Disentangling soil retention from crop provision

The crop provision service is defined as the ecological contribution to the growth of cultivated crops that can be harvested and used as raw material to produce food, feed, fibre and fuel. The ecosystem contribution needs to be separated from human inputs, otherwise the outcomes can be misleading, i.e. intensive agricultural systems (characterized by high use of external inputs, like fertilizers, plant protection products and machineries) generate a higher yield, if compared with extensive agricultural systems or organic farming. The quantity of yield itself does not represent the crop provision service: the ecosystem contribution to yield needs to be disentangled. In chapter 3 of Vallecillo et al. (2019) the biophysical assessment is based on an emergy-based approach, where emergy (from "embodied energy") of a product is defined as the total solar energy needed, directly and indirectly, to make that product. In the emergy calculation, the following flows are included:

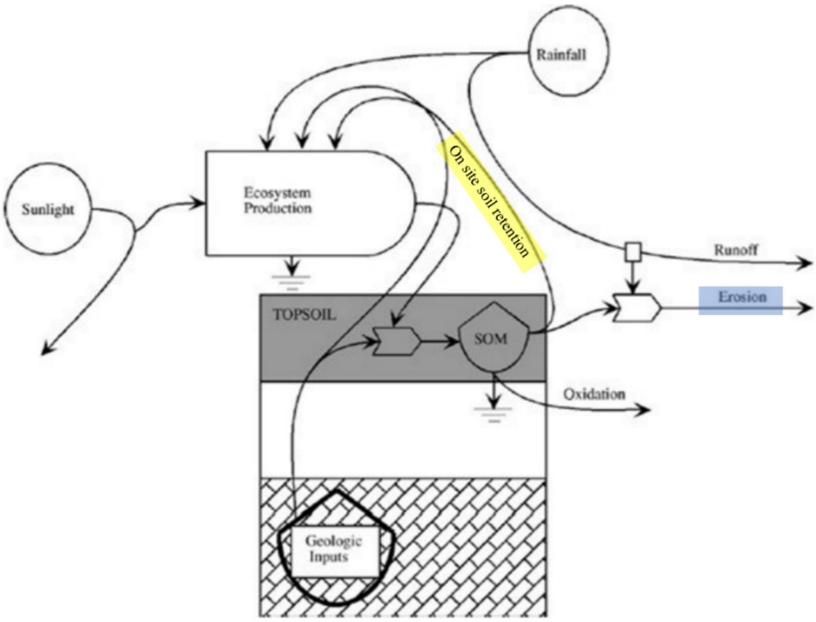
- human (purchased) inputs, that include fertilizers, irrigation, plant protection products, seeds, fuel, use of machinery, electricity, labour;
- natural inputs that include:
  - flows generated by renewable resources (R), i.e. sun radiation energy, wind, rainfall, flowing water and groundwater, all ultimately deriving from solar energy and
  - flows generated by non-renewable or only partly renewable (NR) resources, represented in this case by topsoil depletion[1].

In particular, the emergy flow here called "NR" is calculated as a depletion of soil organic matter (SOM) by multiplying the estimated quantity of SOM consumed by the emergetic transformity of SOM (i.e. the emergy embedded in a unit of SOM, from literature). Figure 1 visualizes the ecosystem inputs provided by soil according to the emergy approach (Perez-Soba M. et al. 2019), specifically "TOPSOIL" in grey. Two arrows originate from "SOM": one flow is going to "ecosystem production" (plant uptake), the other flow is going toward "erosion" by runoff. The flow that is going to "ecosystem production" is also accounted for in this report as "on site soil retention", which would result in a double counting issue if corrections were not applied. NR includes both flows: "on site soil retention" (yellow label) and "erosion" (blue label). To avoid double counting it is necessary to disentangle these two flows to exclude on site soil retention (yellow label) from crop provision when both accounts (crop provision and soil retention) are presented together.

Figure S 1 is a generic figure on how such flows are commonly schematized in the emergy literature. Concerning the specific application used to assess the ecosystem contribution as "crop provision", for the NR component, the study by Pérez-Soba et al. (2019) does not explicitly further distinguish between the two patterns of SOM depletion. For the purposes of this report, if the NR flow only embedded the residual component of superficial runoff by rainfall, then there would not be a double counting issue, as by definition this would not be "soil retained". However, a more conservative (from an accounting perspective) approach suggests considering the NR flow as corresponding to the total SOM depletion (i.e. both soil retained and superficial runoff) and to subdivide this flux into two sub-fluxes through an assumption that minimise the potential double counting error.

[1] Soil depletion here is used an input for agriculture production, since it is used as proxy of soil consumption by plants.

Figure S1 – Visual simplification of the emergy flows contributing to ecosystem production



Source: Adapted from Ridolfi and Bastianoni (2008)

To extract the component of NR at risk of double counting, it is necessary to calculate the proportion of soil retained compared to the proportion of soil eroded, based on the model used to assess the soil retention service[2]. Since NR is proportional to SOM according to a fixed coefficient, to estimate the two sub-flows of NR (soil erosion and retention), it is supposed that the two shares of SOM (hence, emergy) - i) depleted through runoff and ii) depleted as result of plant uptake - are the same of the shares of topsoil eroded and retained. I.e. if in a spatial unit the quantity of soil eroded is equal to the quantity of soil retained, the two NR sub-flows are equal, and 50% of the original NR value is considered to have been already accounted for in the "soil retained" service. If no runoff erosion occurred in a spatial unit, then all the NR flow therein is attributable to soil retained. If soil retained is the double of soil eroded, than 1/3 of the flow is attributed to runoff and the rest to soil retained and so on.

In this way, the share of emergy associated to SOM depleted as result of runoff is subtracted from the total NR, and only the remaining part is considered as already counted in the soil retention service. This represent a first approximation, which was the best option, given available data and their structure - to minimise potential inaccuracies related to double counting. More in general, this exercise is also used to highlight the problem and signal how, in perspective, biophysical approaches such as the emergy one and accounting techniques should be developed jointly to take into account the needs of different – but interrelated – research domains. Compared with the previous account for crop provision (Vallecillo et al. 2019), the results show that about 43% of "flows generated by non-renewable or only partly renewable resources" risks to be double counted both if considered by country or by crop.

References

Perez-Soba M., Elbersen B., Braat L., et al (2019) The emergy perspective: natural and anthropic energy flows in agricultural biomass production. Publications Office of the European Union, Luxembourg

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Ridolfi R., Bastianoni S (2008) Emergy. In: Jorgensen S. E., Fath BD (eds) Encyclopedia of Ecology: Ecological Indicators. pp 1218–1228

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