AMG:
a simple SOC balance model
used in France for decision support

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Content

1 - AMG: description

2 - AMG-Research: a research tool
   - Description
   - Evaluation on several databases

3 - Simeos-AMG: a decision support tool
AMG model is derived of Hénin & Dupuis (HD) model used to simulate SOC evolution on the long term (1945),

Characteristics of HD model:

- 2 compartments of SOC
- time step = 1 year
- only 2 parameters
- input information easily available at the field and the farm level

H&D model has been widely used in France as a support for decision making and formation until recently
Characteristics:

- **3 compartments of OC**
  - Fresh OC
  - Ca = Active SOC
  - Cs = Stable SOC

- **Time step = 1 year**

- **3 parameters:**
  - K1: humification coefficient
  - K: annual mineralization rate
  - Cs/Co: initial fraction of stable C

Fluxes and compartments of OC in the AMG model:

\[
C_t = CS + Ca \cdot \exp(-k \cdot t) \cdot K1 \cdot m / K \cdot (1 - \exp(-K \cdot t))
\]

Andriulo et al., 1999
Determination of FOM inputs

Main crops
Catch crops
Organic Amendments

Aerial residues
Roots

\[
\text{FOM} = \text{crop residues and organic wastes}\]
\[
m = f(\text{crop yield and amount of organic wastes; } C \text{ concentration})\]
\[
K1 = f(\text{nature and composition of FOM})\]
Inputs from crop residues (grain crops)

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I - AMG: description

DM harvested = grains

ADM potentially harvestable = straw

ADM always incorporated = stubble

Root dry matter

ADM always incorporated

= (ADM Total – DMgrain) * a’

Root DM = ADM Total * CR / (1-CR)

DMgrain = yield * DM content

ADM Total = DMgrain / HI

MSA total =ADM total = DMgrain / HI

MSA vegetative

ADM always incorporated = stubble

= (ADM Total – DMgrain) * a’

Root DM = ADM Total * CR / (1-CR)

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1 - AMG: description

Inputs from crop residues (root crops)

DM total
ADM always incorporated = beet tops
ADM potentially incorporated = leaves
ADM unharvested
DM harvested = tuber
Root DM incorporated = rootlets

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Determination of K1

3 main methods:

- **M1)** Model fitting versus observed data in LTE
- **M2)** Calibration with laboratory incubations
- **M3)** Calibration with biochemical analyses
Method M2
Asymptotic remaining $C \approx K1$

% Corg apporté

mineralized C

$C$ remaining in the soil

$C$ stable

temps (années)

$0 \quad 10 \quad 20 \quad 30 \quad 40$
**Method M3**

**Biochemical index ISMO ≈ K1**

More than 650 organic wastes of different types characterized

Lashermes et al., 2009
Calculation of mineralization rate $K$

$C = Ca + Cs$

$dC/dt = K1.m - K.Ca$

$K = K0 * f(clay) * f(lime) * f(T) * f(P-PET) * f(tillage)$
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AMG Research

* Data selection / extraction
* Calculation of:
  - Means
  - Standard deviations
  - Observed soil OC evolution
  - Inputs of C from residues and organic amendments
* Génération of CSV input file

* Calculation of:
  - Simulated soil OC evolution
  - Statistic parameters relative to the evaluation of the adjustment of the model to the data
* Optimisation of model parameters (MCMC process)
Example of SOC variations

Evolution of C, C3 and C4 stocks

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1) Evaluation on a database of soil analyses in arable farms

Years 1970-1997

391 fields selected

Analyzed 3, 4 or 5 times
Selection of the 391 fields

Linear regression versus time
Consistancy of the SOC variation kinetics
Slope = mean rate of change of SOC

Source : B. Mary
Model evaluation
Simulated vs observed rates of change

Fréquence
35%
30%
25%
20%
15%
10%
5%
0%
-2.0 -0.8 -0.4 -0.2 0.0 0.2 0.4 0.8 2.0
Rate of SOC change (t C/ha/an)

observed
simulated

Source: B. Mary

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2) Evaluation on 9 long-term experiments

9 LTE with or without straw removal

- Ultuna (Sweden) 35 years
- Askov (Denmark) 31 years
- Askov 2 (Denmark) 20 years
- Khon Kaen (Thaïland) 26 years
- Issoudun (France) 32 years
- Serreslous (France) 24 years
- Doazit (France) 13 years
- Grignon (France) 18 years
- Boigneville (France) 12 years

Saffih and Mary, 2008
Simulated vs observed changes in SOC stocks due to straw addition

\[ \text{Simulated (t/ha)} \]

\[ \text{Observed (t/ha)} \]

\[ \text{Simulated (% added C)} \]

\[ \text{Observed (% of added C)} \]

Saffih and Mary, 2008

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3) Evaluation on 23 long-term experiments in France

AMG project, (2009-2012)

Database of LTE available in France for testing SOM models

Selection of adequate LTE based on:

- Consistent evolution of SOM versus time
- Available information on crops, yields, residues and organic wastes management
- Number of measurement dates > 3
- Available information on sampling and/or tillage depths
Global evaluation

Simulated vs observed SOC stocks

First results

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SIMEOS-AMG
GCEOS Project (2004-2011)

Cropping system with vegetables and potatoes in a sandy loam
Potatoes / Wheat / Peas / Sugar Beet / Carots

Current system:
- Plowing: 4 yrs/5
- Plowing depth: 28 cm
- Catch crops: 2 yrs/5

1st modif. of the system:
- 1 plowing suppressed: 3 yrs/5
- Plowing depth reduced to 22 cm

2nd modif. of system:
- + 10 T/ha of compost /5yrs
- + Catch crops: 3 yrs/5

3rd modif. of system:
- + 10 T/ha of compost /5yrs
- 1 plowing suppressed and plowing depth reduced to 22 cm

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**System “cereals + sugarbeet”**
Loamy soil
Engrais verts : 1 année/5
Labour à 25 cm

**Hypothesis on soil OM content**
- 1,8 % of OM
- 2,2 % of OM

**Hypothesis on soil tillage**
- 80% Plough
- 40% Plough

**Evolution of SOC Stocks 0-30 cm**

**Simulations by Simeos-AMG**

**Allowed straw exportation**
The C \textit{org} reference concentration

**Principle:**
Avoiding the deterioration of soil organic status and related soil properties on the long term for each main agronomical situation

(type-situation = combination of a soil type and a cropping system type)

**Corg reference concentration** = Median value of the distribution of observed Corg concentrations for a type-situation in the region

System "cereals + sugarbeet"/
Loamy soil
Engrais verts : 1 année/5
Labour à 25 cm
A decision support tool for advisory services

Proportion of straw that might be exported without major risks at the field scale

| Cas-types | Teneurs en C organique actuelles du sol (en g/kg) | Teneurs en MO actuelles du sol (en %) | Possibilités d'exportation des pailles sans apports organiques extérieurs | Possibilités d'exportation des pailles avec apports organiques extérieurs |
|-----------|-----------------------------------------------|-----------------------------------|-------------------------------------------------|--------------------------------|-------------|
| **Système de culture** | **Type de sol** | **Cas 1: 0 à 25 % de céréale** | Sables et limons | 7 à 10 | 14 à 20 | Teneurs en MO faibles et restitution organiques faibles | → pas d'exportation |
| | | + pté - légumes - betteraves | 1 céréale tous les 5 - 6 ans |  |  |  |  |
| **Cas 2: 25 à 40 % de céréale - colza** | Sables, limons et limons argileux | 8,5 à 10,5 | 17 à 21 | Pas d'exportation | 1 paille/2 |
| | + betteraves - pté - légumes | 1 céréale tous les 3 ans |  |  |  |  |
| **Cas 3: 40 à 60 % de céréale - colza** | Sables et limons | 7 à 9 | 14 à 18 | Pas d'exportation | 1 paille/3 |
| | + betteraves - pté - protéagineux | 8,5 à 10,5 | 17 à 21 | 1 paille/5 | 3 pailles/4 |
| | 1 céréale tous les 2 ans | 9 à 11 | 18 à 22 | 1 paille/3 | 3 pailles/4 |
| | | Limons argileux | 11 à 14 | 22 à 28 | 1 paille/3 | 3 pailles/4 |
| | | Cranettes |  |  |  |  |
| | |  |  |  |  |  |
| **Cas 4: 60 à 70 % de céréale - colza** | Sables | 7 à 9 | 14 à 18 | Pas d'exportation | 1 paille/3 |
| | + betteraves - protéagineux | 8,5 à 10,5 | 17 à 21 | 1 paille/5 | 3 pailles/4 |
| | Exemple de rotation: | 9 à 11 | 18 à 22 | 1 paille/3 | 3 pailles/4 |
| | betterave - blé - orge - colza - blé | 10 à 12,5 | 20 à 25 | 1 paille/3 | 3 pailles/4 |
| | Argiles | 11,5 à 14 | 23 à 28 | 1 paille/3 | 3 pailles/4 |
| | Cranettes |  |  |  | Toutes les pailles |

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Application of Simeos-AMG to the diagnosis of SOC evolution at the territory scale

*ABC’Terre Project (2013-2015)*

Spatialized soil and cropping systems data

Spatialized diagnosis of LT variations of SOC stocks of agricultural area

**BDAT**
- Regional DB on cultural practices + Farms typology

**SIMEOS-AMG**
- Tool to rebuild crop rotations
- Agronomical Expertise
- Method to combine Corg x Soil Type
- Method to combine SdC x Soil type

**Simulations of SOC evolution**

**AMG**
- *Etat organique à t + 20 ans*

**Combinaisons**

- SdC X Sol x Stocks Corg localised at the territory scale *(current state)*

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**AMG Model: limitations and improvement prospects**

- The **model does not apply to grasslands and other perennial crops** (miscanthus, ... )
- The **effect of soil moisture** (through a water balance indicator) **must be improved**
- The values of **humification coefficients of organic wastes** (manures, sludges, composts, slurry, ...) **must be updated** using a database of laboratory experiments

These issues are addressed in ongoing studies in France.

**Future prospects**

An interest for evaluating **AMG** on other datasets in Europe and comparing with other models, in this Sompatic group!
THANK YOU
FOR
YOUR ATTENTION