Factors controlling the rate of OM decay

1 Placement
2 Size and Surface Area
3 C:N Ratio
4 Litter Quality
4. **Litter Quality**

\[
\text{C/N > 20 (N immobilized) \rightarrow N immobilized} \\
\text{C/N < 20 (N release) \rightarrow N release}
\]

The graph illustrates the change in mineral nitrogen over time (weeks) with respect to the addition of residues. The x-axis represents the number of weeks, while the y-axis shows the change in mineral nitrogen and net immobilization. The graph divides the residues into four categories based on lignin and polyphenols content and C/N ratio:

- **Low lignin and polyphenols, low C/N**: Net mineralization increases over time.
- **High lignin and/or polyphenols, low C/N**: Net immobilization decreases over time.
- **High lignin and/or polyphenols, high C/N**: Net mineralization increases over time.
- **Low lignin and polyphenols, high C/N**: Net immobilization decreases over time.

The graph helps to understand the impact of litter quality on nitrogen dynamics in ecosystems.
TABLE 12.3 Litter Quality in Relation to the Lignin Content, Polyphenol Content and C/N Ratio of Several Types of Plant Residues

Prunings (leaves and small twigs) of three common agroforestry tree species and afterharvest residues of two cereal crops were applied at a rate of 5 Mg/ha to an Oxic Paleudult in a humid tropical region of Nigeria. Low values of C/N, lignin, and polyphenols all contribute to high litter quality and high speed of decomposition. The inhibitory effect of polyphenol content can be seen by comparing Gliricidia to Leucaena.

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Plant parts</th>
<th>Lignin, %</th>
<th>Polyphenols, %</th>
<th>C/N</th>
<th>Decomposition constant, * W/week</th>
<th>Litter quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gliricidia sepium</td>
<td>Prunings</td>
<td>12</td>
<td>1.6</td>
<td>13</td>
<td>0.255</td>
<td>High</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>Prunings</td>
<td>13</td>
<td>5.0</td>
<td>13</td>
<td>0.166</td>
<td>Medium–high</td>
</tr>
<tr>
<td>Oryza sativa</td>
<td>Straw</td>
<td>5</td>
<td>0.6</td>
<td>42</td>
<td>0.124</td>
<td>Medium</td>
</tr>
<tr>
<td>Zea mays</td>
<td>Stover</td>
<td>7</td>
<td>0.6</td>
<td>43</td>
<td>0.118</td>
<td>Medium</td>
</tr>
<tr>
<td>Dactyladenia barteri</td>
<td>Prunings</td>
<td>47</td>
<td>4.1</td>
<td>28</td>
<td>0.011</td>
<td>Low</td>
</tr>
</tbody>
</table>

\* As each type of residue decomposed during a 14-week season, researchers periodically determined the proportion \( Y \) of the original residue dry matter remaining. The decomposition rate \( k \) was determined from the equation \( Y = e^{-kt} \), in which \( e \) is the base of natural logarithms, and \( t \) is time in weeks. Therefore, the larger the decomposition constant \( k \), the faster the decomposition.

Data selected from Tian, et al. (1992 and 1995).
Rate of Plant Tissue Decay

Rate of organic matter decay depends on:

1. Properties of the organic matter
   Physical - eg. chopped straw vs. whole straw
   Chemical - high lignin & cellulose slows decay
      (eg. wood vs. grasses)

   (A) C:N ratio (this could be consider chemical),
   (B) high surface area (size) and
   (C) resistance to decay
2. Water

Decay fastest in moist soil
Slow in dry or waterlogged soil
3. Stage of Decay

![Graph showing the decay of organic material over time]

- **Amount of Original Organic Material Left**

  - **Rapid Decay**
  - **Slow Decay**

  **Half Life (T½)**

  **Time**

**Decay Rates**

- **Fresh Material**: up to 50%/week
- **Humus**: 3%/year
Table 3. Values $T_{1/2}$ for a variety of experiments in different regions of the world

<table>
<thead>
<tr>
<th>Location</th>
<th>Cropping System</th>
<th>$T_{1/2}$, years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois, USA</td>
<td>Continuous corn</td>
<td>29</td>
</tr>
<tr>
<td>Kansas, USA</td>
<td>Wheat-fallow</td>
<td>11</td>
</tr>
<tr>
<td>Assam, India</td>
<td>Unshaded Tea</td>
<td>7</td>
</tr>
<tr>
<td>Congo, Africa</td>
<td>Food crops</td>
<td>2</td>
</tr>
<tr>
<td>Rothamsted, England</td>
<td>Grass</td>
<td>$25^1$</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>Grass-legume</td>
<td>$3^1$</td>
</tr>
</tbody>
</table>

$^1$Organic matter accumulation, all others organic matter decline.
4. Temperature

Overall soil respiration declines at low temp.

Result: cool climates produce soils with high organic matter

![Graph showing the relationship between temperature and relative decay rate of fresh plant material and humus.](image)
5. **Chemical Factors** ~ factors which might inhibit microbes

- extremes of pH (<4.5, >9) inhibit decay
- very high salinity inhibits decay
- nutrient deficiencies (usually N) inhibit decay.

- C:N ratio (this could be consider physical),
Humus
Nonhumic group consists primarily of polysaccharides
HUMUS - colloidal soil organic matter that decomposes slowly and colors soils brown or black.

- organic "glue" holding mineral particles together as aggregates.

- two important properties like clay:

  1. highly charged (negative), adsorbing exchangeable cations.

  2. large surface area per unit mass.

- very reactive in soil (despite low content).

3 chemical groupings: fulvic acids humic acids humin
HUMUS FORMATION

HUMUS -  A mixture of colloidal organic decay products that resists further decay.

PROPERTIES OF HUMUS -

1. Contains Phenolic Polymers -
   - confers dark color
   - produces resistance to decay
   - buffers pH (in part)

2. Contains Carboxyl (-COOH) Groups
   - buffers pH between 4-6.5
   - \[ \text{COOH} \rightleftharpoons \text{-COO}^- + \text{H}^+ \]
   - generates pH-dependent CEC
   - chelates certain cations (eg. Cu, Zn)

3. Accumulates N and S as it Decays
   - main source of these in unfertilized soils
   - tied up in fairly unavailable form
   - C/N, C/S ratios decrease during decay.
<table>
<thead>
<tr>
<th>Effect on plant growth</th>
<th>Humic substance</th>
<th>Concentration range, mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerated water uptake and enhanced germination of seeds</td>
<td>Humic acid</td>
<td>1–100</td>
</tr>
<tr>
<td>Stimulated root initiation and elongation</td>
<td>Humic and fulvic acids</td>
<td>50–300</td>
</tr>
<tr>
<td>Enhanced root cell elongation</td>
<td>Humic acid</td>
<td>5–25</td>
</tr>
<tr>
<td>Enhanced growth of plant shoots and roots</td>
<td>Humic and fulvic acids</td>
<td>50–300</td>
</tr>
</tbody>
</table>

From Chen and Aviad (1990).
Soil Organic Matter Management

3 Pools of SOM
- Active
- Slow
- Passive
**TABLE 12.5  Factors Affecting the Balance between Gains and Losses of Organic Matter in Soils**

<table>
<thead>
<tr>
<th>Factors promoting gains</th>
<th>Factors promoting losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green manures or cover crops</td>
<td>Erosion</td>
</tr>
<tr>
<td>Conservation tillage</td>
<td>Intensive tillage</td>
</tr>
<tr>
<td>Return of plant residues</td>
<td>Whole plant removal</td>
</tr>
<tr>
<td>Low temperatures and shading</td>
<td>High temperatures and exposure to sun</td>
</tr>
<tr>
<td>Controlled grazing</td>
<td>Overgrazing</td>
</tr>
<tr>
<td>High soil moisture</td>
<td>Low soil moisture</td>
</tr>
<tr>
<td>Surface mulches</td>
<td>Fire</td>
</tr>
<tr>
<td>Application of compost and manures</td>
<td>Application of only inorganic materials</td>
</tr>
<tr>
<td>Appropriate nitrogen levels</td>
<td>Excessive mineral nitrogen</td>
</tr>
<tr>
<td>High plant productivity</td>
<td>Low plant productivity</td>
</tr>
<tr>
<td>High plant root:shoot ratio</td>
<td>Low plant root:shoot ratio</td>
</tr>
</tbody>
</table>
Managing Soil Organic Matter

Purposes:

1. To dispose of organic material (e.g. sewage waste, crop residue)

2. To build up or maintain humus for
   - structure
   - water retention
   - N & S supply
   - cation retention
   - pH buffering

3. Improve water infiltration & aeration (structure-related)

4. Provide a mulch to prevent soil
   - crusting
   - erosion
   - overheating
Managing Soil Organic Matter

1. To dispose of OM waste
   – composting, vermicomposting, etc…

Composting – 3 stage process

1. Mesophilic Stage 1
   Simple sugars & other readily digestible food sources are metabolized raising the temp > 40°C

2. Thermophilic Stage
   Cellulose & other less digestible materials are metabolized raising the temp to 50 to 75°C

3. Mesophilic Stage 2
   “Curing”, during which mesophilic organism recolonize, ↑ in plant stimulating hormones & ↑ hormones detrimental to plant pathogen fungi as well as ↓ in the compost temperature
Benefits of Composting

1. Safe Storage
2. Easier Handling
3. N competition avoidance
4. N stabilization
5. Partial Sterilization
6. Detoxification
7. Disease Suppression
Ways to Increase Organic Matter Levels:

1. Reduce Losses -
   - control erosion
   - select slowly-decaying organics
   - modify soil environment (aeration, etc.)

2. Increase Inputs -
   - add organic wastes-manures, composts
   - incorporate crop residues-green manures, straw, etc.
   - increase crop yield (fertilizer, etc.)
Amount of organic matter in soil is constant if:

\[
\text{Rate of addition of residues to soil} = \text{Rate of loss by decomposition}
\]

Soil formation
organic matter accumulation

% OM in soil

Time (yrs)
Reduce loss by modifying litter quality

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Reduce loss by Soil Environment Modification

Precipitation

Temperature

Increasing SOM decomposition