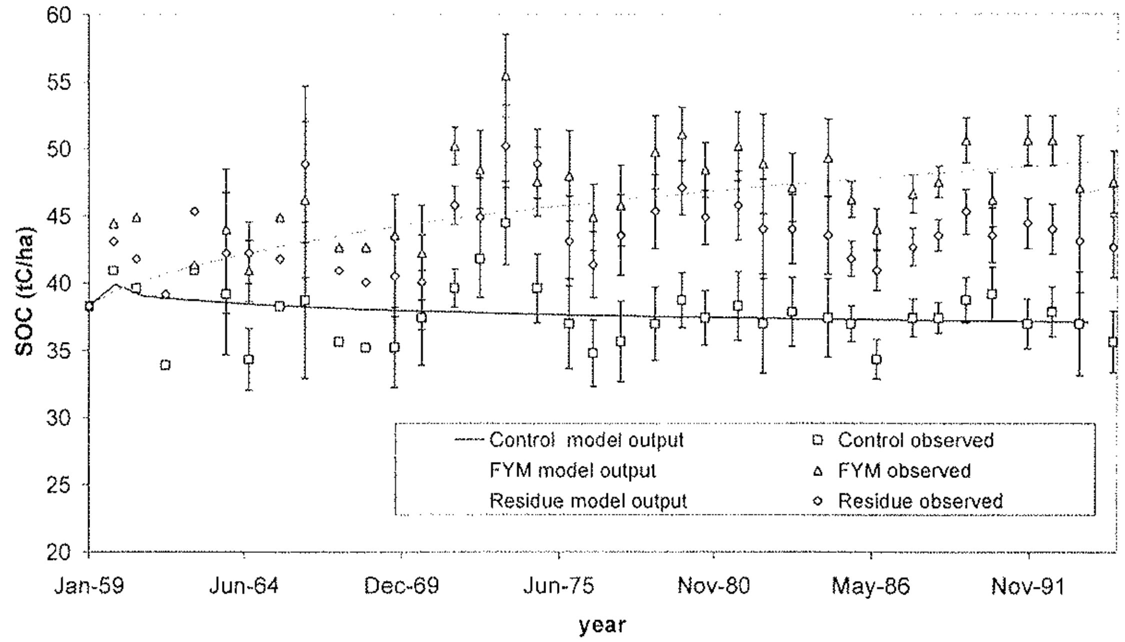

Fig. 2. SOC dynamics in the 0–22 cm topsoil of the long-term experiments of an arable rotation in Gembloux (Fig. 1). A control is compared with a treatment receiving farmyard manure (a) and a treatment where crop residues and green manure are incorporated in the soil (b). Error bars indicate the 95% confidence limits around the mean.

Running the model with annual monthly climate data instead of averaged monthly data or with annual FYM input did not ameliorate the model performance (results not shown). Although the mean annual temperature increased by 1.03°C from 1960 to 2000 and the increase is significant ($r^2 = 0.18$), this increase does not yet result in noticeable differences between model runs with annual climate data and those with long-term average climate data. It is, however, clear that climate change has to be taken into account for predictions of future SOC stocks.

Modelling SOC Stocks for Landscape Units in three Agricultural Regions

We evaluated the performance of the RothC model when applied to the basic LSUs of the spatially explicit inventories. LSUs under cropland in three agricultural regions were considered: Dunes–Polders, Loam belt and Condroz (Fig. 1). These agricultural regions represent broad zones with a dominant soil texture on a climatic transect from maritime (Dunes–Polders) to semi-continental conditions (Condroz). Furthermore, they are currently under predominantly arable land use with only gradual changes in land use having occurred over the past 50 yr (Table 2). The total agricultural area (SAU) has decreased by 10–15% and within the agricultural area a gradual conversion from grassland to arable land has occurred from at least 1958 to 1990. Although this conversion is gradual, we can not exclude that some of the samples in arable land originate from recently converted grasslands and therefore have a higher SOC stock. Given the dominance of arable land in the agricultural regions and the low annual conversion rates, this effect, which is not related to management of arable land, is considered to be negligible.

The SOC stocks in the upper 22 cm for the arable LSUs in each agricultural region are given in Table 1. In the Dunes–Polders, SOC stock increases by 0.3 t C ha^{-1} yr^{-1} between 1960, and 1990, and this increase is significant for 5 out of 10 LSUs. This increase is comparable with the increase of 0.31 t C ha^{-1} yr^{-1} for a larger region including the Dunes–Polders, which was reported by Van Meirvenne et al. (1996) based on a re-sampling in 1990 of 939 arable soils first analysed in the 1960s. However, these authors calculated their 1990 carbon stock to a depth of 36 cm taking into account the increase in tillage depth. The carbon stocks discussed in this paper refer to the upper 22 cm, which have been diluted as a result of the increase in tillage depth from 21 to 25 cm (Van Oost et al. 2000). From 1990 to 2000, the SOC stock decreased in the Dunes–Polders by 0.3 t C ha^{-1} yr^{-1}. However, this decrease is significant for only 3 out of 10 LSUs. This is in agreement with Sleutel et al. (2003) who could not find any significant trends between 1990 and 2000 for the Dunes–Polders region.

SOC stocks in the Loam belt are generally low and only decreased very slightly (0.07 t C ha^{-1} yr^{-1}) between 1960 and 1990. The decrease is significant for three out of six of the soil associations, when association 36 is disregarded because of the small number of samples. The decrease from 1990 to 2000 is in the same order of magnitude as in the Polder region and is significant for four out of six of the soil associations. In the Condroz, the SOC stock decreases from 1960 to 1990 at a rate of 0.19 t C ha^{-1} yr^{-1}, whereby only one out of seven soil associations shows a significant

Table 3. Manure and slurry production in the three agricultural regions

	Dunes-Polders			Loam belt			Condroz		
Year	FYM (t ha^{-1})	slurry (t ha^{-1})	total (t C ha^{-1})	FYM (t ha^{-1})	slurry (t ha^{-1})	total (t C ha^{-1})	FYM (t ha^{-1})	slurry (t ha^{-1})	Total (t C ha^{-1})
1958	13.5	–	1.4	10.2	–	1.0	10.5	–	1.1
1970	17.8	–	1.8	11.7	–	1.2	11.3	–	1.2
1990	10.9	23.8	2.3	6.7	7.3	1.0	7.2	4.5	1.0
2002	10.5	26.5	2.4	7.0	7.2	1.1	7.6	4.3	1.0

decrease. The increase from 1990 to 2000 is very slight and only significant for one soil association.

The dynamics of the SOC in the upper 22 cm of arable land were modelled for a soil association with low and high initial carbon stock in each agricultural region (Fig 3). The plant input of 1.7 t C ha^{-1} yr^{-1} calibrated for the long term in Gembloux was used. An export of crop residues was assumed. The production of FYM and slurry for each agricultural region is given in Table 3. Starting from the 1960 SOC values, the RothC model generally predicts the observed values in 1990 and 2000 reasonably well, although the large increase of the SOC stock in the Dunes–Polders (association 7) from 26.7 t C ha^{-1} in 1960 to 48.0 t C ha^{-1} in 1990 was not predicted (Fig. 3a). The decrease in SOC in each of the associations from 1960 to 1970 is a result of the dilution of organic inputs as a result of an increase in tillage depth. The mechanisation of agriculture was introduced after the Second World War and completed in the 1960s. According to a survey among farmers in the Loam belt this led to an increase of tillage depth from c. 18 cm for animal drought tillage to 25 cm in mechanised systems (Van Oost et al. 2000). This trend is also reflected in the decrease in the number of horses declared by farmers, which decreases rapidly until 1970 to reach a more or less stable value from 1975 onwards (Table 2). Overall, the model fails to predict the decrease in SOC from 1990 to 2000. Sleutel et al. (2003) suggested that this decrease is due to stricter environmental regulations aimed to prevent nitrate pollution of surface and groundwater.

In our calculations we assumed that all FYM and slurry produced in an agricultural region is spread on the agricultural area (SAU; Table 2). The quantity of FYM and slurry produced was estimated from livestock numbers, type of housing and time spent in housing using the method proposed by Dendoncker et al. (2004). Since the bulk of FYM and slurry is produced by cattle and pigs, a mean nitrogen concentration of 4–6 kg t^{-1} FYM or slurry can be assumed (Vlaamse Landmaatschappij 2004; Moniteur belge 2002). The manure production in Table 3 was converted to nitrogen production and then compared with the values published by the Flemish manure bookkeeping (Vlaamse Landmaatschappij 2004). For Flanders, we estimated a production of 197 kt N in 2000, which agrees well with the value of 191 kt N reported by the Flemish government (Vlaamse Landmaatschappij 2004). In 2002, the total nitrogen load in FYM and slurry amounts to 59 kg N ha^{-1} in the Condroz to 70 kg N ha^{-1} in the Loam belt and 180 kg N ha^{-1} in the Dunes–Polders. These values are close to the maximum quantities that can be spread on arable land: 80 to 130 kg N ha^{-1} according to Walloon legislation (Moniteur belge 2002) and 140 to 170 kg N ha^{-1} within nitrate vulnerable zones of Flanders (Vlaamse Landmaatschappij 2004). The limits for grassland are higher at 210 to 230 kg N ha^{-1} in the Walloon region and from 250 to 310 kg N ha^{-1} outside nitrate vulnerable zones in Flanders. In particular for the Dunes–Polders area with an average manure production close to the nitrogen limits for arable land, significant quantities could be concentrated on grassland or exported to other regions with lower manure production. Hence, carbon inputs from organic amendments are probably overestimated for the 1990–2000 period (Fig. 3).

The uncertainty of the regional scale modelling is expressed by the RMSE (Eq. 1) and ranges from 7.5 to 14.4%. As explained earlier, the inability to model the strong increase of SOC in association 7 of the polders region is not taken into account. This uncertainty is somewhat larger than the uncertainty obtained for the modelling of the long-term experiments (RMSE = 5.7–7.8%) and the uncertainty for six long-term experiments (RMSE = 6.8–8.5%) reported by Falloon and Smith (2003). This is not surprising since the quantitative description of the management practices, such as tillage depth and manure or residue input, is rather difficult at the regional scale. An uncertainty of 7.5 to 14.4% of the cropland SOC stocks estimated at 54.3 t C ha^{-1} in 2000 for the upper 30 cm (Lettens et al. 2005) has to be multiplied by the cropland area of 864 076 ha for Belgium (INS 1958–2000). This represents an uncertainty of 3.52 to 6.78 Mt C in the SOC stocks of arable soils. Expressed in CO_2 equivalents, this uncertainty amounts to 12.90 to 24.86 Mt CO_2 and is somewhat larger than Belgium's emission reduction target of 10.6 Mt CO_2 (7.5% of the 1990 emissions at 141 Mt CO_2; Royaume de Belgique 1997). Falloon and Smith (2003) extrapolated the uncertainty of model results for long-term experiments to the European cropland and found values five times the emission reduction target. Alternatively, these uncertainties can be compared with C sequestration in agricultural land. Dendoncker et al. (2004) estimated the Belgian potential for options such as bio-energy crops, spreading animal manure only on arable land, no-till farming and the use of cover crops at 0.95 Mt CO_2 yr^{-1} or a maximum of 5.7 Mt CO_2 in 2010. These are realistic scenarios taking into account environmental legislation and adoption rates of new techniques. At present, modelling SOC dynamics is useful to identify the drivers of changes in stocks and could be used to predict future stocks under different management scenarios. However, the uncertainty of the model predictions either at the site or the regional scale

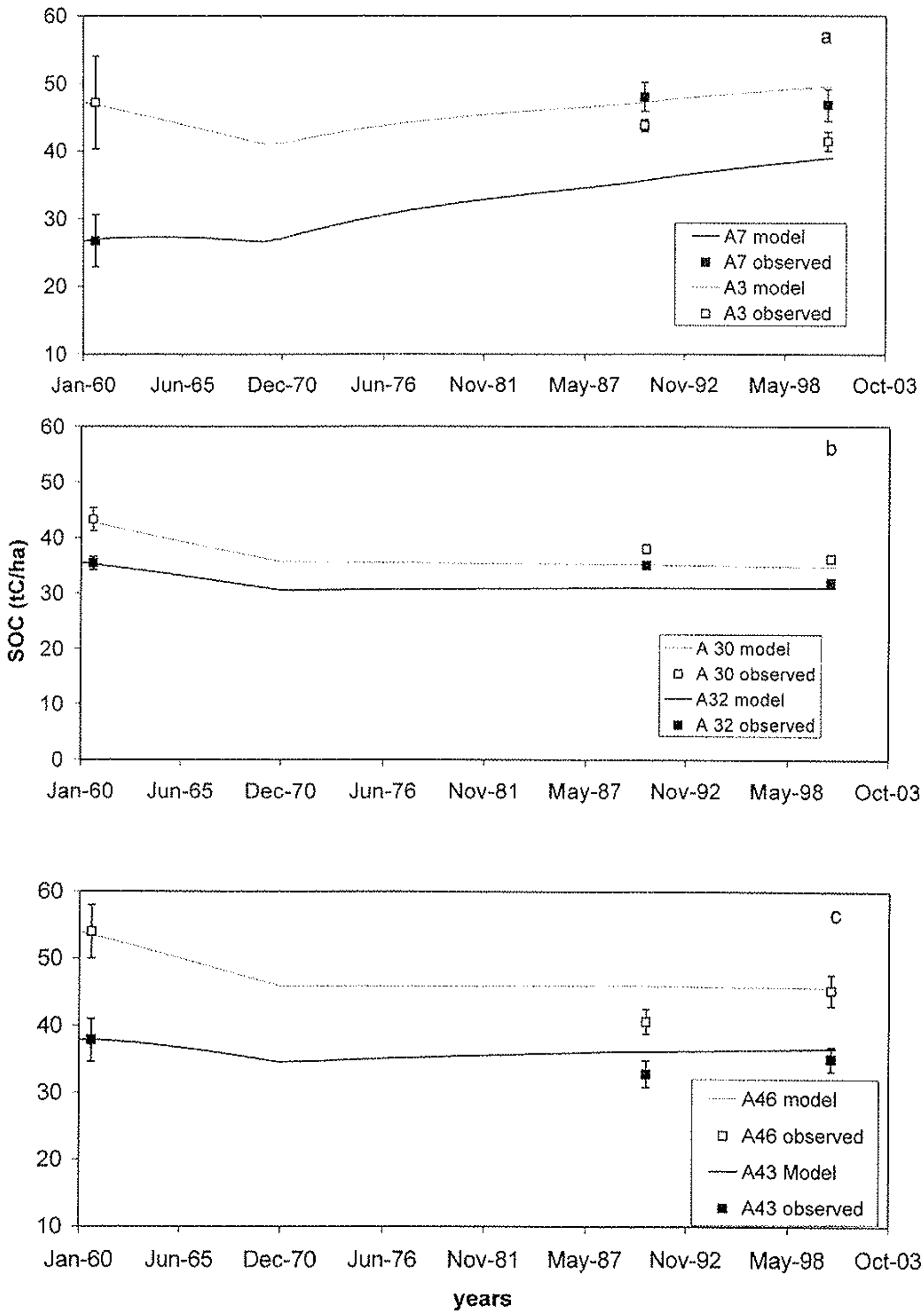

Fig. 3. Evolution of SOC stocks in the upper 22 cm of soil associations under arable land use in the three agricultural regions (a) Dunes–Polders, (b) Loam belt and (c) Condroz.

is still too large for this approach to be used in quantifying greenhouse gas emissions for the first commitment period.

Apart from the obvious interest of the stocks of SOC in the greenhouse gas emission debate, organic matter plays an important role in maintaining the stability of arable soils and increasing its resistance to soil erosion. Research along climatic gradients has demonstrated a strong correlation between soil organic matter (SOM) content and aggregate

Table 4. Evolution of the range of organic matter content in the upper 22 cm of the soil associations

	Soil association	Organic matter (%) 1960	1990	2000
Dunes–Polders	3	2.75	2.55	2.41
	7	1.56	2.80	2.73
Loam belt	30	2.35	2.06	1.97
	32	1.92	1.90	1.73
Condroz	43	2.21	1.92	2.05
	44	2.28	2.15	2.20

stability for SOM contents of up to 2% (Kemper and Koch 1966; Lavee et al. 1998). Under such conditions a stable soil structure can easily deteriorate to a soil crust. Two soil associations had SOM contents below this threshold in 1960 (Table 4). Since overall SOM increased from 1960 to 1990, all soil associations, except one in the Loam belt and one in the Condroz, are well above this threshold. The decrease in SOM from 1990 to 2000 resulted in all soil associations of the Loam belt to attain the 2% SOM threshold. Since, the SOM values are averages over large spatial units, it is very likely that the actual levels of SOM have fallen below the 2% threshold, at least in some parts of the soil associations with low SOM.

CONCLUSIONS

After calibration of the model on long-term experiments representing a typical arable rotation, the evolution in SOC stocks from 1960 to 2000 for the soil associations under cropland of three agricultural regions was simulated. For three Belgian agricultural regions, the evolution of SOC stocks in soil associations under cropland were modelled using the RothC 26.3 model. In general, RothC predicts a slight decrease for arable soils in the Loam belt and the Condroz and an increase in the Dunes–Polders. The main drivers of the changes in SOC are an increase in tillage depth as a result of mechanisation in the 1960s and an increase in the livestock numbers in particular in the Dunes–Polders region. The model fails to predict the decrease in SOC from 1990 to 2000 for the soil associations in the Loam belt and the Dunes–Polders. This is probably due to the fact that the input of manure is based on livestock numbers and excretion coefficients. In the 1990s limits for spreading of manure were introduced based on nitrogen loadings. In particular in the Dunes–Polders regions these limits are exceeded for arable land and hence manure has probably been concentrated on grasslands or maybe even exported. The observed SOC data at three time slices permitted an estimation of uncertainty of the model results (RMSE). The uncertainty ranges from 7.5 to 14.4% for the soil associations and is somewhat larger than the uncertainty around SOC modelling for the long-term experiments both in Belgium and elsewhere in Europe. This greater uncertainty can probably be attributed to the less precise information on management practices such as tillage depth and manure application. Given the large SOC stocks in arable land this uncertainty excludes the model results from application in greenhouse gas emission accounting in the framework of the Kyoto Protocol. Longer-term trends and impacts of agricultural scenarios on SOC stocks can, however, be calculated together with their uncertainty limits. Soil organic matter content is strongly correlated with aggregate stability and erosion risk in particular below the critical 2% level. Nearly all soil associations in the Loam belt have reached this level. Since these are average values, it is likely that large areas are actually below this 2% level.

ACKNOWLEDGEMENTS

This research was supported by the Belgian Science Policy under the Second Multiannual Scientific Support Plan for a Sustainable Development Policy (contract number EV/10/14A). The support is gratefully acknowledged. The authors are grateful to Dr. M. Frankinet of the Centre de Recherche Agronomique de Gembloux for providing us the data of the long-term experiments in Gembloux.

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The Electronic Rothamsted Archive

GCTE SOMNET

The official GCTE Soil Organic Matter Network Database

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1) EXPERIMENT

petite ferme / culture traditionelle

terres arables

- **Experiment name:** Essai permanent
- **Date began:** 1959 ... 1965

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2) CONTACT PERSON

Name: M. Frankinet frankinet@cra.wallonie.be

Address: Station de Phytotechnie, Chemin de Liroux 11, B-5030 Gembloux, Belgium

Telephone number: ~~32-81-61-27-~~41 081 62 5002

FAX: ~~32-81-61-41-52~~

Formal GCTE SOMNET member

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3) ENVIRONMENT

a) Where the experimental site is

Country: Belgium

Continent: Europe

Longitude: 4 degrees 43 minutes East

Latitude: 50 degrees 34 minutes North

b) Site history/geology

Geology: IV loam on III sand-Bruxellien

c) Ecosystem

6) MEASUREMENTS MADE DURING THE EXPERIMENT

a) Vegetation measurements made and frequency

- **Yield:** Annual
- **Total above-ground dry matter:** Annual
- **Total dry matter offtake:** Annual
- **Nitrogen content of offtake:** Annual
- Annual: P, K, Ca, Mg

b) Soil sampling

- Time zero soil measurements taken. 1959: pH, C%, N, exchangeable P, K, Mg, Ca. +aggregate stability using wet sieving +aggregates mean weight, diameter and percentage of stable aggregates. Depth: 20 cm. All samples stored since 1959.
- **Details of soil sampling method:** 2 cm diameter auger; plots sampled are 10m x 70m; 12 samples/plot.

c) Soil measurements made and frequency

- **Total carbon:** Annual
- **Method of measuring total carbon:** Oxydable C: Walkley-Black (Bichromate)

→ x 4/3 = total C

- **Biomass carbon:** Annual
- **Method of measuring biomass carbon:** Method of Stotzky (1960)
- **Total nitrogen:** Annual
- **Method of measuring total nitrogen:** Kjeldahl
- **Total mineral nitrogen:** Sometimes
- **Method of measuring total mineral nitrogen:** Extraction KCl 0.5N. J. Guiot et al. (1992) Bull.Rech.Agon.Gembloux 27(1),61-74.
- **Nitrogen measurements in other organic matter fractions:** Sometimes
- **Method of measuring nitrogen in other organic matter fractions:** Bremner method (1965). (Acid fractionation of N). Mineralization N potential (Stanford & Smith, 1972)
- **Nitrate nitrogen:** Sometimes
- **Method of measuring nitrate nitrogen:** Extraction KCl 0.5N. J. Guiot et al. (1992)
- **Ammonium nitrogen:** Sometimes
- **Method of measuring ammonium nitrogen:** Extraction KCl 0.5N. J. Guiot et al. (1992).
- **Soil bulk density or weight:** Not frequently
- **Method of measuring soil bulk density or weight:** Volume weight

d) Details of the meteorological station

Nearest meteorological station to the site: Gembloux which is 3 km from the site at coordinates 4deg41min E, 50deg33min N
Meteorological data is available from both a manual and an automatic station.

e) Meteorological data available and frequency

Rainfall: 1 manual (daily) and permanent automatic

9) KEY REFERENCES

Frankinet, M., Raimond, Y., Destain, J.P., Roisin, C. & Grevy, L. (1993) Organic matter management and calcic amendments in order to maintain or improve soil fertility. In: Soil biota, nutrient cycling and farming systems, (ed: Paoletti, Foissner, W. and Coleman, D.), Lewis Publishers, Boca Raton: 27-39.

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Information

- Information about the GCTE SOMNET
- Information about the Electronic Rothamsted Archive

Essai Permanent, Long Term Soil Organic Matter Test Plots, Belgium

Brief Record | Distribution | Attributes | Coverage | Personnel | Full Record | Update Record

brief distribution attributes coverage personnel full update

Summary

1999-11-15

This experiment began in 1959. The experiment consists of variable rotation of Sugar Beet followed by 2 or 3 years of other arable crops, mainly cereals (2 or 3 of winter wheat, winter barley, pigeon bean, oats, fallow). The treatments are: 1. Exportation of by-products - all years (split 1991-3); 2. Exportation of by-products (+Krilium 1959) (1959-74), Turning under of by-products + lime + pig slurry + green manure (1975-); 3. Exportation of by-products + lime (1959-74); Exportation of by-products + lime + pig slurry + green manure (1975-); 4. Exportation of by-products + FYM; 5. Turning under of straw; 6. Turning under of by-products + green manure.

The soil is classified as a Eutric cambisol (FAO) or Hapludalf(USDA). The soil properties at the site are:

- Depth of root limiting layer: 110cm
- Approximate carbon:nitrogen ratio: 10
- Approximate soil bulk density: 1.5 g/cm3
- Approximate minimum ground water level: 200 cm
- Percent clay (i.e. particles less than 2 um): 13.5%
- Percent silt (i.e. particles between 2 um and 50 um): 81.3%
- Percent sand (i.e. particles greater than 50 um): 5.4%
- Approximate minimum soil pH: 6
- Approximate maximum soil pH: 7.5
- Method of determining soil pH: H2O-KCl (ph depends on treatment).

The nearest meteorological station to the site is Gembloux which is 3 km from the site at coordinates 4deg41min E, 50deg33min N. Meteorological data is available from both a manual and an automatic station.

Variables measured are listed in the parameters section of this record.

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→ Frankinet, Marc 081/62 50 02

This information was compiled for the GCTE-SOMNET Database, Pete Smith, Pete Falloon, David Powlson, and Jo Smith. Soil Science Department, IACR-Rothamsted, UK.

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Related URL

URL: http://www.res.bbsrc.ac.uk/soils/somnet/index.html
Description: This url links to the GCTE-SOMNET home page where additional project information and methodology can be obtained. This site is currently in a datasharing phase of the network where actual data will become available shortly, at different levels of accessibility. Please follow this link for more information.

Temporal Coverage

Start Date: 1959-01-01

Geographic Coverage

ESSAI PERMANENT GEMBLOUX

TOTAL CARBON MEASUREMENTS

DATE OF MEASUREMENT : DATE
TREATMENT PLOT : TREAT : 1 = EXPORT OF BY-PRODUCTS, 2 = TURNING UNDER OF BY PRODUCTS PIG SLURRY-SLAKED LIME, 3 = EXPORT OF BY-PRODUCTS - PIG SLURRY SLAKED LIME, 4 = EXPORT OF BY-PRODUCTS-FARM YARD MANURE, 5 = EXPORT OF GREEN PRODUCTS-TURNING UNDER OF STRAW, 6 = TURNING UNDER OF BY-PRODUCTS-GREEN MANURE
NUMBER OF REPLICATES TAKEN : 6
NUMBER OF DUPLICATE MEASUREMENTS ON SAME SAMPLE : 1
VALUES OF TOTAL C FOR EACH REPLICATE/DUPLICATE : NONE
MEAN VALUE OF TOTAL CARBON FOR THIS PLOT AT THIS DATE : CVAL (with standard error) : STERR

TREAT	DATE	CVALUE	STERR
1	10/11/59	0.93	*
2	10/11/59	0.96	*
3	10/11/59	0.97	*
4	10/11/59	1.01	*
5	10/11/59	0.96	*
6	10/11/59	0.98	*
1	30/08/60	0.90	*
2	30/08/60	0.97	*
3	30/08/60	0.97	*
4	30/08/60	1.02	*
5	30/08/60	1.03	*
6	30/08/60	0.95	*
1	10/09/61	0.77	*
2	10/09/61	0.82	*
3	10/09/61	0.77	*
4	10/09/61	0.89	*
5	10/09/61	0.93	*
6	10/09/61	0.89	*
1	15/09/62	0.93	*
2	15/09/62	0.93	*
3	15/09/62	0.91	*
4	15/09/62	0.94	*
5	15/09/62	0.95	*
6	15/09/62	1.03	*
1	30/10/63	0.89	0.051
2	30/10/63	0.93	0.051
3	30/10/63	0.99	0.051
4	30/10/63	1.00	0.051
5	30/10/63	1.00	0.051
6	30/10/63	0.96	0.051
1	20/08/64	0.78	0.026
2	20/08/64	0.84	0.026
3	20/08/64	0.81	0.026
4	20/08/64	0.93	0.026
5	20/08/64	0.89	0.026
6	20/08/64	0.96	0.026
1	20/09/65	0.87	*
2	20/09/65	0.89	*
3	20/09/65	0.80	*
4	20/09/65	1.02	*
5	20/09/65	0.92	*
6	20/09/65	0.95	*
1	10/08/66	0.88	0.066
2	10/08/66	0.89	0.066
3	10/08/66	0.88	0.066
4	10/08/66	1.05	0.066
5	10/08/66	0.95	0.066
6	10/08/66	1.11	0.066
1	10/10/67	0.81	*
2	10/10/67	0.86	*

SITE NAME : ESSAI PERMANENT GEMBLOUX

SOIL SERIES DESCRIPTION :LEACHED BROWN SOIL (HAPLUDALF)

DESCRIPTION OF SOIL HORIZONS AND DEPTHS : PARENT MATERIAL LOESS : DEPTH, MORE THAN 200 cm

DEPTH OF SOIL IMPERMEABLE LAYER : NONE

APPROXIMATE SOIL WATER HOLDING CAPACITY OR RANGE : 58,5 mm Horizon 0/50

APPROXIMATE SOIL CLAY CONTENT OR RANGE : 15.4 %

APPROXIMATE SOIL CATION EXCHANGE CAPACITY OR RANGE : NONE

DETAILS OF SOIL PARTICLE SIZE DISTRIBUTION AND DENSITY : 15.3 % < 2 µ < 28.5 % < 20 µ < 51.3 % < 50 µ < 4.9 %

APPROXIMATE SOIL ORGANIC MATTER CONTENT OR RANGE : 1,5 (oxydable c x 1.724)

APPROXIMATE SOIL DELTA CARBON13 VALUE : NONE

APPROXIMATE SOIL DELTA CARBON14 VALUE : NONE

APPROXIMATE SOIL INERT CARBON CONCENTRATION : NONE

APPROXIMATE SOIL TOTAL N CONTENT : KJELDAHL : 0.020 /°°°

APPROXIMATE SOIL DELTA NITROGEN15 VALUE : NONE

APPROXIMATE SOIL BULK DENSITY : 1,5

APPROXIMATE SOIL WILTING POINT : 18 % Vol.. PF 4,2

APPROXIMATE SOIL WATER CONTENT : 35 % Vol. PF 2,48

APPROXIMATE SOIL HYDRAULIC CONDUCTIVITY : 8 cm/Day to 40 cm/Day (field measurements)

APPROXIMATE SOIL THERMAL CONDUCTIVITY : NONE

DETAILS OF SOIL WATER RETENTION CURVE : pF1 = 40 % Vol, pF2 = 37 % Vol, pF3 = 31 % Vol, pF3.7 = 22 % Vol, pF4.18 = 18 % Vol

DETAILS OF DISPERSIVITY : NONE

DETAILS OF ION CONCENTRATIONS IN SOIL SATURATED PASTE EXTRACTS (Ca, Mg, Na, K, Al, Fe, SO4, Cl) : EXCHANGEABLE Ca = 180 mg/100 gr soil, Mg = 20 mg/100 gr soil, K = 18 mg/100 gr soil

DETAILS OF OXIDE AND PHOSPHATE PRECIPITATES IN : EXCHANGEABLE P = 15 mg/100 gr soil

DETAILS OF SOIL EXCHANGEABLE PHOSPHORUS :18 mg/100 gr soil

APPROXIMATE ANNUAL EROSION LOSSES : NONE

WEIGHT OF ANNUAL LITTER FALL (KG/M) : 805

APPROXIMATE NITROGEN CONTENT OF ANNUAL LITTER FALL : NONE

APPROXIMATE ASH CONTENT OF ANNUAL LITTER FALL : NONE

DETAILS OF LITTER PARENT MATERIAL : NONE

DETAILS OF ATMOSPHERIC N DEPOSITION : NONE
DETAILS OF SITE SPECIFIC INFORMATION : 50 Deg 33 min 28 sec Lat N, 4 Deg 43 min 39 sec Long E, ALTITUDE : 170 m

3	10/10/67	0.84	*
4	10/10/67	0.97	*
5	10/10/67	0.90	*
6	10/10/67	0.93	*
1	10/09/68	0.80	*
2	10/09/68	0.78	*
3	10/09/68	0.84	*
4	10/09/68	0.97	*
5	10/09/68	0.84	*
6	10/09/68	0.91	*
1	10/09/69	0.80	0.034
2	10/09/69	0.78	0.034
3	10/09/69	0.81	0.034
4	10/09/69	0.99	0.034
5	10/09/69	0.87	0.034
6	10/09/69	0.92	0.034
1	20/08/70	0.85	0.040
2	20/08/70	0.82	0.040
3	20/08/70	0.82	0.040
4	20/08/70	0.96	0.040
5	20/08/70	0.89	0.040
6	20/08/70	0.91	0.040
1	10/10/71	0.90	0.016
2	10/10/71	0.93	0.016
3	10/10/71	0.92	0.016
4	10/10/71	1.14	0.016
5	10/10/71	0.99	0.016
6	10/10/71	1.04	0.016
1	30/08/72	0.95	0.033
2	30/08/72	0.93	0.033
3	30/08/72	0.89	0.033
4	30/08/72	1.10	0.033
5	30/08/72	1.03	0.033
6	30/08/72	1.02	0.033
1	20/07/73	1.01	0.035
2	20/07/73	0.99	0.035
3	20/07/73	0.98	0.035
4	20/07/73	1.26	0.035
5	20/07/73	1.08	0.035
6	20/07/73	1.14	0.035
1	30/08/74	0.90	0.029
2	30/08/74	0.94	0.029
3	30/08/74	0.91	0.029
4	30/08/74	1.08	0.029
5	30/08/74	0.99	0.029
6	30/08/74	1.11	0.029
1	10/10/75	0.84	0.038
2	10/10/75	0.86	0.038
3	10/10/75	0.85	0.038
4	10/10/75	1.09	0.038
5	10/10/75	0.86	0.038
6	10/10/75	0.98	0.038
1	10/08/76	0.79	0.028
2	10/08/76	0.84	0.028
3	10/08/76	0.80	0.028
4	10/08/76	1.02	0.028
5	10/08/76	0.90	0.028
6	10/08/76	0.94	0.028
1	30/07/77	0.81	0.034
2	30/07/77	0.89	0.034
3	30/07/77	0.83	0.034
4	30/07/77	1.04	0.034
5	30/07/77	0.92	0.034
6	30/07/77	0.99	0.034
1	15/10/78	0.84	0.031
2	15/10/78	0.88	0.031

3	15/10/78	0.86	0.031
4	15/10/78	1.13	0.031
5	15/10/78	0.92	0.031
6	15/10/78	1.03	0.031
1	30/09/79	0.88	0.023
2	30/09/79	0.96	0.023
3	30/09/79	0.90	0.023
4	30/09/79	1.16	0.023
5	30/09/79	0.97	0.023
6	30/09/79	1.07	0.023
1	01/08/80	0.85	0.023
2	01/08/80	0.93	0.023
3	01/08/80	0.89	0.023
4	01/08/80	1.10	0.023
5	01/08/80	0.93	0.023
6	01/08/80	1.02	0.023
1	01/10/81	0.87	0.029
2	01/10/81	0.98	0.029
3	01/10/81	0.90	0.029
4	01/10/81	1.14	0.029
5	01/10/81	0.94	0.029
6	01/10/81	1.04	0.029
1	20/08/82	0.84	0.042
2	20/08/82	1.00	0.042
3	20/08/82	0.88	0.042
4	20/08/82	1.11	0.042
5	20/08/82	0.92	0.042
6	20/08/82	1.00	0.042
1	25/08/83	0.86	0.029
2	25/08/83	0.96	0.029
3	25/08/83	0.89	0.029
4	25/08/83	1.07	0.029
5	25/08/83	0.97	0.029
6	25/08/83	1.00	0.029
1	14/11/84	0.85	0.033
2	14/11/84	0.99	0.033
3	14/11/84	0.93	0.033
4	14/11/84	1.12	0.033
5	14/11/84	0.93	0.033
6	14/11/84	0.99	0.033
1	01/09/85	0.84	0.015
2	01/09/85	1.01	0.015
3	01/09/85	0.89	0.015
4	01/09/85	1.05	0.015
5	01/09/85	0.90	0.015
6	01/09/85	0.95	0.015
1	20/07/86	0.78	0.017
2	20/07/86	0.89	0.017
3	20/07/86	0.86	0.017
4	20/07/86	1.00	0.017
5	20/07/86	0.89	0.017
6	20/07/86	0.93	0.017
1	20/10/87	0.85	0.016
2	20/10/87	0.97	0.016
3	20/10/87	0.90	0.016
4	20/10/87	1.06	0.016
5	20/10/87	0.92	0.016
6	20/10/87	0.97	0.016
1	10/09/88	0.85	0.013
2	10/09/88	1.00	0.013
3	10/09/88	0.92	0.013
4	10/09/88	1.08	0.013
5	10/09/88	0.92	0.013
6	10/09/88	0.99	0.013
1	20/08/89	0.88	0.019
2	20/08/89	1.04	0.019

3	20/08/89	0.96	0.019
4	20/08/89	1.15	0.019
5	20/08/89	0.95	0.019
6	20/08/89	1.03	0.019
1	20/07/90	0.89	0.023
2	20/07/90	1.04	0.023
3	20/07/90	0.95	0.023
4	20/07/90	1.05	0.023
5	20/07/90	0.98	0.023
6	20/07/90	0.99	0.023
1	10/10/91	0.84	0.021
2	10/10/91	1.08	0.021
3	10/10/91	0.92	0.021
4	10/10/91	1.15	0.021
5	10/10/91	0.99	0.021
6	10/10/91	1.01	0.021
1	15/08/92	0.86	0.021
2	15/08/92	1.03	0.021
3	15/08/92	0.97	0.021
4	15/08/92	1.15	0.021
5	15/08/92	0.94	0.021
6	15/08/92	1.00	0.021
1	01/07/93	0.84	0.044
2	01/07/93	1.01	0.044
3	01/07/93	0.92	0.044
4	01/07/93	1.07	0.044
5	01/07/93	0.95	0.044
6	01/07/93	0.98	0.044
1	10/10/94	0.81	0.026
2	10/10/94	1.03	0.026
3	10/10/94	0.95	0.026
4	10/10/94	1.08	0.026
5	10/10/94	0.90	0.026
6	10/10/94	0.97	0.026

BIOMASS CARBON MEASUREMENTS : NONE

DELTA CARBON13 MEASUREMENTS : NONE

TOTAL NITROGEN
DATE OF MEASUREMENT : DATE
TREATMENT PLOT : TREAT : 1 = EXPORT OF BY-PRODUCTS, 2 = TURNING UNDER OF BY PRODUCTS PIG SLURRY-SLAKED LIME, 3 = EXPORT OF BY-PRODUCTS - PIG SLURRY SLAKED LIME, 4 = EXPORT OF BY-PRODUCTS-FARM YARD MANURE, 5 = EXPORT OF GREEN PRODUCTS-TURNING UNDER OF STRAW, 6 = TURNING UNDER OF BY-PRODUCTS-GREEN MANURE
NUMBER OF REPLICATES TAKEN : 6
NUMBER OF DUPLICATE MEASUREMENTS ON SAME SAMPLE : 1
VALUES OF TOTAL C FOR EACH REPLICATE/DUPLICATE : NONE
MEAN VALUE OF TOTAL NITROGEN AT THIS PLOT AT THIS DATE : NVAL (with standard error) : STERR

TREAT	DATE	NVALUE	STERR
1	10/11/59	0.994	0.047
2	10/11/59	0.994	0.047
3	10/11/59	1.080	0.047
4	10/11/59	1.036	0.047
5	10/11/59	1.003	0.047
6	10/11/59	1.064	0.047
1	30/08/60	0	0
2	30/08/60	0	0
3	30/08/60	0	0
4	30/08/60	0	0
5	30/08/60	0	0
6	30/08/60	0	0
1	10/09/61	0.998	0.065
2	10/09/61	0.980	0.065
3	10/09/61	1.045	0.065
4	10/09/61	1.045	0.065
5	10/09/61	1.100	0.065
6	10/09/61	1.020	0.065
1	15/09/62	0.950	*
2	15/09/62	0.990	*
3	15/09/62	0.970	*
4	15/09/62	1.030	*
5	15/09/62	1.000	*
6	15/09/62	1.002	*
1	30/10/63	1.000	0.025
2	30/10/63	0.990	0.025
3	30/10/63	1.010	0.025
4	30/10/63	1.070	0.025
5	30/10/63	1.020	0.025
6	30/10/63	1.040	0.025
1	20/08/64	0.959	0.037
2	20/08/64	0.980	0.037
3	20/08/64	0.998	0.037
4	20/08/64	1.068	0.037
5	20/08/64	1.008	0.037
6	20/08/64	0.998	0.037
1	20/09/65	0.919	*
2	20/09/65	0.910	*
3	20/09/65	0.914	*
4	20/09/65	0.975	*
5	20/09/65	0.919	*
6	20/09/65	0.961	*
1	10/08/66	0.926	0.027
2	10/08/66	0.921	0.027
3	10/08/66	0.914	0.027
4	10/08/66	1.012	0.027
5	10/08/66	0.970	0.027
6	10/08/66	0.989	0.027

1	10/10/67	0.915	0.016
2	10/10/67	0.939	0.016
3	10/10/67	0.900	0.016
4	10/10/67	1.026	0.016
5	10/10/67	0.938	0.016
6	10/10/67	0.994	0.016
1	10/09/68	0.900	0.023
2	10/09/68	0.900	0.023
3	10/09/68	0.905	0.023
4	10/09/68	1.012	0.023
5	10/09/68	0.938	0.023
6	10/09/68	1.003	0.023
1	10/09/69	0.910	0.036
2	10/09/69	0.900	0.036
3	10/09/69	0.924	0.036
4	10/09/69	1.008	0.036
5	10/09/69	0.942	0.036
6	10/09/69	0.975	0.036
1	20/08/70	0.882	0.021
2	20/08/70	0.849	0.021
3	20/08/70	0.863	0.021
4	20/08/70	0.961	0.021
5	20/08/70	0.914	0.021
6	20/08/70	0.942	0.021
1	10/10/71	0.905	0.014
2	10/10/71	0.910	0.014
3	10/10/71	0.868	0.014
4	10/10/71	1.027	0.014
5	10/10/71	0.919	0.014
6	10/10/71	0.961	0.014
1	30/08/72	0.870	0.017
2	30/08/72	0.868	0.017
3	30/08/72	0.862	0.017
4	30/08/72	0.998	0.017
5	30/08/72	0.904	0.017
6	30/08/72	0.938	0.017
1	20/07/73	0.930	0.016
2	20/07/73	0.930	0.016
3	20/07/73	0.910	0.016
4	20/07/73	1.050	0.016
5	20/07/73	0.950	0.016
6	20/07/73	1.040	0.016
1	30/08/74	0.850	0.023
2	30/08/74	0.850	0.023
3	30/08/74	0.840	0.023
4	30/08/74	0.970	0.023
5	30/08/74	0.890	0.023
6	30/08/74	0.960	0.023
1	10/10/75	0.845	0.022
2	10/10/75	0.873	0.022
3	10/10/75	0.868	0.022
4	10/10/75	0.989	0.022
5	10/10/75	0.910	0.022
6	10/10/75	0.985	0.022
1	10/08/76	0.919	0.018
2	10/08/76	0.961	0.018
3	10/08/76	0.915	0.018
4	10/08/76	1.069	0.018
5	10/08/76	0.994	0.018
6	10/08/76	1.027	0.018
1	30/07/77	0.872	0.026
2	30/07/77	0.910	0.026
3	30/07/77	0.872	0.026
4	30/07/77	1.050	0.026
5	30/07/77	0.956	0.026
6	30/07/77	1.008	0.026

1	15/10/78	0.875	0.016
2	15/10/78	0.913	0.016
3	15/10/78	0.888	0.016
4	15/10/78	1.071	0.016
5	15/10/78	0.926	0.016
6	15/10/78	0.965	0.016
1	30/09/79	0.810	0.018
2	30/09/79	0.845	0.018
3	30/09/79	0.860	0.018
4	30/09/79	1.020	0.018
5	30/09/79	0.860	0.018
6	30/09/79	0.950	0.018
1	01/08/80	0.868	0.022
2	01/08/80	0.910	0.022
3	01/08/80	0.863	0.022
4	01/08/80	1.087	0.022
5	01/08/80	0.895	0.022
6	01/08/80	0.973	0.022
1	01/10/81	0.873	0.023
2	01/10/81	1.008	0.023
3	01/10/81	0.961	0.023
4	01/10/81	1.087	0.023
5	01/10/81	0.915	0.023
6	01/10/81	0.985	0.023
1	20/08/82	0.844	0.028
2	20/08/82	0.938	0.028
3	20/08/82	0.919	0.028
4	20/08/82	0.898	0.028
5	20/08/82	0.914	0.028
6	20/08/82	0.966	0.028
1	25/08/83	0.828	0.017
2	25/08/83	0.898	0.017
3	25/08/83	0.835	0.017
4	25/08/83	0.966	0.017
5	25/08/83	0.877	0.017
6	25/08/83	0.954	0.017
1	14/11/84	0.882	0.014
2	14/11/84	0.989	0.014
3	14/11/84	0.961	0.014
4	14/11/84	1.096	0.014
5	14/11/84	0.956	0.014
6	14/11/84	1.040	0.014
1	01/09/85	0.874	0.017
2	01/09/85	0.963	0.017
3	01/09/85	0.947	0.017
4	01/09/85	1.031	0.017
5	01/09/85	0.888	0.017
6	01/09/85	0.943	0.017
1	20/07/86	0.889	0.025
2	20/07/86	1.003	0.025
3	20/07/86	0.957	0.025
4	20/07/86	1.034	0.025
5	20/07/86	0.915	0.025
6	20/07/86	0.992	0.025
1	20/10/87	0.917	0.015
2	20/10/87	1.008	0.015
3	20/10/87	0.978	0.015
4	20/10/87	1.076	0.015
5	20/10/87	0.964	0.015
6	20/10/87	0.996	0.015
1	10/09/88	0.971	0.015
2	10/09/88	1.010	0.015
3	10/09/88	1.064	0.015
4	10/09/88	1.140	0.015
5	10/09/88	1.023	0.015
6	10/09/88	1.081	0.015

1	20/08/89	0.876	0.028
2	20/08/89	1.009	0.028
3	20/08/89	0.924	0.028
4	20/08/89	1.038	0.028
5	20/08/89	0.909	0.028
6	20/08/89	0.984	0.028
1	20/07/90	0.929	0.035
2	20/07/90	0.994	0.035
3	20/07/90	0.901	0.035
4	20/07/90	1.017	0.035
5	20/07/90	0.952	0.035
6	20/07/90	1.017	0.035
1	10/10/91	0.882	0.028
2	10/10/91	1.045	0.028
3	10/10/91	0.980	0.028
4	10/10/91	1.120	0.028
5	10/10/91	0.975	0.028
6	10/10/91	1.003	0.028
1	15/08/92	0.870	0.032
2	15/08/92	0.997	0.032
3	15/08/92	0.927	0.032
4	15/08/92	1.042	0.032
5	15/08/92	0.938	0.032
6	15/08/92	0.988	0.032
1	01/07/93	0.795	0.039
2	01/07/93	0.939	0.039
3	01/07/93	0.845	0.039
4	01/07/93	0.996	0.039
5	01/07/93	0.876	0.039
6	01/07/93	0.870	0.039
1	10/10/94	0.810	0.043
2	10/10/94	1.014	0.043
3	10/10/94	0.933	0.043
4	10/10/94	0.993	0.043
5	10/10/94	0.860	0.043
6	10/10/94	0.991	0.043