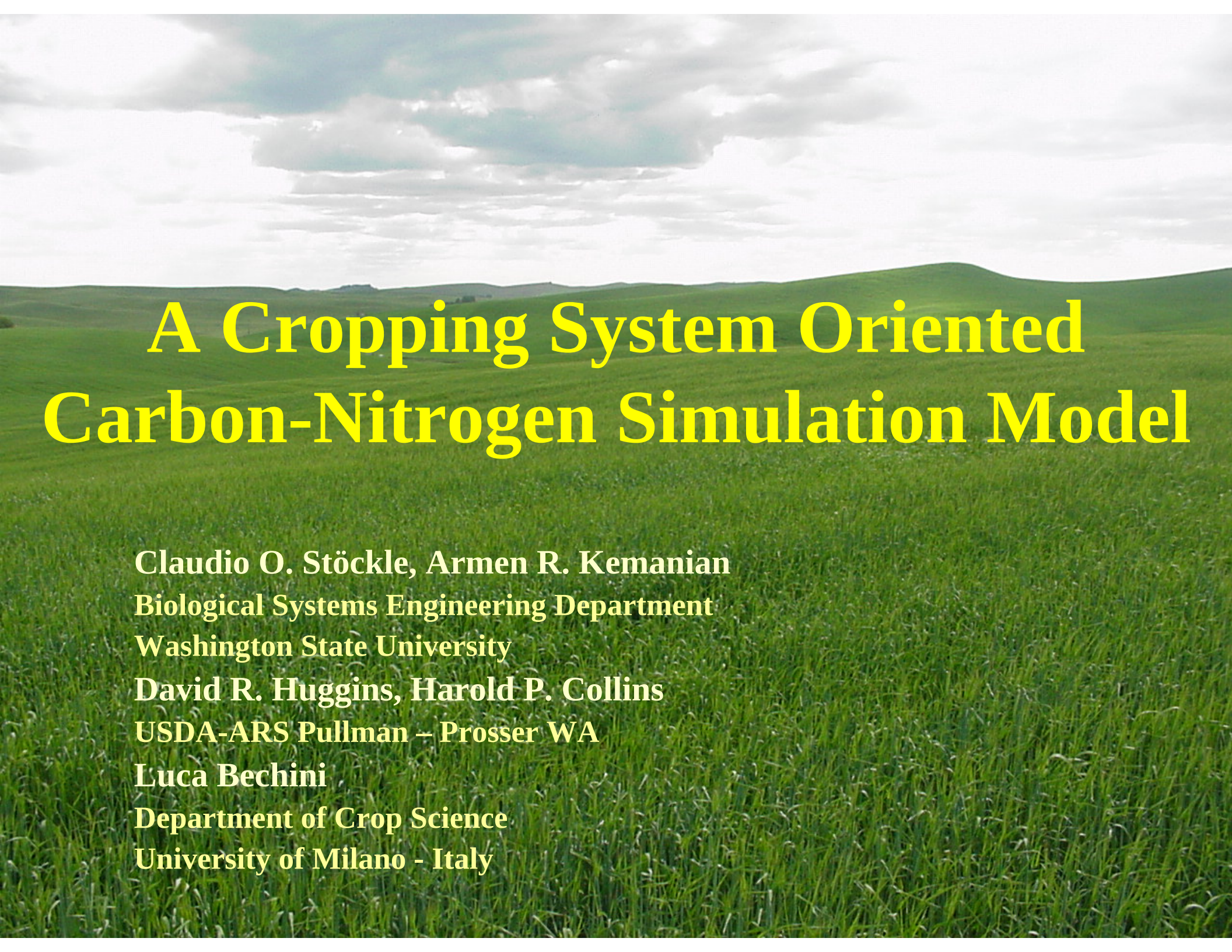

A Cropping System Oriented Carbon-Nitrogen Simulation Model

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Outline

- The model for the need: a CN model from the cropping system perspective.
- Current approaches strengths and weaknesses.
- A modified version of Verberne et al. (1990) CN model.
- Simulations.
- Concluding remarks.

What are the needs?

- **Simulation of short term N dynamics (inputs decomposition, crop N uptake, denitrification, volatilization, and leaching).**
- **Consideration of residues quality, quantity, and interaction with tillage.**
- **Simulation of long-term soil C and N dynamic.**
- **The simplest possible yet useful structure with minimum calibration needs.**

Concepts evolution

- Hénin and Dupuis (1945): C balance
- Jansson (1958): tracer experiments
- Swift (1979): the cascade of decomposition
- Jenkinson and Rayner (1977): SOC pools
- Paul and coworkers (1979-present)
- Phoenix model (McGill et al. 1981)
- Century, NCSoil, Verberne et al. (1990)…
- Hassink and Withmore (1997): C saturation

“Consensus” concepts

- **SOM can be divided in pools with narrowly defined properties: fast, intermediate, and slow cycling pools.**
- **Carbon in organic inputs (residues, manures) decomposes as if it were composed of three compartments.**
- **The soil environment (temperature, moisture, oxygen, texture) controls the decomposition rates and the transfer among pools.**

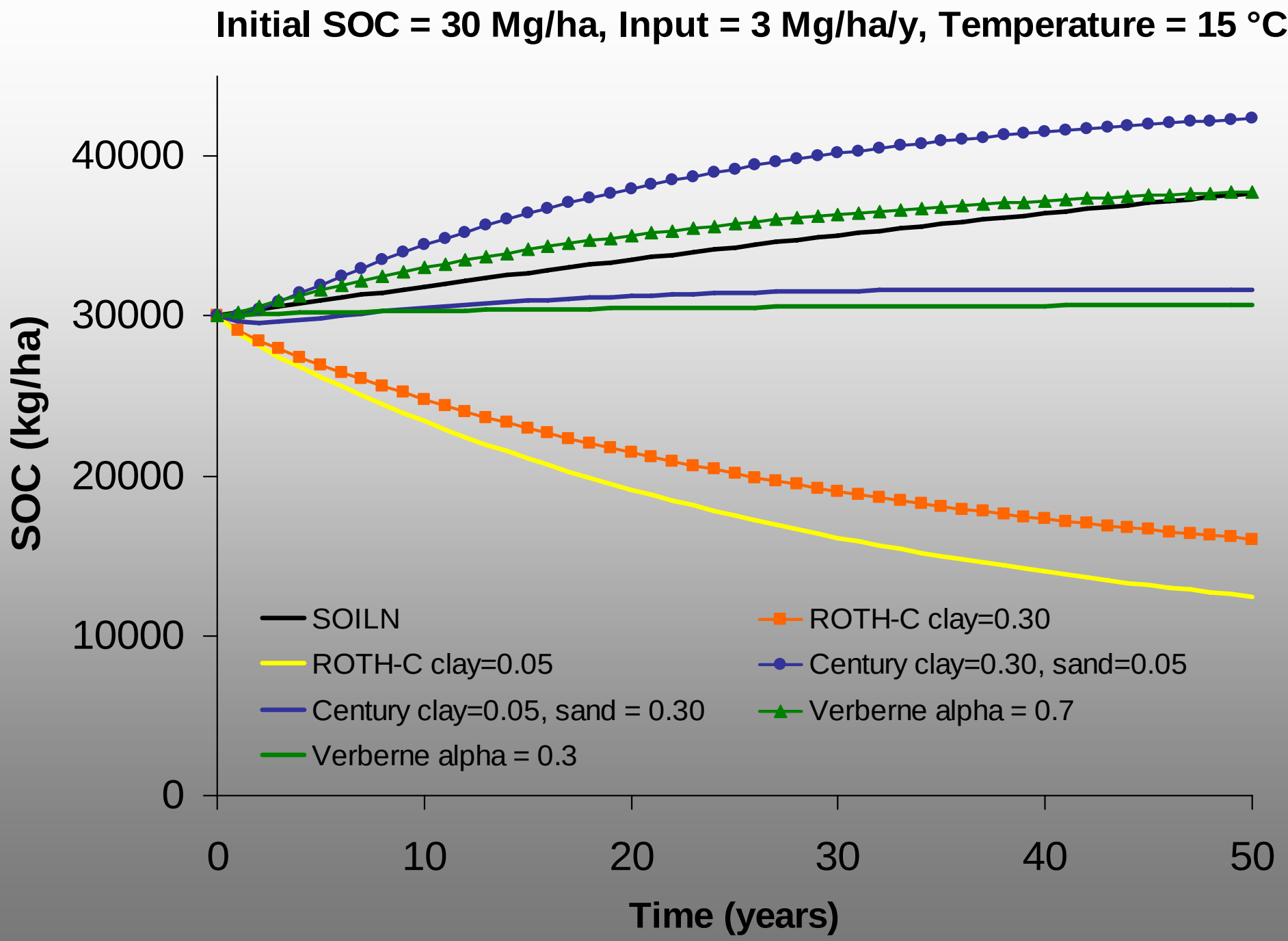
Challenge: quantitative representation

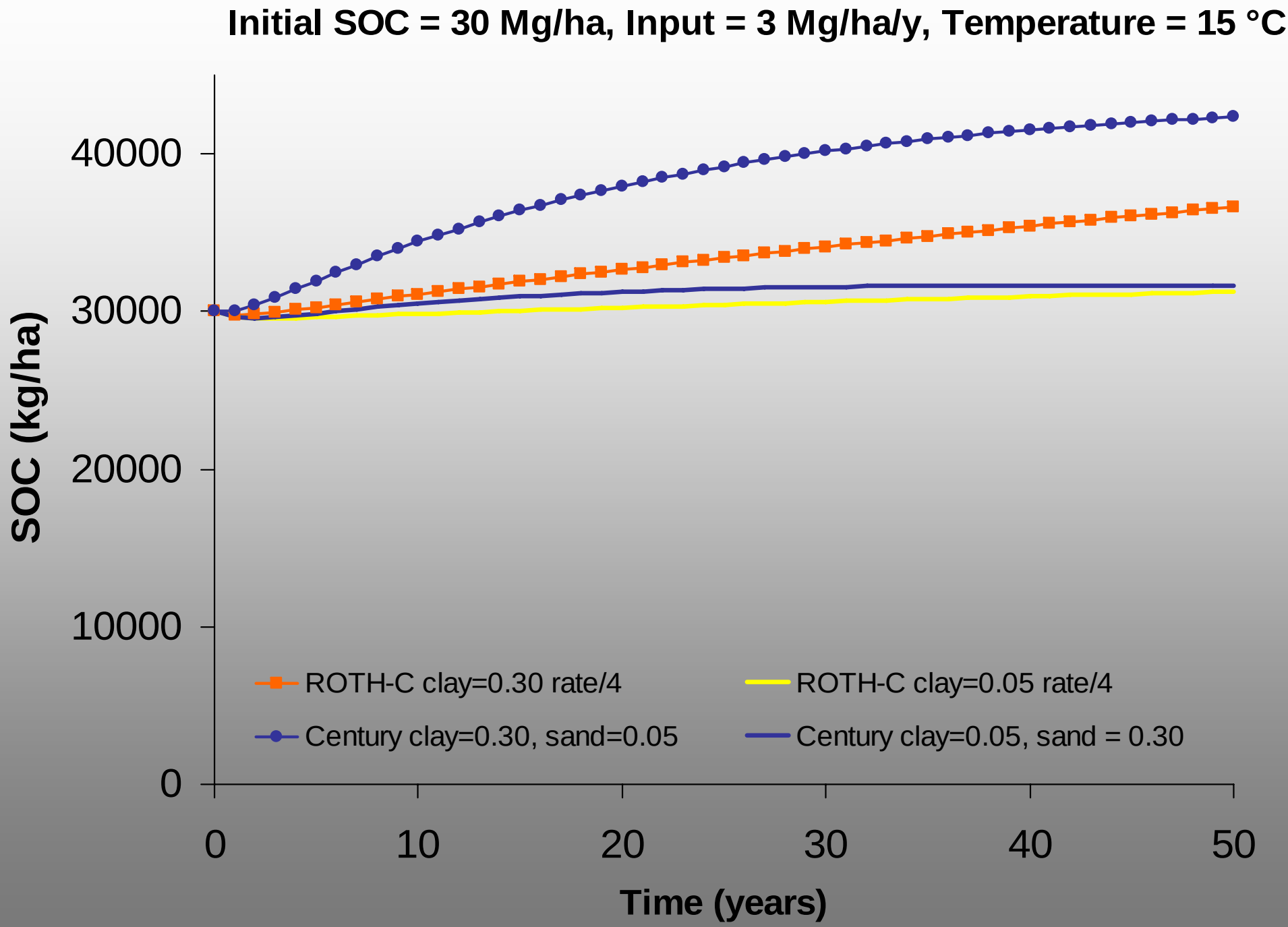
- **Simplest: one SOC(N) pool, one residue pool, no microbial biomass (SOILN).**
- **More evolved structure: multiple SOC pools, microbial biomass, explicit consideration of efficiencies, multiple controls over C transfers among pools (Century, NCSoil, and others).**

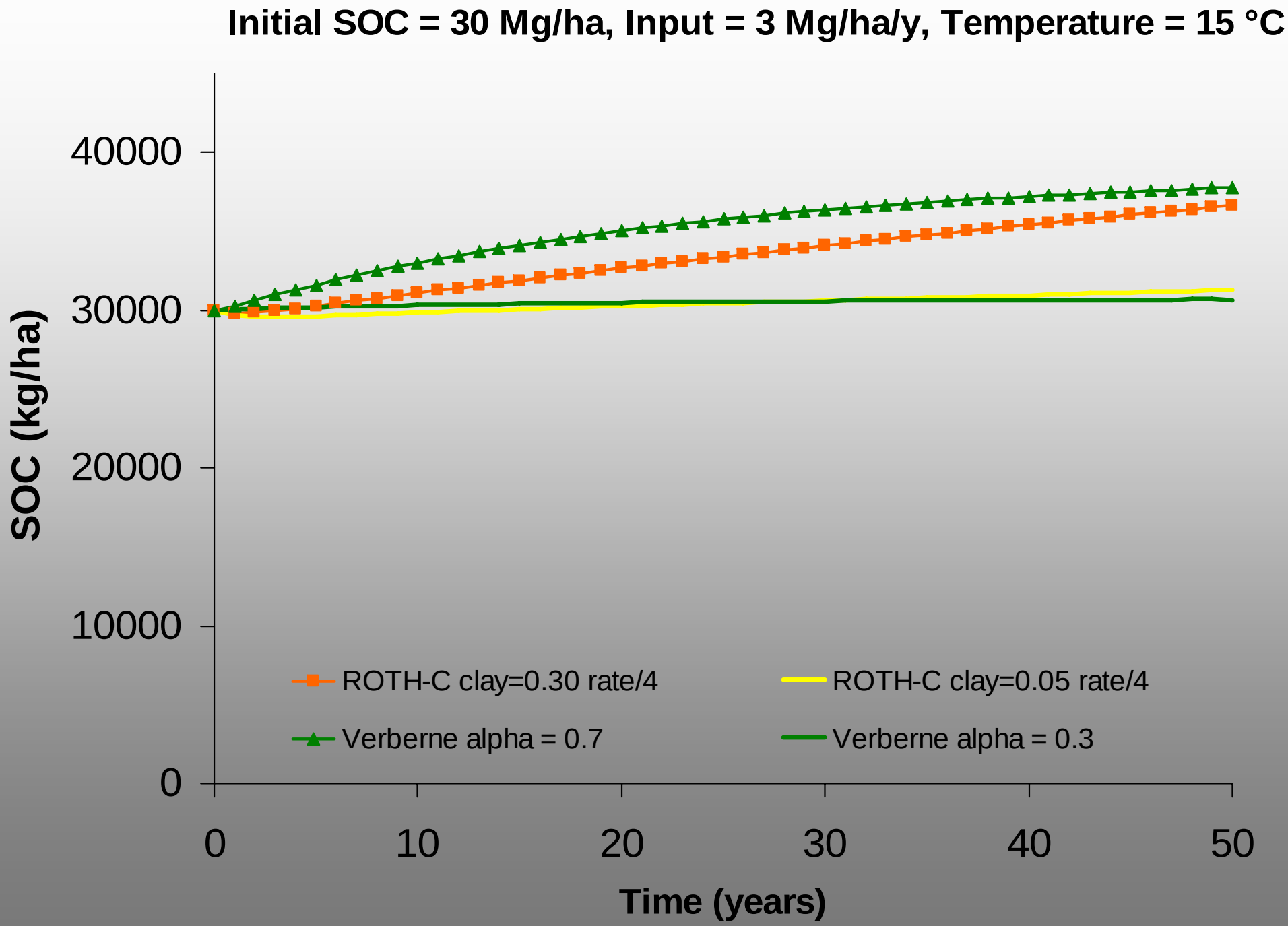
Simple or complicated?

Comparing SOILN (Andrén and Paustian, 1987), ROTH-C (web manual), Verberne et al. (1990) and Century (Parton et al., 1987):

1. **Long-term C balance**
2. **Short-term N mineralization/immobilization**


Initial SOC = 30 Mg/ha, Input = 3 Mg/ha/y, Temperature = 15 °C
SOC (kg/ha)
40000
30000
20000
10000
0
0
10
20
30
40
50
Time (years)
SOILN
ROTH-C clay=0.05
Century clay=0.05, sand = 0.30
Verberne alpha = 0.3
ROTH-C clay=0.30
Century clay=0.30, sand=0.05
Verberne alpha = 0.7


Initial SOC = 30 Mg/ha, Input = 3 Mg/ha/y, Temperature = 15 °C
SOC (kg/ha)
40000
30000
20000
10000
0
0
10
20
30
40
50
Time (years)
ROTH-C clay=0.30 rate/4
ROTH-C clay=0.05 rate/4
Century clay=0.30, sand=0.05
Century clay=0.05, sand = 0.30


Initial SOC = 30 Mg/ha, Input = 3 Mg/ha/y, Temperature = 15 °C
SOC (kg/ha)
40000
30000
20000
10000
0
0
10
20
30
40
50
Time (years)
ROTH-C clay=0.30 rate/4
ROTH-C clay=0.05 rate/4
Verberne alpha = 0.7
Verberne alpha = 0.3

Overview of Verberne et al. (1990)

- Residues are divided in three fractions with distinct CN ratio (6 to 150).
- Microbial biomass has a protected and a non-protected component.
- SOM consist of (1) a non-protected, (2) a protected and (3) a stabilized fraction.
- Except for the transfers to the microbial pool, efficiency = 1 (no CO_2 loss).
- Textural effects incorporated in the transfer to non-protected and to protected biomass.

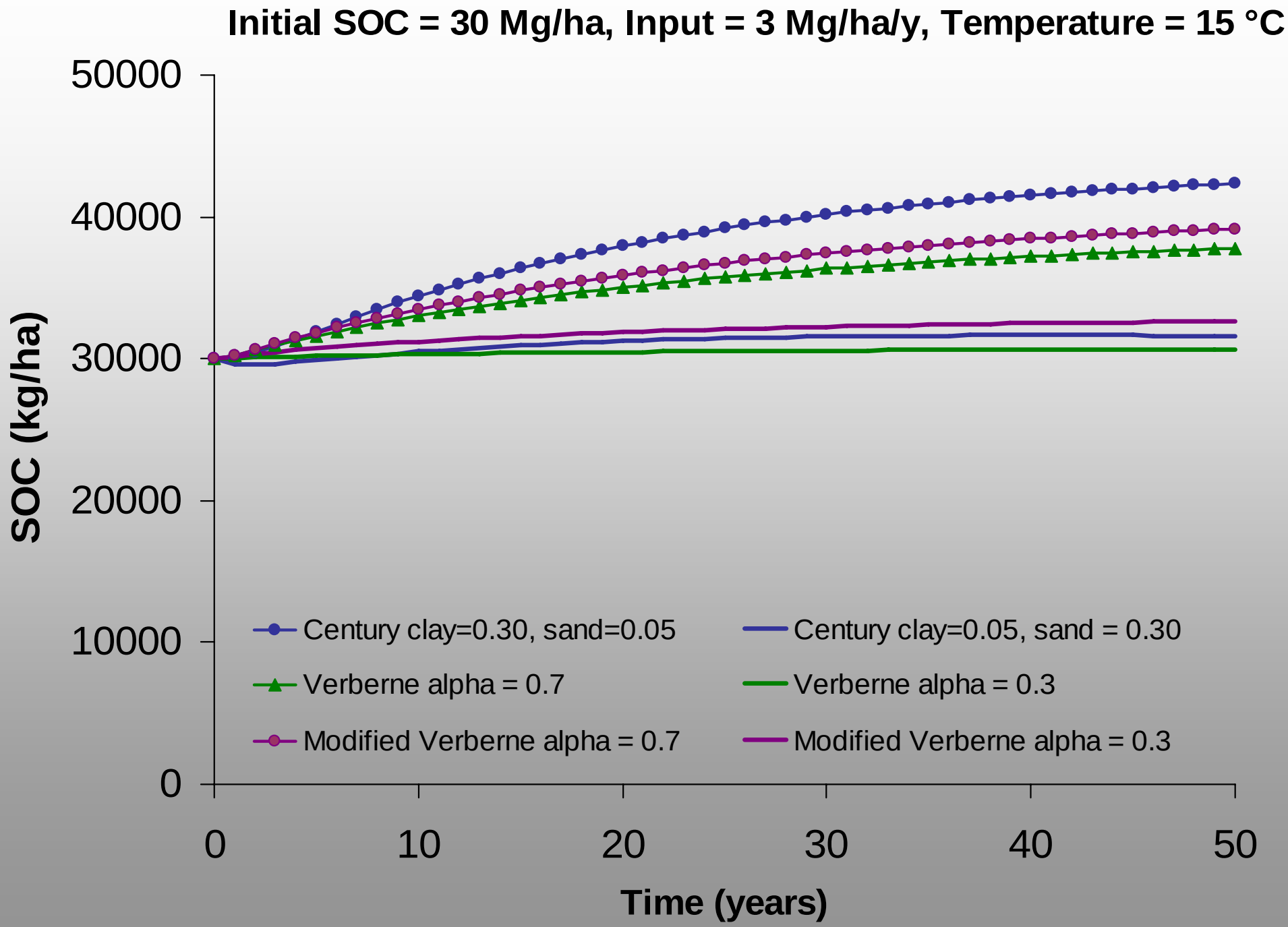
Modifications to Verberne et al. (1990)

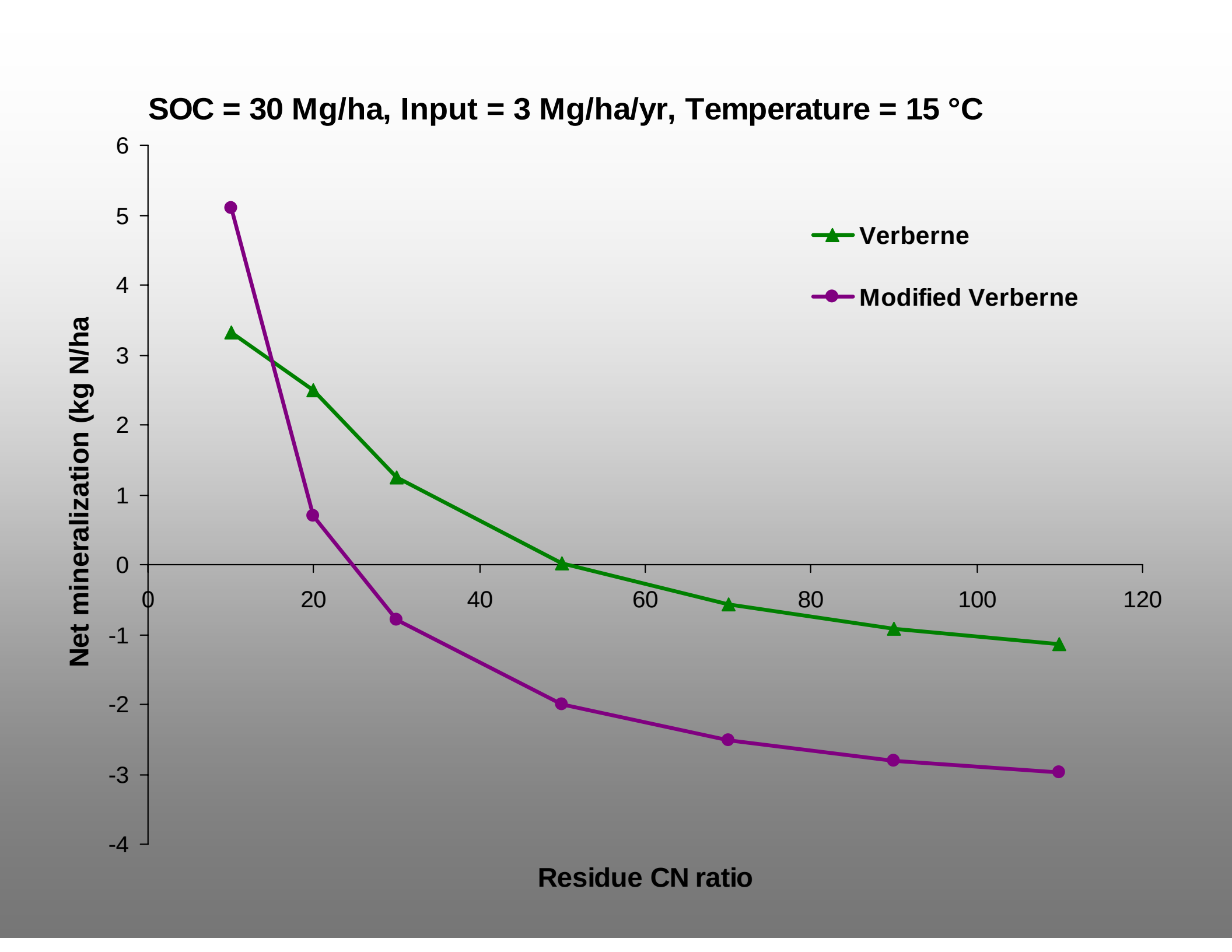
1. All residue fractions have the same CN ratio.
2. Decomposition of lignified component has an associated fractional CO_2 loss (0.3).
3. Lignified products transferred to protected pool.
4. Non-protected microbial biomass eliminated.
5. Textural effect is a function of the sand fraction.
6. Turnover rate of stable pool increased.
7. Tillage effect incorporated.

Non-protected → *LABILE*

Protected → *METASTABLE*

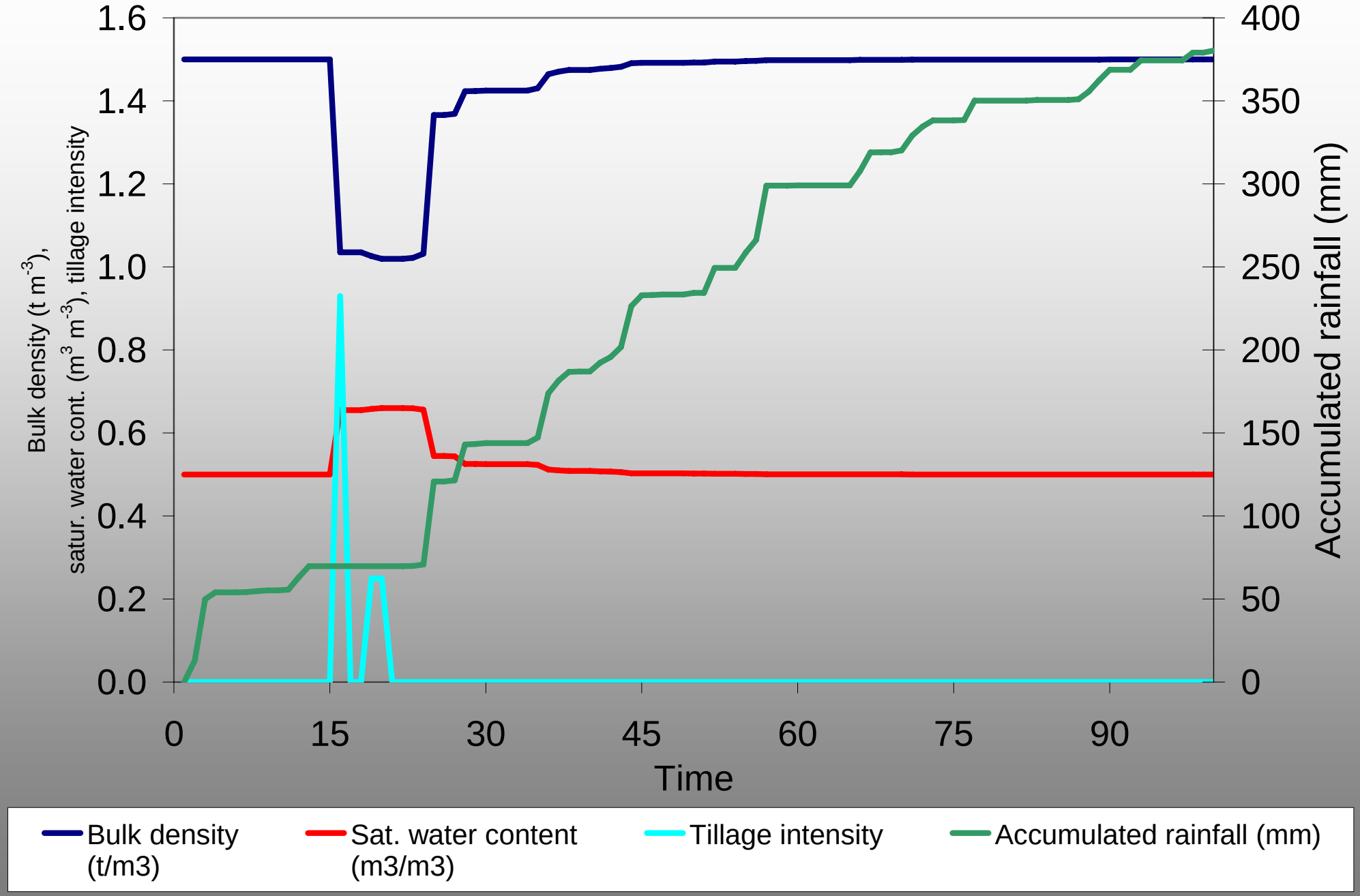
Stabilized → *STABLE*


Initial SOC = 30 Mg/ha, Input = 3 Mg/ha/y, Temperature = 15 °C
SOC (kg/ha)
50000
40000
30000
20000
10000
0
0
10
20
30
40
50
Time (years)
Century clay=0.30, sand=0.05
Century clay=0.05, sand = 0.30
Verberne alpha = 0.7
Verberne alpha = 0.3
Modified Verberne alpha = 0.7
Modified Verberne alpha = 0.3


SOC = 30 Mg/ha, Input = 3 Mg/ha/yr, Temperature = 15 °C
Net mineralization (kg N/ha
Residue CN ratio
Verberne
Modified Verberne
6
5
4
3
2
1
0
-1
-2
-3
-4
0
20
40
60
80
100
120

Features added to CropSyst

- User defined turnover rate of labile, metastable, and stable pools.
- User defined residue or manure input properties.
- Residues are standing, flat, or incorporated in the soil.
- Dynamic simulation (rotation).
- Each new residue generates a new residue pool.
- User defined tillage depth – residue incorporation.
- Denitrification.


1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Bulk density (t m-3), satur. water cont. (m3 m-3), tillage intensity
400
350
300
250
200
150
100
50
0
Accumulated rainfall (mm)
0
15
30
45
60
75
90
Time
Bulk density (t/m3)
Sat. water content (m3/m3)
Tillage intensity
Accumulated rainfall (mm)

Missing features

- **Pool properties' do not change with time.**
- **There is no limit on soil C carrying capacity - C saturation concept (Hassink and Whitmore, 1997).**

Concluding remarks

- **The modifications to Verberne et al. (1990) provided a simple yet versatile CN model, keeping a minimum number of parameters while respecting basic knowledge on soil biology.**
- **Major defects of the original model proposed were easily removed, and tillage effect was incorporated.**
- **The model can be run in complicated rotations.**
- **Do not loose perspective! This and other models are still SIMPLIFICATIONS of actual systems.**

Acknowledgments

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