CLEWS – Climate Land Energy and Water Strategies
*A case study*

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- Developing an approach
- A CLEW case study
- Elements modeled: Climate, Land, Energy and Water
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Water - Energy - Land Use: Some issues

- 1.6 billion people have no access to electricity
- 1.1 billion people have no access to safe water
- Food shortages, land-use competition, skyrocketing prices and stresses on arable land
- Assessments, planning, policy and decision making are usually isolated
- Needs an integrated interdisciplinary approach
Water - Energy - Land Use: A fragmented approach

- Water, energy and land-use are intimately interlinked
- All affect the climate
- Therefore, issues related to water, energy or land use
  - cannot be dealt with in isolation
  - cannot be met sustainably without trade-offs between them.
- Still, most water, energy and land-use planning, decision and policy making occurs in separate and disconnected institutional entities.

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The CLEW Nexus: Meeting the MDGs

- The main global challenges for the next decades are:
  - Limiting increased burden on the Climate and environment
  - Land use competition straining food production for a growing population
  - Growing demand for affordable Energy
  - Ensuring fresh Water supply
- These are all inter-linked demanding integrated approach: CLEW
Developing a prototype CLEW approach

- Starting with a less complex system with limited and well-defined boundaries
- Simple 'accounting framework' for CLEW relations
  - Providing first step before more complex trade-off and optimization analysis (e.g. costs of water versus energy etc...)
  - Supporting a clear understanding of the relations
  - Similar to popular and useful approaches in resources assessments, such as LEAP for energy
Mauritius - A CLEW case study

- Island of Mauritius in Indian Ocean
  - Excellent data availability, clear boundaries!
  - But the study is ultimately ONLY illustrative

- The policy question: should sugar-cane be processed into ethanol instead of sugar?
  - Consistent with current policy goals

- Scenario analyses quantifying the resource (CLEW) and economic implications of this policy under different conditions (technological and others)
The elements modeled

- **Local GHG emissions**
  1. Fertilizer use, farming emissions, land-use change
  2. Electricity production
  3. Substitution of gasoline with ethanol

- **Foreign GHG emissions**
  4. Fertilizer production and transport
  5. Indirect land use change
  6. Extraction and supply of coal
  7. Extraction and refining of oil
The elements modeled (Land)

- 100 ha of cropland used for sugarcane production
- Hypothetical sensitivities on land type:

<table>
<thead>
<tr>
<th>Factors</th>
<th>Irrigation need:</th>
<th>Yield:</th>
<th>Fertilizer need:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land converted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropical forest</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Wetlands</td>
<td>0%</td>
<td>108%</td>
<td>50%</td>
</tr>
<tr>
<td>Tropical savannah</td>
<td>100%</td>
<td>102%</td>
<td>90%</td>
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</tbody>
</table>
The elements modeled (Energy)

Local energy:
1. Energy for farming,
2. Electricity production/use (e.g. pumping and distributing irrigation water) on site
3. Petrol displaced by ethanol

Foreign energy
1. Fertilizer production and transport
2. Coal extraction and transport for electricity production
3. Oil extraction and refining
The elements modeled (Water)

- Local fresh water use
  1. Water applied for irrigation
  2. Water used for ethanol/sugar processing
  3. Power station cooling
Scenarios

1. SSM - Sugar production in conventional sugar-mills (no surplus bagasse)
2. ASM - Sugar production with high-pressure boilers (surplus electricity from bagasse)
3. SEP - Ethanol production with high-pressure boilers (surplus electricity from bagasse)
4. AEP - Ethanol production (2. gen) with hydrolysis of bagasse (electricity deficit)
Results

- Results are in terms of:
  - On-site (sugar cane field + mill/ethanol plant) or Off-site (national electricity grid)
  - Local (e.g. burning bagasse to produce electricity) or Foreign (e.g. emissions from fertilizer manufacture)

- Results reported include:
  - Energy balances, local and total
  - Local water balances
  - GHG balances, local and global and cumulative
  - Selected economics and oil price changes
  - Changes in irrigation technologies
  - Use of “bio-fertilizer”
Scenario comparison: Local energy balance

Local Energy balance [TJ]

Note: Negative quantities are energy gains
Scenario comparison: Local water balance

Water balance [1000 m$^3$]

- 4AEP
- 3SEP
- 2ASM
- 1SSM

Legend:
- Irrigation
- Ethanol production
- Sugar production
Scenario comparison: Local GHG balance

Local GHG balance [t CO$_2$-eq.]

- Energy for pumping of water
- Electricity from/to plant
- Farming
- Ethanol subst. petrol
- Fertilizer use

1SSM
2ASM
3SEP
4AEP
What about reduced sugar production?

- Assumption: Lower production causes land use change outside Mauritius
- Necessity to understand these externalities
- Opens the opportunity to account for leakages
- Impact on agricultural labor force

Scenario comparison: Total (local + foreign) GHG balance

Local GHG balance [t CO$_2$-eq.]

- 1SSM
- 2ASM
- 3SEP ext GHG
- 4AEP ext GHG
- 3SEP
- 4AEP

2010 2015 2020 2025 2030
Cumulative GHG balance

Difference between cumulative local & total GHG emissions
Economics of 3SEP
Standard Ethanol Production

Note: Negative costs = economic gains

Revenue – 1000 $

60 $/barrel (3SEP)
120 $/barrel (3SEP)
180 $/barrel (3SEP)
180 $/barrel (4AEP)

Sugar sales
Petrol substitution
Electricity sales
Electricity purchases
Carbon cost
When does ethanol production become economically viable?

Ethanol economics at today's sugar price of 522 $/t

- 3SEP - Standard Ethanol Production
- 4AEP - Advanced Ethanol Production

Oil market price

- 60 $/bbl
- 120 $/bbl
- 180 $/bbl

-300
-200
-100
0
100
200
300
Changing from flood to drip irrigation

- Direct water savings: 177,000 m³, which represents 33% of all water consumption
- 162 GJ, or 12.7% of all energy used in the agricultural steps is saved
- Mitigates 13.7 ton of GHG-emissions, or 8.6% of all farm related local emissions
Sensitivity: changing fertilizer

Shift from 100% mineral to 50% bio-compost fertilizer: Impact on energy use

<table>
<thead>
<tr>
<th></th>
<th>TJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farming</td>
<td>-2.5</td>
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<tr>
<td>Electricity from grid (primary energy)</td>
<td>-2</td>
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<tr>
<td>Ethanol</td>
<td>-1.5</td>
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<tr>
<td>Fertilizer production (foreign)</td>
<td>-1</td>
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<tr>
<td>Electricity source provision (fuel chain)</td>
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<tr>
<td>Oil refining (foreign)</td>
<td>0.5</td>
</tr>
</tbody>
</table>

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Cumulative GHG balance: Earlier net GHG gains

I: 100 Mineral fertilizer
II: 50 % bio-compost
Conclusions (with caveats)

- Inter-linkages between C-L-E-W are evident and strong
- External (foreign) effects may be considerable, especially for GHGs
- Ethanol becomes economic at today’s sugar-prices at oil prices >$120
- Use of bio-compost increases yield, sequesters carbon and improves water-balance; but needs more detailed analysis
- CLEW framework can address cross-sectoral (spill-over) effects and thus is a useful tool for policy analysis and improved decision making
Next steps

- Include explicitly local food provision /demand as well as other CLEW services as “exogenous” drivers.
- Increase the number of case studies and practical applications as well as interactions with stakeholders and policy makers.
- Include a variety of crops and connect the model with a database that keeps track of site-specific issues related to climate, soil, water availability, etc.
- Include generic crop yield calculator, for initial scanning of CLEW land strategies. (A possibility includes merging the CLEW-accounting model with the IIASA/FAO model called AEZ (Agro-Ecological Zones)).
Next steps

- With that in place the accounting model could play a role as a first-order assessment model at the local/regional scale.

- Develop linkages to other more specialized models whenever a higher resolution of specific CLEW features is needed.

- Having demonstrated that CLEW relations can be quantified, the development of a formal framework for undertaking economic, social and environmental trade-offs.
...atoms for peace.