CHALLENGES FOR ORGANIC AGRICULTURE RESEARCH IN TROPICAL ZONES

Soil Fertility and Waste Management in the Tropics

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The Soil

A. Soil, one of the most important natural resources.

B. Consist of the following components:

- Mineral = 45%
- Water = 20-30%
- Air = 20-30%
- Organic matter = 5%

C. Soil provides multiple ecosystem services.

D. Soil is a living organism, needs
   - nourishment,
   - need care, and
   - protection

Fig. 1: Functions of Soils in the Ecosystem
Definition of soil fertility

Soil fertility is defined as “the quality of a soil that enables it to provide nutrients in adequate amounts and in proper balance for the growth of specified plants or crops” [SSSA 1997]
Geographical Distribution of Soils

Major Tropical Soils
- Alfisols
- Entisols (Psamments)
- Inceptisols (tropets)
- Oxisols
- Ultisols
- Vertisols

Fig. 2: Global soil regions
<table>
<thead>
<tr>
<th>USDA Soil Taxonomy</th>
<th>FAO Soil Taxonomy</th>
<th>Description</th>
<th>Inherent low soil fertility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfisols</td>
<td>Luvisols, Eutric, Nitosols, &amp; Lixisols</td>
<td>Gray to brown surface soils. Medium to high base nutrients and organic content.</td>
<td>- Dominance of low activity clays in the clay fraction.</td>
</tr>
<tr>
<td>Entisols</td>
<td>Various</td>
<td>Soils with poorly developed layers. Wind deposit.</td>
<td>- Low CEC</td>
</tr>
<tr>
<td>Psammets</td>
<td>Arenosols &amp; Regosols</td>
<td>Sandy, acid, infertile soils.</td>
<td>- Low organic matter</td>
</tr>
<tr>
<td>Tropepts</td>
<td>Cambisols</td>
<td>Well drained inceptisols (Dystropepts=acid, infertile; Eutropepts=high base saturation).</td>
<td>- Low capacity to retain &amp; supply nutrients</td>
</tr>
<tr>
<td>Oxisols</td>
<td>Ferrasols &amp; Plinthisols</td>
<td>Deep, highly weathered, infertile status soils, excellent drainage.</td>
<td>- High P fixation</td>
</tr>
<tr>
<td>Utisols</td>
<td>Acrisols, Dystric, Nitosols &amp; Alisols</td>
<td>Similar to Oxisols except for a clay increase with depth. Texture from sandy to clayey.</td>
<td>- Low base cations</td>
</tr>
<tr>
<td>Vertisols</td>
<td>Vertisols</td>
<td>Dark heavy clay soils that shrink and crack when dry. Moderately high base status.</td>
<td>- Acidic, pH &lt; 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Low micronutrients</td>
</tr>
</tbody>
</table>
Why Soil Fertility Management...

Fig. 3: Soil degradation

Percent Arable land degraded
- 74% C. America
- 45% S. America
- 36% Asia
- 65% Africa
Oldeman (1999); Scherr (1999)

Causes of land degradation
- CA & SA – Nutrient loss
- Asia – Salinization & Nutrient loss
- Africa – Nutrient mining
Evidence of Accelerated Soil degradation in SSA

1995-1997

2002-2004

Table 2: Annual Nutrient Balance in Africa 1993-1995

<table>
<thead>
<tr>
<th>Region</th>
<th>N  (kg/ha)</th>
<th>P$_2$O$_5$ (kg/ha)</th>
<th>K$_2$O (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sahellian Belt</td>
<td>-233</td>
<td>-81</td>
<td>-206</td>
</tr>
<tr>
<td>Central Africa</td>
<td>-93</td>
<td>-43</td>
<td>-83</td>
</tr>
<tr>
<td>West Africa</td>
<td>-347</td>
<td>-104</td>
<td>-279</td>
</tr>
<tr>
<td>East Africa</td>
<td>-290</td>
<td>-98</td>
<td>-300</td>
</tr>
<tr>
<td>Southern Africa</td>
<td>-157</td>
<td>-19</td>
<td>-214</td>
</tr>
<tr>
<td>Total</td>
<td>-1121</td>
<td>-346</td>
<td>-1081</td>
</tr>
</tbody>
</table>

Source: Hanao & Baanante, 2006; IFDC 2006

Fig 4: Nutrient mining of agricultural land in Africa kg/ha/year
Soil Erosion & Leaching

Bush burning

Uncontrolled Timber logging

Harvest and removal of crop Residues to urban markets

Soil Erosion

- Most African countries (especially W.A and C.A) lose about 50 tons of soil per hactare per year.
- Equivalent to 20 billion tons of N, 2 billion tons of Phoshorous & 41 billion tons of potassium per year

Source: FAO
Negative Impact of land degradation

A. Per Capital Food Production in Africa and Asia

B. Ecological imbalance

C. Increasing level of poverty

40% SSA population living below the poverty line

Fig. 5: Changes in Cereal Production in Sub-Saharan Africa Due to Changes in Area and Yield (1961 = 100)

Fig.6: Change in Cereal Production in Asia Due to Changes in Area and Yield (1961 = 100)

Source: IFDC, 2006; UNEP, 2002
# Paradigm shift of management of soil fertility in Africa

## Table 3

<table>
<thead>
<tr>
<th>Year</th>
<th>Soil fertility management approaches</th>
<th>Factors that discourage the practice/Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1960</td>
<td>Traditional bush fallow method (10 or more years)</td>
<td>• Population growth</td>
</tr>
<tr>
<td>From 1960s-1970s</td>
<td>External inputs (mineral fertilizer, lime, irrigation water &amp; improved cereal germplasm)</td>
<td></td>
</tr>
<tr>
<td>1980s</td>
<td>Low external inputs sustainable agriculture (LEISA)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The availability of organic inputs.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ability to access &amp; pay for mineral fertilizers</td>
</tr>
</tbody>
</table>

---

**Critical Lesson Learned**

A highly context-specific approach is required which takes into account:

- The status of soil fertility.
- The availability of organic inputs.
- Ability to access & pay for mineral fertilizers.

Source: Bationo, 2009
Technologies developed to improve agricultural production & soil fertility in SSA

**Benefits**
- Favourable microclimate,
- Permanent cover,
- Improved SOM and biological activities,
- Improved soil structure,
- Increased infiltration of water,
- Improved nutrient cycling and soil fertility

**Constraints**
- Areas lost for crop production,
- Recommended trees did not meet the immediate and long term needs or expectation of farmers
- Lack of planting materials (seed and seedlings)

**Constraints...**
- Competition with crops for space and natural resources (water, nutrients, sunlight etc).
- Land tenure system
- Farm size - area of land & duration
- Problems with residue management

Source: Kwesiga et al. (2003); Minae et al. (1989); Jalloh et al. (2011); Ngwira et al. (2014)
Green manure and cover crop

**Benefits**
- **Cover crops**
  - Provide soil cover
  - Loosen compacted soil
  - Improved water infiltration
  - Maintain or increase soil organic matter
  - Prevent soil erosion
  - Suppress weeds
  - Reduce insects pests & diseases

**Green manuring**
- Suppression of soil-borne diseases

**Constraints**
- Biophysical factors, faced by land users who are mostly smallholder farmers.
- Only few species of exotic and traditional legumes performed well across most sites.
- Environmental stress and constraints e.g. water limitation, drought, soil acidity, nutrient deficiency, etc.
- Some crops recommended by researchers were not suitable to farmers needs or criteria

Source: Nederlof & Dangbégnon (2007); Gachene et al. (1999); Pessarrakli (1999)
 Technologies developed to improve agricultural production & soil fertility in SSA

**Benefits**

1. Organic matter content
2. Soil structure
3. Soil water holding capacity
4. Soil fertility (nutrients & microbial activity)
5. Crop yield

**Constraints, cover**

- Not so appreciable in wet conditions
- May harbour pests and diseases
- Dependent on local biophysical and socio-economic environment

**Constraints, composting**

- Labour intensive and machinery is rarely available to smallholders
- Low nutrient content, require large application to fields thus increase cost
- Competing use of residues in sub humid and arid areas (livestock, burning, and construction)

Source: Ouédraogo et al. (2001); Mando et al. (2005); Danso et al. (2007)
Major issues still confronting SSA

- Soils of Africa cannot sustain high productivity and growth without organic inputs (see table below).
- The population of Africa is expected to double by 2050.
- Demand for food will increase.
- Global warming may alter soil fertility patterns.

**Table 4: Typical characteristics of some soils in Africa**

<table>
<thead>
<tr>
<th>Order Soil Taxonomy</th>
<th>FAO</th>
<th>Relative amount of major minerals</th>
<th>Mineral in soils (%)</th>
<th>Organic matter (%)</th>
<th>CEC Cmol(+)/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfisols</td>
<td>Chromic Lixisols</td>
<td>KK-5; MT-3</td>
<td>KK-55</td>
<td>0.93</td>
<td>3.9</td>
</tr>
<tr>
<td>Entisols</td>
<td>Haplic Arenosols</td>
<td>KK-4</td>
<td>KK-15</td>
<td>0.81</td>
<td>6.2</td>
</tr>
<tr>
<td>Mollisols</td>
<td>Chromic Livuisols</td>
<td>KK-3; MT-3</td>
<td>KK-34</td>
<td>1.72</td>
<td>20.1</td>
</tr>
<tr>
<td>Oxisols</td>
<td>Rhodic Ferrasols</td>
<td>KK-4</td>
<td>KK-43</td>
<td>2.24</td>
<td>17.2</td>
</tr>
<tr>
<td>Utilisols</td>
<td>Ferric Acrisols</td>
<td>KK-5</td>
<td>KK-43</td>
<td>0.71</td>
<td>5.0</td>
</tr>
<tr>
<td>Utilisols</td>
<td>Rhodic Ferrasols</td>
<td>KK-5</td>
<td>KK-41</td>
<td>1.44</td>
<td>11.5</td>
</tr>
<tr>
<td>Vertisols</td>
<td>Vertisols</td>
<td>KK-4; MT-3</td>
<td>KK 33</td>
<td>1.63</td>
<td>34.1</td>
</tr>
</tbody>
</table>

(Key: KK= Kaolinite, MT= Montmorillonite; 5= Dominant; 4= abundant, 3= Moderate)

*Source: Lungu et al., 2015 (un published)*
Major issues still confronting soil fertility in Africa

Options to build up SOM

The Way Forward?

- Maintaining high equilibrium levels of soil organic matter is key to sustainable production on tropical soils.
- Annual additions of residues and manipulation of the decomposition rate of organic matter

Need to investigate the biophysical, socio-economic and cultural issues that prevent the adoption of agroforestry, cover cropping & green manuring, composting, residue cover & mulching.

Integration of the above into Organic Agriculture (crop rotation, intercropping)
Why Organic Agriculture an Option for the Tropics?

A. Potential to Support the Multispecies African Farming Systems
### Why Organic Agriculture an Option for the tropics?

#### Case study: Kenya

Table 5: Long term systems comparison trial in Kenya (Chuka and Thika) (2007= B, &2012= A)

<table>
<thead>
<tr>
<th>Site</th>
<th>Texture</th>
<th>Soil type</th>
<th>Clay</th>
<th>Silt</th>
<th>Sand</th>
<th>Crops</th>
<th>Treat</th>
<th>pH</th>
<th>pH</th>
<th>CEC</th>
<th>CEC</th>
<th>Org C</th>
<th>Org C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chuka</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td></td>
<td>M, B, V, P</td>
<td>Conv-High</td>
<td>5.7</td>
<td>5.5</td>
<td>18.8a</td>
<td>20.6b</td>
<td>24.7</td>
<td>27.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M, B, V, P</td>
<td>Org-High</td>
<td>5.8</td>
<td>6.0</td>
<td>17.8a</td>
<td>26.7a</td>
<td>21.7</td>
<td>27.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M, B, V, P</td>
<td>Org-Low</td>
<td>5.7</td>
<td>5.5</td>
<td>16.8a</td>
<td>17.8b</td>
<td>24.5</td>
<td>26.8</td>
</tr>
<tr>
<td>Thika</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M, B, V, P</td>
<td>Org-Low</td>
<td>5.8</td>
<td>5.9</td>
<td>16.5a</td>
<td>16.5b</td>
<td>22.0</td>
<td>26.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M, B, V, P</td>
<td>Conv-Low</td>
<td>5.4</td>
<td>5.6</td>
<td>11.0</td>
<td>18.0a</td>
<td>23.0</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M, B, V, P</td>
<td>Org-High</td>
<td>5.3</td>
<td>6.9</td>
<td>10.5</td>
<td>20.1a</td>
<td>22.1</td>
<td>18.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M, B, V, P</td>
<td>Conv-Low</td>
<td>5.4</td>
<td>5.2</td>
<td>10.8</td>
<td>14.7b</td>
<td>22.8</td>
<td>18.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>M, B, V, P</td>
<td>Org-Low</td>
<td>5.4</td>
<td>5.4</td>
<td>11.8</td>
<td>14.9b</td>
<td>22.4</td>
<td>17.7</td>
</tr>
</tbody>
</table>

Percentage change in organic carbon (org-C) at Chuka: Conv-High = 11%; Org-High= 25%; Conv-Low = 7%; Org-Low = 19%. CEC, Cation exchange capacity; High input (229 kg N/ha: 128 kg P/ha); Low input (47 kg N/ha: 31kg P/ha)

Source: Adamtey et al., Forth coming; M= maize; B= Beans; V= vegetables; P= Potato
Why Organic Agriculture an Option for the tropics?

Case study : Zambia

Table 6 Influence of Agro Ecological Region on Adoption of Agricultural Practices

<table>
<thead>
<tr>
<th>Sustainable Agricultural practices adopted</th>
<th>Area (agro-ecological region)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chongwe &amp; Rufunsa (I/IIA)</td>
</tr>
<tr>
<td>Fertility trees</td>
<td>87.0%</td>
</tr>
<tr>
<td>Green manures</td>
<td>63.0%</td>
</tr>
<tr>
<td>Compost</td>
<td>52.2%</td>
</tr>
<tr>
<td>Animal manure</td>
<td>84.8%</td>
</tr>
<tr>
<td>Manure &amp; leaf extract</td>
<td>34.8%</td>
</tr>
<tr>
<td>Crop rotation</td>
<td>84.8%</td>
</tr>
<tr>
<td>Cover crop</td>
<td>47.8%</td>
</tr>
<tr>
<td>Intercrop</td>
<td>65.2%</td>
</tr>
<tr>
<td>No burning</td>
<td>56.5%</td>
</tr>
<tr>
<td>Mulching</td>
<td>21.7%</td>
</tr>
</tbody>
</table>

Overcoming Inadequate Residue use in OA in SSA

A. Use of Solid Waste in Agriculture

OECD = Organization for Economic Co-operation & Development
ECA = Europe and Central Asia
AFR = Africa Region
SAR = South Asia
MENA = Middle East & North Africa
LAC = Latin America & Caribbean
EAP = East & Pacific Asia

Global waste generation = 1.3 billion tons/year
SSA (waste generation) = 62 million tons /year
Tropical region (waste generation) = 49.8% of Global generation

Source: World Bank 2012

Fig. 8: Waste Generation by Region

Projections in 2025

Global waste generation = 2.2 billion tons/year
SSA (waste generation) = 124 million tons /year
Tropical region (waste generation) = 49.8% of Global generation
Overcoming Inadequate Residue Use in OA in SSA

0.65 billion tons of organic fraction is generated per year in the tropics

31 million tons of organic fraction is generated per year in SSA

Projection in 2025
61 million tons of organic fraction will be generated per year in SSA

Fig. 9: Municipal solid waste fractions in selected cities of Africa and Asia

Organic fraction (average) = 50% of the total waste generation

Source: Cofie et al. 2006
### Overcoming Inadequate Residue use in OA in SSA

#### Quality of compost from MSW in some cities of Ghana

**Table 8: Concentration of Heavy Metals in Composting Materials (mg/kg dry weight)**

<table>
<thead>
<tr>
<th>Composting materials</th>
<th>Pb</th>
<th>Zn</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Cd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Household waste (HW)$_1$</td>
<td>74</td>
<td>56</td>
<td>22</td>
<td>1,958</td>
<td>160</td>
<td>*</td>
</tr>
<tr>
<td>Household waste (HW)$_2$</td>
<td>38</td>
<td>115</td>
<td>12</td>
<td>2,070</td>
<td>451</td>
<td>*</td>
</tr>
<tr>
<td>Market waste (MW)$_1$</td>
<td>39</td>
<td>54</td>
<td>38</td>
<td>2,449</td>
<td>186</td>
<td>*</td>
</tr>
<tr>
<td>Market waste (MW)$_2$</td>
<td>47</td>
<td>64</td>
<td>15</td>
<td>1,884</td>
<td>450</td>
<td>*</td>
</tr>
</tbody>
</table>

**Table 9: Concentration of Heavy Metals in Compost (mg/kg dry weight of compost)**

<table>
<thead>
<tr>
<th>Compost Heaps</th>
<th>Pb</th>
<th>Zn</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
<th>Cd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compost heap 1</td>
<td>87</td>
<td>146</td>
<td>63</td>
<td>11,748</td>
<td>249</td>
<td>*</td>
</tr>
<tr>
<td>Compost heap 2</td>
<td>47</td>
<td>128</td>
<td>43</td>
<td>8,405</td>
<td>258</td>
<td>*</td>
</tr>
</tbody>
</table>

| Threshold values$^a$ | 150 | 400 | 100 | -    | -   | 1.5 |

* Trace amount (below detection)


Source: Adamtey, 2006
Challenges Associated with MSW composting in SSA

- High cost of operation hindered private sector involvement.
- Over emphasis placed on electricity demanding and often fragile mechanised process rather than labour intensive operations.
- Unstable compost quality.
- Inadequate attention to biological processes requirements for example under tropical conditions.
- Lack of vision and marketing plans for the final product (i.e. compost).
- Poor accounting practices that neglect the fact that the economics of composting rely on externalities such as reduced water contamination, avoided transport and disposal costs.
- Difficulties in securing finances.
- Lack of enabling institutional (e.g. Private-public partnership) framework.

Source: Hoornweg et al., 1999; Cofie et al. 2006; Drechsel et al., 2010
Current Research Policies & MSW Management or Composting in SAA

Gaps in existing research policies

Case study: Ghana

1. The constitution does not make a direct reference to composting.
2. The Environmental Sanitation Policy does not incorporate incentives that could attract private sector participation in composting.
3. The Local Government Act does not include waste separation at source and this may affect compost quality.
4. National Fertilizer Policy provides subsidy on mineral fertilizer but not on compost.
THANK YOU for your Attention!

(noah.adamtey@fibl.org)
THE WAY FORWARD

Interventions to Reuse MSW for fertility management in the Tropics

1. Unless there are people caring for their soils, policies will not work. General awareness and education is key to successful soil fertility management.

2. Policies and market mechanisms that make returning nutrients to productive land, economically attractive to farmers.

3. Policies on waste management (including incentives for source separation of waste, waste collection and recycling (composting), capacity building and knowledge sharing) so that reuse of nutrients is ensured, including ways to make sure these policies are implemented on the ground in tropical countries.

4. Policies incentive for organically-sourced fertilisers, that also take into account the health of the farming community.
THE WAY FORWARD

Interventions to Reuse MSW for fertility management in the Tropics

5. Much more research and development on different options for reusing waste, including development of best techniques for composting in different scenarios and on producing high quality compost specific for particular types of soils and crops

6. Policies to develop the local animal production industry in terms of industrial livestock operations, amount that is produced and consumed, and the waste management. To integrate animal waste into MSW composting

7. Societal change in understanding and value of waste, not as waste, but as a resource that needs consideration and care.
## Case study: Ghana

### Table 7a

<table>
<thead>
<tr>
<th>Policy, Act</th>
<th>Key issues</th>
</tr>
</thead>
</table>
| Constitution of Ghana 1992                      | ▪ empowers parliament to pass all laws on the environment  
▪ direct states to take appropriate measures to promote the development of agriculture & industry  
▪ It encourages all citizens to protect & safeguard the environment                                      |
| Environmental Sanitation Policy 20010           | ▪ seek to promote benefits of alternative use of waste through reduction, re-use, recycling and recovery.  
▪ reference is made to recycling through composting  
▪ it seeks to ensure that site for treatment & disposal of waste are safe & hygienic                  |
| Local Government Act , 462, 1993                 | ▪ place MSW including composting under the responsibilities of MMDAS  
▪ it mandates the MMDAS to set up waste management departments                                                                                     |
## Case study: Ghana...

<table>
<thead>
<tr>
<th>Policy, Act</th>
<th>Key issues</th>
</tr>
</thead>
</table>
| Environmental Protection Agency Act, 490 1994  | ▪ main government institutions or agency responsible for environmental protection & compliance  
                                              | ▪ demands environmental impact assessment prior to issuing a permit for compost plant construction  
                                              | ▪ responsible for controlling the generation, treatments, storage, transportation 6 disposal of waste |
| National Fertilizer Policy Act, 2013            | ▪ directs overall approaches & practices in the compost sector  
                                              | ▪ It acknowledge organic fertilizer from organic materials such as sewage, animal manure & plant residues prepared through composting, fermentation, etc. |
| Plants and Fertilizer Act 2010                  | ▪ it directs that no person shall import, manufacture or distribute fertilizer in commercial quantities unless the person is registered  
<pre><code>                                          | ▪ it directs on how to register a compost plant, seek certification for a compost product |
</code></pre>
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<th>FAO Soil Taxonomy</th>
<th>Description</th>
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<td>Gray to brown surface soils. Medium to high base nutrients and organic content</td>
</tr>
<tr>
<td>Andisols</td>
<td>Andosols</td>
<td>Volcanic soils, moderate to high fertility, P fixation by allophane</td>
</tr>
<tr>
<td>Aridisols</td>
<td>Solonchak &amp; solonetz</td>
<td>Dry or desert soils, high in base nutrients &amp; low organic matter</td>
</tr>
<tr>
<td>Entisols</td>
<td>Various</td>
<td>Soils with poorly developed layers. Wind deposits</td>
</tr>
<tr>
<td>Fluvents</td>
<td>Fluvisols</td>
<td>Alluvia soils usually of high fertility</td>
</tr>
<tr>
<td>Psammets</td>
<td>Arenosols &amp; Regosols</td>
<td>Sandy, acid, infertile soils</td>
</tr>
<tr>
<td>Gelisols</td>
<td>Histosols</td>
<td>Wet, highly organic soils (&gt; 20% organic matter)</td>
</tr>
<tr>
<td>Inceptisols</td>
<td>Various</td>
<td>Young soils with A-B-C horizon development. Fertility highly variable</td>
</tr>
<tr>
<td>Aquepts</td>
<td>Glysoils</td>
<td>Poorly drained moderate to high fertility</td>
</tr>
<tr>
<td>Tropepts</td>
<td>Cambisols</td>
<td>Well drained inceptisols (Dystropepts= acid, infertile. Eutropepts=high base saturation)</td>
</tr>
<tr>
<td>Mollisols</td>
<td>Chernozems</td>
<td>Thick, dark soils high in organic content and base derived from calcareous materials</td>
</tr>
<tr>
<td>Oxisols</td>
<td>Ferrasols &amp; Plinthisols</td>
<td>Deep, highly weathered, acid, low base status. Excellent structure &amp; good drainage</td>
</tr>
<tr>
<td>Spodosols</td>
<td>Podzols</td>
<td>Sandy surface horizon underlain with a horizon of organic &amp; amorphous C, Fe &amp; Al compounds. Acid &amp; infertile or low in base nutrients</td>
</tr>
<tr>
<td>Utisols</td>
<td>Acrisols, Dystric, Nitosols &amp; Alisols</td>
<td>Similar to Oxisols except for a clay increase with depth. Texture from sandy to clayey</td>
</tr>
<tr>
<td>Vertisols</td>
<td>Vertisols</td>
<td>Dark heavy clay soils that shrink and crack when dry. Moderately high base status</td>
</tr>
</tbody>
</table>

**Why Soil Research in the Tropics?**

- Dominance of low activity clays in the clay fraction.
- Low CEC
- Low organic matter
- Low capacity to retain & supply nutrients
- High P fixation
- Low base cations
- Acidic, pH < 5
- Low micronutrients