SOIL CARBON STOCKS IN SARAWAK, MALAYSIA

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INTRODUCTION

- Soil carbon sequestration specifically deals with the transfer of carbon dioxide from the atmosphere into the soil via crop residues and other organic solids in a form that is not easily released back into the atmosphere.

- Carbon sequestration - emerging as important topic - helps to offset emissions from the combustion of fossil fuels and other anthropogenic activities that contribute to the emission of carbon.

- An additional benefit of carbon sequestration would be to enhance soil quality and to improve the crop and soil productivity.
CURRENT ISSUES

- The relationship between greenhouse gas emission and climate change has led research to identify and manage the natural sources and sinks of the gases.

- CO₂, CH₄, and N₂O have an anthropogenic source and of these CO₂ is the least effective in trapping long wave radiation (Mitchell, 1989).

- Some wetland soils are also a source of methane and some soils oxidize atmospheric CH₄.
Carbon Dioxide Concentration

Data updated 06.30.10

PROXY (INDIRECT) MEASUREMENTS
Data source: Reconstruction from ice cores.

DIRECT MEASUREMENTS: 2005-PRESENT
Data source: Monthly measurements (corrected for average seasonal

Land Ice

Data updated 06.30.10

ANTARCTICA MASS VARIATION SINCE 2002
Data source: Ice mass measurement by NASA’s Grace satellites.

GREENLAND MASS VARIATION SINCE 2002
Data source: Ice mass measurement by NASA’s Grace satellites.

Notes: In the above charts, negative numbers indicate mass loss; positive numbers indicate mass gain. (Reference)
CHANGE IN METHANE WITH TIME

Intergovernmental Panel on Climate Change, 2001
INCREASING TRENDS

Since 1750, anthropogenic sources are believed to increase the concentration of the following:

- CO$_2$ – 31% increase
- CH$_4$ – 151% increase
- N$_2$O – 17% increase

Source: INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 2001
ARE WE HEADING IN THE RIGHT DIRECTION?


Carbon dioxide levels in our atmosphere are rising. Left: July 2003. Right: July 2007. Both images show the spreading of carbon dioxide around the globe as it follows large-scale patterns of circulation in the atmosphere. The color codes in these two pictures are different in order to account for the carbon dioxide increase from 2003 to 2007. If the color bar for 2003 were to be used for 2007, the resulting 2007 map would be saturated with reddish colors, and the fine structure of the distribution of carbon dioxide obscured.
"The picture's pretty bleak, gentlemen. ... The world's climates are changing, the mammals are taking over, and we all have a brain about the size of a walnut."

"Your carbon footprint! Now we're going to tax you."
PROBLEM STATEMENT

- Insufficient data on SOC distribution and variations in soils
- Lack of information on controlling factors
OBJECTIVES

- To obtain reliable estimates of SOC in the major soil types in Sarawak.

- To evaluate the mechanisms involved that determine the sustainability and resilience of the SOC in the various systems.
There are three major pools of carbon; ocean, terrestrial and atmosphere.

The oceans contribute ~ 39,000 Pg ($10^{15}$ g) of C, the terrestrial system, ~ 2,500 Pg and, the atmosphere ~ 750 Pg (IPCC, 1990).

Soil - largest terrestrial pool and the amount of global soil organic carbon (SOC) to 1m depth is estimated by several authors to range from, 1,220 Pg (Sombroek et al., 1993), 1,576 Pg (Eswaran et al., 1993), and 1,462-1,548 Pg (Batjes, 1996).
MATERIALS AND METHODS

- Samples for this study were collected from several locations in the state during a 15 year period.

- Some of the organic carbon data were obtained from legacy unpublished data.

- Soil organic carbon (SOC) estimates were made for a standard depth of 100 cm unless the soil by definition is less than this depth, as in the case of lithic subgroups.
GLOBAL CARBON STORAGE

Carbon storage in terrestrial ecosystems.

Total carbon tonnes/ha

0 - 13
10 - 20
20 - 50
50 - 100
100 - 200
200 - 500
500 - 1000
> 1000

IPB International Convention Centre
International Workshop on Evaluation and Sustainable Management.

NRCS Natural Resources Conservation Service
This map is part of the 1:5,000,000 scale Global Soil Organic Carbon map. Soil organic carbon was calculated to three depths, 0-25, 0-50 and 0-100 cm. Mean carbon values are calculated by soil suborder. The dominant soil suborders for each map unit of the global soil regions map are assigned a mean carbon value from the NRCS pedon database.
MAJOR PHYSIOLOGICAL SUBDIVISIONS

- Diversified landscape
- Lowlands - Histosols
- Rest - mineral soils
SOIL MAP OF SARAWAK (1968)
## Estimates for Carbon (1m)

<table>
<thead>
<tr>
<th>Order</th>
<th>C Average Kg m⁻² m⁻¹</th>
<th>Sub Group</th>
<th>C Average Kg m⁻² m⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inceptisols</td>
<td>6.51</td>
<td>Aeric Endoaquept</td>
<td>6.51</td>
</tr>
<tr>
<td>Ultisols (NB. Some sub-groups are not shown here)</td>
<td>16.95</td>
<td>Aquic Hapludult</td>
<td>24.40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Typic Hapludult</td>
<td>13.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Typic Epiaquult</td>
<td>34.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Typic Paleudult</td>
<td>9.76</td>
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<tr>
<td></td>
<td></td>
<td>Typic Paleudult</td>
<td>9.76</td>
</tr>
<tr>
<td>Oxisols</td>
<td>20.60</td>
<td>Typic Haploperox</td>
<td>20.60</td>
</tr>
<tr>
<td>Entisols</td>
<td>9.51</td>
<td>Lithic Udipsamment</td>
<td>9.51</td>
</tr>
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<td>Entisols</td>
<td>9.51</td>
<td>Lithic Udipsamment</td>
<td>9.51</td>
</tr>
<tr>
<td>Histosols</td>
<td>109.31</td>
<td>Hydric Haplofibrast</td>
<td>109.31</td>
</tr>
</tbody>
</table>

IPB International Convention Centre
International Workshop on Evaluation and Sustainable Management.
COMPARISONS BETWEEN SOIL ORDERS (1m depth)

- Oxisols have relatively high SOC content.
  - Long periods available for sequestration.
  - Deeper admixture of SOC in soil by biologic activity
  - Lower decomposition rates for deep-seated SOC.
  - Presence of stable micro-aggregates

- OC in Entisols > Inceptisols

- Ultisols:
  - Typic Epiaquult & Aquic Hapludult quite high in C.
  - Lower rates of mineralization due to higher degrees of water saturation c.f. the other sub-groups.
- Histosols have highest percentage of OC distribution.

- Peat dome - initially rapid growth; slows down later (Anderson, 1964).
  - Growth dynamics - well enunciated (Driessen & Subagio, 1975).
  - Parent material - wood or soft tissues (Hwai et al., 2001).
    - Differences in bulk densities of sapric material
      - wood (~ 0.4-0.8gcm\(^{-3}\)); softer tissues (< 0.3gcm\(^{-3}\)).
  - The erratic stratification with depth – spatial variability in
    - rate of lateral flow, saturated hydraulic conductivity, rates of decomposition, humic to fulvic acid ratios and cation exchange capacities.
  - Contributes to erratic C distribution.
SPATIAL AND TEMPORAL VARIABILITY

DEPTH VARIATION IN 0.25ha (5m INTERVAL)

- 0-0.5m (9%)
- 0.5-1.0m (12%)
- 1.0-1.5m (22%)
- 1.5-2.0m (24%)
- 2.0-2.5m (28%)
- 2.5-3.0m (2%)
- >3.0m (3%)
IMPACT OF MICROVARIABILITY ON USE AND MANAGEMENT

- Differences in
  - bearing capacity
  - bulk density
  - Subsidence and irreversible shrinkage rates,
  - nutrient status
  - mechanisms of adsorption and desorption of cations and anions.
  - maintaining optimal hydrological conditions
  - impact of developing such soils on the conditions and performance of adjoining soils.
### VARIABILITY IN FUNCTIONAL GROUPS

<table>
<thead>
<tr>
<th>Bond (Frequency Range, 1/cm)</th>
<th>Possible Type of compound</th>
<th>% T</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
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<tbody>
<tr>
<td>C-O (1050-1300)</td>
<td>Alcohols, ethers, carboxylic acids, esters</td>
<td></td>
<td>1085</td>
<td>1083</td>
<td>1083</td>
<td>1083</td>
<td>1083</td>
<td>1083</td>
<td>1085</td>
<td>1087</td>
<td>1085</td>
<td>1083</td>
<td>1080</td>
</tr>
<tr>
<td>C=C (1500-1600)</td>
<td>Aromatic rings</td>
<td></td>
<td>1506</td>
<td>1506</td>
<td>1508</td>
<td>1506</td>
<td>1512</td>
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<td>1512</td>
<td>1508</td>
<td>1512</td>
<td>1515</td>
<td></td>
</tr>
<tr>
<td>C-H (2850-3300)</td>
<td>Alkanes, alkenes, alkynes, aromatic rings</td>
<td></td>
<td>2852</td>
<td>2852</td>
<td>2852</td>
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<tr>
<td>O-H (3200-3600)</td>
<td>Hydrogen-bonded alcohols, phenols</td>
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<tr>
<td>C=O (1690-1760)</td>
<td>Aldehydes, ketones, carboxylic acids, esters</td>
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<td></td>
<td></td>
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<td>1706</td>
</tr>
</tbody>
</table>
SUMMARY OF FTIR

- Different intensities for various functional groups.
- Stretching bonds such as C=O restricted to some Histosols.

IMPLICATIONS TO MANAGEMENT AND C SEQUESTRATION

- Response of Histosols to drainage or global climate change (resilience and capacity to sequester carbon) extremely complicated and unfortunately still poorly understood.
- Such tremendous variations could be better reflected in the taxonomic classification of Histosols.
Areas affected by deforestation

From 1970 to 1990 there was significant deforestation of both primary and secondary forests in Thailand: during this thirty year period, the area covered by primary and secondary forest declined by more than half. Many other regions of the world are affected by deforestation: namely in South America (Brazil), Central Africa (Congo), Southeast Asia (Indonesia) and Eastern Europe.

Severity of land degradation

Very degraded soils are found especially in semi-arid areas (Sub-Saharan Africa, Chile), areas with high population pressure (China, Mexico, India) and regions undergoing deforestation (Indonesia).


http://maps.grida.no/go/graphic/severity-of-land-degradation
FOREST FIRES (EXAMPLE IN SUMATRA – JUNE 24 2004)

Detected by the Moderate Resolution Imaging Spectroradiometer (MODIS) on the TERRA satellite. Active fires are marked with red dots.
OTHER SOURCES OF CARBON
IMPACT OF SOC CHANGES ON LAND DEGRADATION

- Management Technology
- Mismatch between land use and land quality
- Resource Stress
- Loss of SOC

Soil Type
ESTIMATING CHANGES OF SOC

- Issues
  - Choice of baseline
  - Sampling strategies
  - Sampling depths
  - Comparison to current practice
  - Start and end time points
  - Measure C sequestration
  - Comparison to legacy data
Development of database at national level to monitor current and potential rates of carbon sequestration in forest soils as well as cultivated soils and under various types of management practices - essential to the effective management of carbon.

- involves establishing baselines for carbon sequestration potential for major soil types in pristine versus cultivated areas.

- Adoption of best management practices would be beneficial in maintaining the soil carbon status in a particular soil type.
CONCLUSIONS

- Most widely used soils for agriculture also hold large reservoirs of carbon.
  - potential to sequester large amounts of C, with appropriate soil management practices.
  - Ultisols and Oxisols make up a sizeable proportion of arable land in Sarawak.
  - Aquic or wetter conditions favor C-sequestration over mineralization.

- Histosols (also to be treated as wetlands) hold about the highest percentage of the total SOC distribution in the state.
  - Maintaining Histosols in natural state - good policy to enhance carbon sequestration.
  - Draining reported to release CO$_2$ to the atmosphere.
    - Difficult to restore original levels of SOC in a human time-span.
CONCLUSIONS

- Degradation of C pool is irreversible
  - Tension zones have to be identified
  - More accurate soil maps needed

- It is known that the most widely used soils for agriculture also hold large reservoirs of carbon.
  - It is stressed again that these soils also have the potential to sequester large amounts of C

- Past estimates also show that wetlands hold about 30% of the total SOC.
  - Maintaining wetlands and soils with aquic or wetter SMRs in their natural state is a good policy to enhance carbon sequestration.
THANK YOU