Assessing eco-efficiency of sugarcane production using customised LCA tool

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Aim

Making environmental life cycle assessment (LCA) more accessible and rapid for agriculturalists so they can evaluate alternative agricultural practices

LCA researchers → Customised LCA tools for agriculture → Transfer to environmental knowledge to agriculturalists → Decisions about agricultural practices → Eco-efficiency
Why is this important for bio-energy?

- GHG mitigation from eco-efficient agriculture can be significant compared to GHG abatement from bio-energy production.

- Eco-efficient agriculture mitigates other environmental trade-offs from bio-energy production.
Implications of eco-efficient agriculture for bio-fuels

Consequential LCA results of sugarcane bio-production compared with eco-efficient sugarcane production (per 100t cane processed)

<table>
<thead>
<tr>
<th>Environmental impact categories</th>
<th>Utilisation of mill co-products from processing of existing sugarcane</th>
<th>Dedicated bio-production resulting in expanded cane production</th>
<th>Eco-efficient cane growing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit</td>
<td>Electricity from bagasse</td>
<td>Ethanol from molasses</td>
</tr>
<tr>
<td>Energy use</td>
<td>GJ</td>
<td>-45.3</td>
<td>-51.1</td>
</tr>
<tr>
<td>GHG emissions</td>
<td>t CO$_2$(eq)</td>
<td>-4.1</td>
<td>-4.3</td>
</tr>
<tr>
<td>Eutrophication</td>
<td>kg PO$_4$(eq)</td>
<td>-2.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Acidification</td>
<td>kg SO$_2$(eq)</td>
<td>-148</td>
<td>-74</td>
</tr>
<tr>
<td>Water use</td>
<td>kL</td>
<td>0.0</td>
<td>-1.7</td>
</tr>
<tr>
<td>Land use</td>
<td>ha</td>
<td>0.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

-ve results= decreased impact  
+ve result = increased impact  
Red values are environmental trade-offs

CaneLCA Eco-Efficiency Calculator
for Australian sugarcane growing
(Version 1.03)

Customises the LCA process for the sugarcane sector by:

• focusing on ‘cradle to farm gate’ processes
• focusing on relevant environmental impact categories
• parameterising practice variables
• presenting results in a way that facilitates interpretation by agriculturalists

Available from: UniQuest web site (http://eshop.uniquest.com.au/)
CaneLCA system scope

System boundary

Crop classes and areas in the sugarcane system

Plant cane crop 1/(n+2) of area

Ratoon 1 → Ratoon 2 → Ratoon ... → Ratoon n → Fallow / break crop 1/(n+2) of area → Un-productive areas (headlands)

Background processes

Production of agrochemical, fuels, energy

Production of machinery and infrastructure

Transport for supply of agrochemicals and materials

Foreground processes

Fuel use for machinery operations

Nutrient application

Pesticide application

Irrigation (and drainage)

Harvest and haulout

1 tonne harvested sugarcane at the farm gate

Mid-point impact indicators assessed:

Non -renewable energy use

Climate change

Consumptive water use

Eutrophication

Freshwater ecotoxicity

Components of CaneLCA

System components:
1. System definition
   - Details of sugarcane crops:
     - Crop classes, areas & yields
     - Type, area, yield, fate
   - Details of unproductive areas:
     - Fallow, headlands

2. Machinery
   - List of machinery in service:
     - Tractors, implements
   - Row width
   - Operating parameters:
     - Field efficiency
     - Load factor
     - Speed

3. Nutrient application
   - Application rates for:
     - Fertilisers
     - Mill by-products
     - Ameliorants
   - Application methods
   - Tractor operations
   - Supply distances / modes

4. Pesticide application
   - Application rates for:
     - Herbicides
     - Insecticides
     - Fungicides
   - Application methods
   - Tractor operations
   - Supply distances / modes

5. Harvesting
   - Type of harvesting
   - Harvesting efficiency
   - Residue management
   - Infrastructure

6. Water management
   - Volumes pumped
   - Energy for pumping

INPUT / OUTPUT INVENTORY
Calculated by the tool

Inputs (per t harvested cane):
- Fertilisers (kg)
- Pesticides (kg)
- Soil ameliorants (kg)
- Tractor fuel use (MJ)
- Harvester fuel use (MJ)
- Electricity for irrigation (kWh)
- Machinery (kg)
- Irrigation infrastructure (kg)
- Water (KL)
- Transport effort (shipping, rail, road) (tkm)

Emissions (per t harvested cane):
- Nitrous oxide (N$_2$O) to air
- Ammonia (NH$_3$) to air
- N & P losses to water
- Sugar losses to water
- Pesticide losses to water
- Crop residue burning emissions to air

LIFE CYCLE IMPACT ASSESSMENT (LCIA) RESULTS
Calculated by the tool

LCIA absolute values
(per t harvested cane):
- Non-renewable energy
- Climate change
- Consumptive water use
- Eutrophication
- Ecotoxicity

ECO-EFFICIENCY PERFORMANCE INDICATORS
Relative performance
(as a % of industry max):
- Fossil fuel use
- Carbon footprint
- Water use
- Water quality - nutrient
- Water quality - toxics

Applications to date

Development of CaneLCA (V1,01) by Australian sugar industry and pilot testing - 2011


Example application of CaneLCA (V1,02) to hypothetical practice change scenarios - 2014


Detailed method description of CaneLCA (V1,03) and application to actual practice changes - 2017

Example evaluation of practice change at 6 case study farms in Australia

• Practice changes

  – increased row spacing to reduce traffic areas and reduce soil compaction
  – reduced tillage intensity and number of machinery operations, also to reduce soil compaction
  – GPS guidance on tractors and harvesters, for controlled traffic measures, and precision application of fertilisers and pesticides
  – changes to machinery and implements, to enable the above
  – reduced N application rates
  – legume break crop, to reduce synthetic urea-N use and surpress weed pressure and herbicide use
  – mill-mud application (a by-product from the sugar mill) to utilise its residual nutrients (N,P,K)
  – changed herbicides with reduced toxicity, and reduced application rates through more precise application methods
  – sub-surface application of N to to avoid NH₄ volatilisation
Example results

Range of reductions

<table>
<thead>
<tr>
<th></th>
<th>0% - 34%</th>
<th>7% - 32%</th>
<th>3% - 41%</th>
<th>7% - 41%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrient application</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Machinery operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pesticide application</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Harvesting</td>
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</tbody>
</table>

Legend

Machinery operation
- Fuel combustion in tractors
- Fuel combustion in harvesters

Nutrient application
- Nitrous oxide (N2O) to air from denitrification of N
- Carbon dioxide (CO2) to air from carbonation of lime
- Nutrient (N and P) emissions to water
- Ammonia (NH3) emissions (to air)
- Production of fertilisers and ameliorants

Pesticide application
- Emissions of herbicide to water
- Emissions of insecticide to water
- Emissions of fungicide to water
- Production of pesticides

Harvesting
- Cane burning emissions to air
- Organic emissions (COD) to water from sugar loss