LUCI - a spatially and temporally explicit framework exploring opportunities for enhancing multiple ecosystem services through targeted land management

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* continuing work involving a cast of thousands, but particularly; Tim Pagella, Alex Henshaw, Barbara Orellana, Neil McIntyre, Brian Reynolds, Fergus Sinclair
LUCI-Land Utilisation and Capability Indicator GIS toolbox

Holistic and spatially explicit consideration of impacts of land use on the following services:

• Food provisioning
  – agricultural productivity
• Water regulation
  – flood risk
  – erosion and sediment transfer
  – water quality (N & P, but more to come...)
• Climate regulation
  – carbon stock versus sequestration/emissions
• Biodiversity
• Cultural/historical features

Allows stakeholders to simply and actively explore tradeoffs
LUCI-Land Utilisation and Capability Indicator GIS toolbox

- Values existing features and potential for change by “service”.
- Explores where multiple benefits and financial incentives exist.
- “Tier 1” designed to rapidly explore spatial trade offs and synergies with other ecosystem services – explores impacts of small-scale (sub-field level) changes at landscape scale.
- “Tier 2” algorithms allow quantification of performance of these scenarios of land use under different climatic events.
- Designed to work with widely available (national) data and update with local knowledge where possible - applications to date in UK (Wales and England), NZ (Hawkes Bay and East Coast), Ghana, Greece.
LUCI allows interventions to be spatially targeted according to end-user priorities.
e.g. small but strategic features can have large effects

Flood peak reduction with small strategically targeted tree planting and wetland creation
Bassenthwaite catchment, Lake District, Northwest England
Latest application - Bassenthwaite

- Scheme in place paying farmers to reduce impact of production on environment.
- Concerns current interventions are not delivering “best value for money”
- LUCI being applied to identify where to better target agri-environment measures to improve carbon, water flow and quality, biodiversity while maintaining productivity
Agricultural productivity—predicted versus current

Note similarity—overall most of the catchment appears to be at close to optimum utilisation

Predicted “Optimum” agricultural utilisation

Current agricultural utilisation
Much of the land is already providing flood mitigation (red) or being mitigated (orange); but some areas remain where additional protection through targeted land use could be added.
Groundtruthing (Uawa Farm, New Zealand)

Green (soggy) areas have been drained by farmer.

Farmer: “I never realised this was boggy land until my tractor got stuck here two years ago.”

Farmer agrees this is wet, overland flow generating land. Plans to put in further drainage routing off land.
Carbon stocks are low, & much of the catchment appears to be continuing to lose carbon.
Carbon layers - stock vs sequestration

Current Stock

Emissions to Steady State
Habitat connectivity – broadleaved woodland

Legend
- Red: Broadleaved woodland
- Brown: Other UK “priority habitat”
- Orange: Marginal gains from planting woodland
- Green: Opportunities for enhanced connectivity of habitat
Bassenthwaite erosion and sediment delivery layers
Flood mitigation / carbon additive tradeoff layer

Legend
- Red: Existing value in both services
- Brown: Existing value in 1 service
- Orange: Marginal values or tradeoffs between services
- Green: Opportunity to improve 1 service
- Light green: Opportunity to improve both services

Opportunity for improvement here
Carbon, productivity and flood mitigation opportunities

Once we move to consider three independent services change in most areas requires trading off services against each other (orange areas).

However, quite a few opportunities remain to improve at least two services (dark green) with no negative effect on the third, a few opportunities exist to improve all three (light green).

Legend
- Existing value in both services
- Existing value in 1 service
- Marginal value or tradeoffs between services
- Opportunity to improve 1 service
- Opportunity to improve both services
## Changing valuation of landscape from two scenarios (2)

### Table 1: Area of catchment accessible to broadleaf focal species (%)

<table>
<thead>
<tr>
<th></th>
<th>Broadleaf habitat</th>
<th>Other priority habitat</th>
<th>Other areas accessible to habitat species</th>
<th>Area non-accessible to habitat species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre- tree planting</td>
<td>3.0</td>
<td>21.8</td>
<td>15.0</td>
<td>60.2</td>
</tr>
<tr>
<td>Post  tree planting</td>
<td>9.8</td>
<td>21.5</td>
<td>36.7</td>
<td>32.0</td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td><strong>+6.8</strong></td>
<td><strong>-0.3</strong></td>
<td><strong>+21.7</strong></td>
<td><strong>-28.2</strong></td>
</tr>
</tbody>
</table>

### Table 2: Changing proportions of mitigated land using two vegetation scenarios (%)

<table>
<thead>
<tr>
<th></th>
<th>Mitigating land</th>
<th>Mitigated land</th>
<th>Non-mitigated land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre- tree planting</td>
<td>27.2</td>
<td>31.4</td>
<td>41.4</td>
</tr>
<tr>
<td>Post  tree planting</td>
<td>30.4</td>
<td>40.2</td>
<td>29.4</td>
</tr>
<tr>
<td><strong>Change</strong></td>
<td><strong>+3.2</strong></td>
<td><strong>+8.8</strong></td>
<td>12</td>
</tr>
</tbody>
</table>
Tier 2: problem of prohibitive cost of spatially explicit routing between landscape elements solved by new algorithm.

Cost of implementation 50% higher than parallel routing, << distributed model. No requirement for additional parameters or lumping of responses.
Ongoing development

- Further testing, development, groundtruthing, & augmentation of algorithms in contrasting locations

- Adding temporal functionality to allow impact of varying climate events to be considered: e.g. to track nutrients sediment/erosion, and crop growth/fitness in time

- Addition of economic valuations, improved biodiversity representation, greenhouse gas emissions, protection of infrastructure, etc…
Conclusions

LUCI is an ecosystem service tool covering
1) climate regulation,
2) food provisioning,
3) water flow and quality regulation
4) biodiversity

It uses nationally available data (but incorporates local data where available)

LUCI’s uniqueness is:
1) It simply and actively address tradeoffs between ecosystem services;
2) It has the ability to represent sub-field management interventions at catchment scale.
Thank you!

Questions?

For further information:

Paper in press:

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