Development of the SWAT-Integrated Critical Zone Model

Nikolaidis N.P., Valstar J., Rowe E., Moirogiorgou K.
SOIL FUNCTIONS

- Food and fibre production
- Filtering water
- Transforming nutrients
- Carbon storage
- Biological habitat
- Gene pool

Modeling Soil Functions and Soil Threats

**Soil Functions...**
1. Food and biomass production
2. Carbon and nitrogen sequestration
3. Habitat and gene pool (biodiversity)
4. Filtering and transformations

**Soil Threats...**
1. Loss of organic matter
2. Loss of biodiversity
3. Erosion
4. Compaction
Integrated CZ Model - Soil Functions

C/N Cycle and Structure Model – CAST (TUC-BOKU-USHEF)

Acid- Base Chemistry, Weathering - ForSAFE (DELTARES-LUND)

Plant Production Model – PROSUM (CEH)

Terrestrial Ecology Model – TEM (WU)

H2O transformations

Hydrology and Solute Transport
HYDRUS 1D (DELTARES) and SWAT (TUC)

C/N Sequestration

Biomass Production

Biodiversity

Integrated CZ Model
CAST Model - Conceptual Structure

Incorporation of POM plant residues and roots

POM colonization by microbial decomposers

Macro-aggregate formation

Decrease of microbial activity, loss of aggregate stability, aggregate disruption

POM fragmentation, micro-aggregate formation
ROTH-C Model

DPM/RPM ratio
- Crops and improved grassland: 1.44
- Unimproved grassland and scrub: 0.67
- Forest: 0.25

Initialize with cropland:
- \( \text{DPM} + \text{RPM} = \text{POC} \)
- \( \text{BIO} + \text{HUM} + \text{IOM} = \text{silt-clay related carbon} \)
  - \( \text{BIO} = 3\% \text{ of SOC} \)
  - \( \text{IOM} = 0.049\times\text{SOC}^{1.139} \)

Decay: \( Y e^{-abckt} \), \( t: 1/12 \)
- \( a \): modifying factor for temperature
- \( b \): modifying factor for moisture
- \( c \): modifying factor for soil cover
- \( k \): the decomposition rate constant, \( y^{-1} \)

**RPM**: Resistant Plant Material
**DPM**: Decomposable Plant Material
**BIO**: Microbial Biomass
**HUM**: Humified OM
**IOM**: Inert Organic Matter

Determined by \( f(\text{clay}) \)
CAST Model - Conceptual Structure

Stamati, F.E., Nikolaidis, NP, Banwart, S.W., Blum, A., Coupled Carbon, Aggregation, and Structure Turnover Model for topsoils, GEODERMA (In Press)

www.herslab.tuc.gr
Carbon Amendments - Soil Fertility and Structure

Four Treatments

- Control, conventional fertilizers
- Manure (50 t/ha)
- 30/70 mixture of manure and compost (50 t/ha)
- Compost (50 t/ha)

Properties

- Water content profiles
- Field capacity
-Bulk density
- Soil texture
- WSA determination
- Soil pH and electrical conductivity
- Organic C and total N
- Extractable P
- PMN (Potential Mineralizable Nitrogen)
- EMN (Exchangeable Mineral Nitrogen)
- Net N mineralization rate
- Net nitrification rate
- Bulk chemical analysis
Carbon Sequestration (2011-2012)

2011

TOC (0-15 cm)

Aug-11 Sep-11 Oct-11 Nov-11

2012

TOC (0-15 cm)

May-12 Jun-12 Jul-12
Carbon Amendments
Primary Productivity

2011

<table>
<thead>
<tr>
<th></th>
<th>Fruits</th>
<th>Leaves</th>
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<th>Roots</th>
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<tbody>
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<td>Conventional fertilizers</td>
<td>15.00</td>
<td>0.66</td>
<td>1.20</td>
<td>0.10</td>
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<tr>
<td>Compost</td>
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2012

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Carbon Amendments - Soil Fertility and Structure

![Graphs showing total nitrogen and organic carbon in aggregates with different amendments.

- Total Nitrogen in aggregates (g/kg aggregate):
  - Macroaggregates
  - Microaggregates
  - Silt-clay size aggregates

- Organic Carbon in aggregates (g/kg aggregate):
  - Macroaggregates
  - Microaggregates
  - Silt-clay size aggregates

Amendments:
- Inorganic fertilizer
- Compost
- Manure
- 70% compost, 30% manure

The graphs illustrate the impact of different amendments on soil fertility and structure, showing higher values for combinations of compost and manure compared to inorganic fertilizer alone.
Biomass Production

1D-ICZ Model – Plant Module Results

- Biomass Production
  - Total shoot at harvest, g C m⁻²
    - 1to1
    - Shoot
  - Total shoot at harvest, g N m⁻²
    - 1to1
    - Shoot

Graphs showing biomass production and shoot harvest data.
1D-ICZ Model – Solute Transport Module Results

Water Filtration and Transformation
1D-ICZ Model – C/N/P and Soil Structure Module
Simulation of 2 year of Compost Addition

![Soil Organic Carbon Stock Distribution, tC/ha](image1)

Carbon sequestration

![Soil Water Stable Aggregate (WSA) Distribution, %](image2)

Water Stable Aggregates – soil fertility

![Porosity & Bulk Density Distribution](image3)

Porosity & Bulk Density – soil structure
Soil Layer 1
Water Content

Soil Layer 2
Water Content

Shallow Aquifer
Water Storage

Hydrologic Representation of SWAT

Precipitation/Snow Melt

Surface runoff (overland)

ET

Irrigation

ET

REvap

Base Flow
To Channel

Deep aquifer flow

Percolation

Lateral Flow

Percolation (GW Recharge)
Soil Function Status of Koiliaris CZO

Biomass Production

Koiliaris River Basin Productivity (kg/ha/y)

Legend
- River
- 0.000 - 1000.000
- 1000.001 - 2468.251
- 2468.252 - 4936.000
- 4936.001 - 10000.000
- 10000.001 - 89148.110

Biodiversity

Bacteria / Fungi Ratio distribution across Koiliaris CZO
Soil Function Status of Koiliaris CZO

Carbon Sequestration

Water Filtration and Transformation

Annual Nitrate Flux to the Reach - Wet Year

Legend

Annual Nitrate Flux (kg N/ha/year)

- 0.25 - 1.30
- 1.31 - 3.70
- 3.71 - 6.40
- 6.41 - 11.00
- 11.01 - 16.00

Reach
ICZ Model - Dynamic Linking to Soil Structure

As a function of WSA, SOC and BD
Rigorous simulation and quantification of critical soil functions and ecosystem services:

• C, N and P storage in soils, a fundamental soil function which is simulated dynamically, including relationships between soil structure and organic matter protection;
• Biomass production including effects of mycorrhizae and exudates on nutrient acquisition;
• Quantification of C in microorganisms, fungi and consumers, as an index of soil biodiversity; and
• Water transformations and filtration and simulation of the weathering of base cations / nutrient elements.
Thank You