Comparative LCA Analysis of Different Edible Oils and Fats

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Background to the studies

- Sustainability criteria under development in EU and member states;
- EU sets renewable energy and transport targets (20% and 10% by 2020);
- EU determines what counts as “sustainable”
- Member states give subsidies to achieve targets

- Carbon Balance is an important part of sustainability criteria;
- In current directive proposal: 35% minimum;
- Default value for palm oil at 17% - 51%, depending on methane capture
- $\text{CO}_2$ balance to be assessed for individual supply chains
Initial questions:

- What is the carbon balance of “typical” Malaysian palm oil like?
- What room for improvement is there?

In a second study:

- How does palm oil based biodiesel compare to other vegetable oils?
Basic parameters

• Carbon balance based on typical supply chain data;
• Two supply chains:
  – Biodiesel with CPO as feedstock;
  – Renewable energy production from direct CPO combustion
• Allocation based on market value of products;
• Average yield: 3.9 t/ha/a
• Land use data over 2000 - 2004

\[
\text{CO}_2\text{ reduction} = \frac{(\text{CO}_2\text{ emissions fossil chain} - \text{CO}_2\text{ emissions biofuel chain})}{\text{CO}_2\text{ emissions fossil chain}}
\]
The supply chain

- N, P, K Fertilizer
- Traction
- Oil Palm Plantation
- Pesticides
- Water
- Palm Oil Mill
- Truck transport
- Truck
- Palm kernels
- Heat
- Electricity
- Transport
- CPO
- FFB
- Palm Oil
- Fibre
- Shell
- POME
- EFB
- Disposal
- Ponding
- Biodiesel Refining
- Renewable Electricity
- Sea vessel
- CPO
- FFB
- Palm kernels
LCA Model for Palm Oil Supply Chains

1. Fertilizer Production (N, P, K)
2. \(\text{N}_2\text{O}\) Fertilizer (N) application
3. Emissions from Pesticide use
4. Emissions from Machinery & transport
5. Emissions from energy use milling and refining
6 & 7. EFB POME
8. Milling & CPO transport
9. CPO Combustion or Biodiesel refining

- Palm oil production (FFB)
- Harvesting and transport of FFB
- Palm kernels
- Glycerine
- EFB
- POME
- Comparison: Biomass chain vs Fossil fuel chain

- Land use change (carbon stocks and soil carbon changes)
- Economic activity on land prior to Biomass production
- Displacement of prior Production process
- Displacement of prior residue Of production process
- Pre-treatment Fossil fuels

Emissions from fossil energy use
Results average Malaysian palm oil (excluding land use)

<table>
<thead>
<tr>
<th>Application</th>
<th>Net CO₂ Reduction</th>
<th>%</th>
<th>Net Energy Reduction</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biodiesel</td>
<td>2,634 kg CO₂/t biodiesel</td>
<td>62%</td>
<td>43.14 GJ/t</td>
<td>78%</td>
</tr>
<tr>
<td>Renewable energy</td>
<td>1,813 kg CO₂/t CPO</td>
<td>60%</td>
<td>34.44 GJ/t</td>
<td>83%</td>
</tr>
</tbody>
</table>

- Per hectare of plantation land: 7 – 9.5 t CO₂/ha/a
- Energy balance more positive than carbon balance
- Caused by CH₄ and N₂O emissions
Breakdown of Results Biodiesel

- **Milling Waste**: 22%
- **Fertilizer**: 7%
- **Refining**: 5%
- **Other**: 3%

**Greenhouse gas emissions**

- **Fossil Diesel Emissions**: 100%
- **Net CO₂ Reduction**: 63%
Breakdown of Results Renewable Energy

- **Fossil Emissions**: 100%
  - Milling Waste: 28%
  - Fertilizer: 9%
  - Other: 4%

- **Net CO₂ Reduction**: 59%

- **CPO emissions**
Land use issues
Land use conversion

- Cacao
- Forest
- Rubber
- Grassland
- Coconut
Carbon sequestration cycles

- Comparison of mean standing biomass stock;
- Time scales > 1 rotation cycle
- Carbon to soil (e.g. necromass);
- Carbon in harvested timber
- Emissions to air within 1 rotation cycle
Incorporating carbon sequestration
Carbon effects of land use conversion

- Based on land use data 2000 - 2004
What about peat soil drainage?

- **Natural situation:**
  - Water table close to surface
  - Peat accumulation from vegetation over thousands of years

- **Drainage:**
  - Water tables lowered
  - Peat surface subsidence and CO₂ emission starts

- **Continued drainage:**
  - Decomposition of dry peat: CO₂ emission
  - High fire risk in dry peat: CO₂ emission
  - Peat surface subsidence due to decomposition and shrinkage

- **End stage:**
  - Most peat carbon above drainage limit released to the atmosphere within decades,
  - unless conservation / mitigation measures are taken

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Wetlands International:
- 1 Meter drainage depth
- 90 t CO₂/ha/a
- Plantation on drained peat
- Negative carbon balance

But… what is the influence from soil respiration?
Room for improvement?
Improvements in waste handling

- Palm oil mill
- Lagoons
- EFB
- POME
- FFB
- Inorganic Fertilizer
- Power plant
- Generator
- Refinery/Process
- Fossil fuels
- Power grid
- CO₂
- CH₄
- Plantation
- Waterways
- Landfill
- Mulching
- Refinery/Process
- Mulching
- Landfill
- Inorganic Fertilizer
Further Improvement – carbon balance
Further improvement – energy balance
Further improvement – Yield increase

- Industry CPO average: 3.9 t/ha/a
- Leading plantations: 6.7 t/ha/a
- Direct effect on carbon and energy balance: + 5%
- In combination with waste handling: 80% – 95%
Weighing the options

<table>
<thead>
<tr>
<th></th>
<th>Applicability</th>
<th>Implementation speed</th>
<th>Barriers to implementation</th>
<th>Overall sustainability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield increase</td>
<td>++</td>
<td>-</td>
<td>Knowledge</td>
<td>++</td>
</tr>
<tr>
<td>EFB combustion</td>
<td>-</td>
<td>+</td>
<td>Business case &amp; Logistics</td>
<td>+</td>
</tr>
<tr>
<td>POME biogas</td>
<td>+/-</td>
<td>+</td>
<td>Business case</td>
<td>+</td>
</tr>
<tr>
<td>Composting</td>
<td>++</td>
<td>+</td>
<td>Technology</td>
<td>++</td>
</tr>
</tbody>
</table>
Europe’s dilemma

- New (EU) demand for palm oil
- More palm oil production
- More land conversion

Existing palm oil
Existing land use
Origin known
Sustainability known

Extra palm oil
Extra land conversion
Origin ?
Sustainability ?
Comparison with other biofuels

"I do feel a lot better since we switched to the trans-fat free oil."
General modelling parameters

- Biodiesel delivered to Rotterdam harbour;
- Crushing and trans-esterification based on existing vegetable oil supply chains;
- Replacement of fossil diesel;
- Dominant fertilizer use for each vegetable oil
Biodiesel production from rape seed

- Grown in temperate climates
- Spring and winter plantings
- Plants grow 1 metre high

1 ha land

- 2.98 t Straw
- 2.88 t Raw rapeseed
- 1.70 t Rape meal
- 1.17 t Crude Rapeseed Oil
- 0.03 t Waste
- 1.14 t Refined Rapeseed Oil
- 0.12 t Methanol
- 1.08 t Biodiesel
- 0.11 t Glycerine

Methanol

Glycerine
Supply chain for rape seed oil

T1 = 250 km
T2 = 0
T3 = 0
T4 = 250 km
Biodiesel production from canola seed

- Grown in Canada and Australia
- Low moisture content
- Related to rape seed
- Summer harvest

1 ha land

1.73 t Straw
1.64 t Raw canola
0.97 t Canola meal
0.70 t Crude Canola Oil
0.01 t Waste
0.67 t Refined Canola Oil
0.07 t Methanol
0.65 t Biodiesel
0.07 t Glycerine
Supply chain for canola oil

Canola Cultivation
- Seed
- Fertilizers
  - N (Ammonia, Urea)
  - P (P_2O_5)
  - K (K_2O)
  - Ca (Lime; CaO)
  - S, ... (Sulphur)
- Crop Protection
  - Herbicides
  - Insecticides
  - Fungicides
- Field Emissions
  - N Application
  - N Fixation
  - N Residue Crop

Storage
- Transport from farm to storage
  - T_1
- Transport from storage to crusher
  - T_2

Crusher / Refinery
- Energy
  - Electricity
- Heat / steam
- Process Water
  - Phosphoric Acid
  - Hexane
  - Other
- Refined Canola Oil
- Canola Meal

Biodiesel plant
- Electricity
- Heat / steam
- Glycerine
- Methanol
- Caustic Soda

Transport from farm to storage
- T_1 = 250
Transport from storage to crusher
- T_2 = 0
Transport from crusher to harbour and to receiving harbour (long distance shipping)
- T_3 = 12500
Transport from harbour to biodiesel plant
- T_4 = 100
Biodiesel production from sunflower seed

- Grown worldwide
- Requires much mulch
- Heights 2.5 – 3.5 metres
Supply chain for sunflower oil

T1 = 250 km
T2 = 0
T3 = 0
T4 = 500 km
Biodiesel production from soy bean oil

- Grown in North and South America
- Strong Nitrogen fixation
- Hot summers required for growth

Flowchart:
- 1 ha land
  - Residu 2.55 t
    - Unprocessed beans 1.94 t
      - Soy meal 0.43 t
        - Crude Soy Oil 0.42 t
          - Waste 0.01 t
            - Refined Soy Oil 0.42 t
              - Biodiesel 0.42 t
                - Methanol 0.05 t
                  - Glycerine 0.04 t
Supply chain for soy bean oil

T1 = 12850 km
T2 = 0
T3 = 0
Results carbon balances

<table>
<thead>
<tr>
<th></th>
<th>CO2eq emissions / ton biodiesel</th>
</tr>
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<tbody>
<tr>
<td>rape</td>
<td></td>
</tr>
<tr>
<td>soy</td>
<td></td>
</tr>
<tr>
<td>canola</td>
<td></td>
</tr>
<tr>
<td>sunflower</td>
<td></td>
</tr>
<tr>
<td>oil palm</td>
<td></td>
</tr>
<tr>
<td>oil palm</td>
<td></td>
</tr>
<tr>
<td>fossil diesel</td>
<td></td>
</tr>
</tbody>
</table>

- **Cultivation**
- **Transport, storage**
- **Crushing/Milling waste disposal**
- **Crushing & Refining**
- **Biodiesel Production**
Comparison with palm oil

Potential of waste reduction techniques, composting, mulching, etc.
Conclusions

• Different vegetable oils have roughly the same carbon balances (≈ 50 – 60% net reduction)
• Typical Malaysian palm oil also is comparable, but…

• Potential for palm oil is much greater:
• How?
  – Increasing yields;
  – Reducing waste emissions;
• Under the condition of:
  – Responsible land use
Wrap up

- Good carbon balance average Malaysian palm oil;
- Waste handling + yield improvements $\rightarrow > 80\%$;
- Land use effects mixed;
- Sustainability challenge: Managing land conversion arising from EU demand for palm oil;
- Raising yields is essential!
Thank you