Biofuel impacts on ecosystem services, biodiversity and human well-being – the contribution of SWAT modelling to integrated land use governance

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Ecosystem services are benefits people obtain from ecosystems:

- *Provisioning* (food, fuels, fibre, timber, etc), regulating (flood or pest control, climate regulation),
- *Supporting* (services necessary for the delivery of other services, such as nutrient cycling)
- *Biodiversity* own category or supporting
- *Cultural*

Landscapes provide services which benefit humans.
Governance of land (scapes)

- Land use and management influences system processes and structure and thus the provision of services
- **Trade-offs** between ecosystem services
- How should we deal with trade-offs?
- Risk of sub-optimal allocation of land and societal conflict
Biofuels

New demands of land for the production of biomass for biofuel can:

+ reduce transport GHG emissions, improve food security, provide development opportunities in rural areas

- compete with food production, and contribute to climate change and biodiversity loss
Integrated Land Management Solutions for a Sustainable Bioeconomy

Overall aim: provide tools to promote wider agreement on the role of bioenergy technologies for environmental quality and human well-being

Decision making support tool:

- Landscape assessment of the impacts of biofuel systems on ecosystem services and human well-being
- Simulate alternative scenarios of land use & management
ILAMS - Case studies

1. Biodiesel from soya bean – Mato Grosso, Brazil

2. Ethanol from sweet sorghum – Texas, US

3. Ethanol from giant reed (Arundo Donax) – Sardinia, Italy
Sardinian case study

Ethanol production unit:
- Biochemtex Technology: second generation ethanol
- 400 kt/y biomass feedstock - 160 kt/y imported wheat straw, and 240 kt/y GR (210 kt/y cultivated)
- Output: 80 kt/y ethanol and 240 kt/y wet lignin

Why Sardinia?
ILAMS project

- Integrated Model
  - Decision making support tool
    - Stakeholder engagement
    - User interface
Stakeholders’ engagement

**Aim**: allow stakeholders to articulate their preferences in relation to biofuel, ecosystem services and human well-being

1. Assessment of stakeholders:
   - Key concerns
   - Alternative scenarios for land use/management

2. Simulation of scenarios with stakeholders
   - Workshop
   - Facilitate discussions
Stakeholders engagement in Sardinia

Biofuel controversial issue

Wide range of stakeholders
Results of stakeholders assessment

Key concerns

• Water availability
• Food security and production of (high quality) food
• Employment
• Biodiversity

Alternative scenarios

• Irrigation using recycled water WWT
• Use of polluted land (mines/industrial sites)
• Use of marginal land (not cultivated in last 5 years)
• Introduction/expansion of corridors and improved protection of preservation areas
ILAMS project

Integrated Model

Decision making support tool

Stakeholder engagement

User interface
Integrated model

- Cover all stakeholders’ key concerns
- Simulate current status and alternative scenarios of land use/management
- Landscape approach

➢ Use existing models
1. Biophysical processes module

- SWAT – water availability, crop production, carbon storage
- InVEST habitat quality & MatrixGreen – biodiversity
- InVEST carbon – carbon storage
2. GHG emissions module

- LCA (excel) – GHG emission of biofuel
- Inventory (excel) – GHG of transport and el/heat in the landscape
3. Human well-being module

- Mass balance model (excel) – food/feed/energy security
- Employment generation (ArcGIS)
- Revenues (ArcGIS) – farm revenues
1. SWAT

Outputs of interest:
- Water availability
- Crop production
- Carbon storage (biomass above & below ground and DOM)

Data:
- DEM 10m - Sardinia Region
- LULC - CORINE 2011
- Soil - European Soil Database
- Weather - CFSR
- Digitalized river stream network - Sardinia Region
Conditions:

- 6000 ha
- Potentially irrigated
- 75km max distance from production unit
- Outside protected areas
Basin:
550 000 ha
108 subbasins
851 HRS

Land use:
10% forest
12% rangeland
60% agriculture
SWAT – ongoing work

- More accurate LULC map
- Land management data
- Data for reservoirs and WWT
- Run and calibrate model
- Prepare alternative scenarios
1. InVEST – habitat quality

Habitat quality as an indicator of the status of biodiversity. Areas of high quality are generally better able to maintain biodiversity.

Data
- LULC
- Threats (urban&industry, agriculture, roads)
- Habitat accessibility (parks & reserves)
- Habitat sensitivity (grasslands < forests < wetlands)
Habitat quality – preliminary results

Habitat quality map
- Quality of habitat
- Proximity to threats

Habitat degradation map
- Distance to threats
- Habitat sensitivity
- Habitat accessibility
1. MatrixGreen - connectivity

- It models connectivity and spatial distribution of habitats.
- Data: map of habitats
- Component based connectivity
- Outputs: map and total value of habitat connectivity
Storage is the amount of carbon in an ecosystem at any given point in time.

Carbon stock as a function of land use/land cover.

Data:
- LULC
- Carbon coefficients for each LULC class.
1. Carbon storage

4 carbon pools:
- Above ground biomass
- Below ground biomass
- Dead Organic Matter
- Soil Carbon

Table of carbon pools
(metric tons / hectare)

<table>
<thead>
<tr>
<th>LULC</th>
<th>LULC_name</th>
<th>C_above</th>
<th>C_below</th>
<th>C_soil</th>
<th>C_dead</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Forest</td>
<td>140</td>
<td>70</td>
<td>35</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Coffee</td>
<td>65</td>
<td>40</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Pasture/grass</td>
<td>15</td>
<td>35</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Shrub/undergrowth</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>13</td>
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<tr>
<td>5</td>
<td>Open/urban</td>
<td>5</td>
<td>5</td>
<td>15</td>
<td>2</td>
</tr>
</tbody>
</table>
2. GHG emissions – biofuel LCA

- Impact of the project on GHG emissions of the area
- Production of biofuels generates GHG credits

<table>
<thead>
<tr>
<th>Functional Unit</th>
<th>Global Warming Potential/GWP100 (kgCO₂-eq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per 1 ton of bioethanol</td>
<td>4.5</td>
</tr>
<tr>
<td>Per 1 ton\textsubscript{dry} of <em>Arundo donax</em></td>
<td>0.9</td>
</tr>
<tr>
<td>Per 1 hectare</td>
<td>22.6</td>
</tr>
<tr>
<td>Per 1 year (total emissions)</td>
<td>181178</td>
</tr>
<tr>
<td><strong>GHG savings from petrol</strong></td>
<td><strong>99.3%</strong></td>
</tr>
</tbody>
</table>

- Incl. cultivation, harvest, transport and transformation
- Exclude LUC
3. Human well-being - Security

- Security as physical availability of water, food, feed and energy
- Mass balance for the watershed
- Excel files

Water

Availability from SWAT results
3. Human well-being - Security

Food security

- Supply: crop production (SWAT) + animal production data (milk & meat)

- Consumption per family/person: food statistics for the region
3. Human well-being - Security

Feed security

- Supply: feed production from pasture, rangeland, crops (SWAT)

- Consumption: number of animals (cows, goats/sheep and pigs) and intake coefficients
3. Human well-being - Security

Energy security

- Supply: energy provided from resources within watershed (coal, wind, solar & biomass)

- Consumption: energy used for transport, el/heat per person, or ha within watershed
Employment generation

Employment

- Agricultural employment coefficients
- Agricultural employment GR for cultivation, harvest, transport (Beta Renewables data for subcontractor)
ILAMS project

- Integrated Model
  - Decision making support tool
  - Stakeholder engagement
  - User interface
User interface

- Allow users to simulate scenarios
- Simple, transparent and responsive to end-user needs
- Information on the spatial distribution of ecosystem services
- Understanding of trade-offs and win-win opportunities

Example The Global Calculator
Conclusions

- **Modelling** is a tool that can be used to build consensus about biofuels, minimizing conflicts and improving project outcomes.
- It requires **knowledge integration** - biophysical, technical and social aspects.
- SWAT can be used with other models to provide a comprehensive understanding of biofuel impacts at landscape level.
Thank you for the attention!