The role of life cycle assessment in the evaluation of soil-related activities and impacts

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What is life cycle assessment (LCA)?

LCA addresses the environmental aspects and potential (e.g. use of resources and the environmental consequences of releases) environmental impacts of a product through all stages of its life cycle.

- LCA provides an instrument for environmental decision support.
- The International Organisation for Standardisation (ISO), has standardised this framework within the series ISO 14040 on LCA.

From: UNEP website
What is life cycle assessment (LCA)?

LCI is defined as the compilation and quantification of inputs and outputs for a given product system throughout its life cycle.

Direct applications:
- Product development and improvement
- Strategic planning
- Public policy making
- Marketing

LCIA

Goal and scope definition
Inventory analysis
Impact assessment
Interpretation
An LCIA helps to interpret emissions and resource consumption data that are associated with a product’s life cycle in terms of human health, natural environment and resources.

**Life cycle impact assessment (LCIA)**

- Soil erosion
- Depletion of aquatic organisms
Soil-related activities and impacts

Potential environmental impacts of different product systems

Soil-related activities (land use systems):
- Forest
- Agricultural crops
- Mixed systems

Application of soil fertilizers/conditioners

Topsoil erosion by water:
high [suspended solids (SS)] in freshwater become detrimental to aquatic organisms living in the systems
Impacts of SS on aquatic biota

**Characterisation factors (CF$_i$)**

$$\text{CF}_i = (\text{FF}_i \times \text{EF}_i) \times V_i \quad \text{(eq. 1)}$$

- **average volume of freshwater section $i$**
- **effect factor for freshwater section $i$**
- **fate factor for freshwater section $i$**

**Fate factors (FF$_i$)**

$$\text{FF}_i = \frac{\Delta C_{SS,i}}{\Delta E_i} \quad \text{(eq. 2)}$$

- marginal increase in the concentration of SS in freshwater section $i$

$$\text{FF}_i = \frac{\Delta LSS_i}{\Delta E_i \times Q_i} = \frac{1}{Q_i} \quad \text{(eq. 3)}$$

- increased rate of SS throughout the freshwater section $i$
- average flow of the freshwater section $i$

marginal increase in emission rate of SS to freshwater section $i$
Effect factors ($E F_i$): The PDF of macroinvertebrates, and algae and macrophytes versus the natural logarithm of $C_{SS}$

**Macroinvertebrates**

$$EF_i = \frac{e^{3.62}}{C_{SS,i}^{1.75} \times 1.33 \left(\frac{e^{3.62} + 1}{C_{SS,i}^{0.75}}\right)^2} \quad (eq.4)$$

**Algae and macrophytes**

$$EF_i = \frac{e^{3.16}}{C_{SS,i}^{1.67} \times 1.50 \left(\frac{e^{3.16} + 1}{C_{SS,i}^{0.67}}\right)^2} \quad (eq.5)$$
Case study on *E. globulus*

**Functional Unit**

- 1 ha of *E. globulus* managed forest over one revolution (36 years)

**System description**

- Four *E. globulus* stands located at the lower-middle watershed of Tagus river
Case study on *E. globulus*

- Topsoil erosion – RUSLE
- SS transported through landscape to surface-water systems

**a) Digital elevation model (SRTM-DEM)**

**b) Drainage network map**

**c) Parcel map**

**d) Soil erodibility map**

**e) Crop management map**
Case study on *E. globulus*

Environmental impacts

![Graph showing SS impact assessment for different stands.](image-url)

- **Stand 1**: SS impact assessment for macroinvertebrates and algae and macrophytes.
- **Stand 2**: Significantly higher SS impact assessment for macroinvertebrates.
- **Stand 3**: Moderate SS impact assessment for both macroinvertebrates and algae and macrophytes.
- **Stand 4**: Low SS impact assessment for both macroinvertebrates and algae and macrophytes.
Take home messages

- Effects of SS on aquatic biota:
  - SS impacts on aquatic organisms can vary substantially when using a local resolution scale

- The SS potential impacts should also be assessed for other forest types and cropping systems
- Evaluating the feasibility of applying the developed method for assessing the potential impacts caused by post-fire soil erosion
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