2019 Forum of Experts in SEEA Experimental Ecosystem Accounting, 26-27 June 2019, Glen Cove, NY

Background paper
Session 4a: Advances in biophysical modelling for ecosystem accounting

Guidance on Biophysical Modelling for System of Environmental-Economic Accounting (SEEA) Experimental Ecosystem Accounting (EEA)

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https://seea.un.org/events/2019-forum-experts-seea-experimental-ecosystem-accounting

Guidance on Biophysical Modelling for System of Environmental-Economic Accounting (SEEA) Experimental Ecosystem Accounting (EEA)

Concept note: developing guidance on biophysical modelling

There is a great need for compilation guidelines on biophysical modeling for ecosystem accounting that detail the practical steps for undertaking ecosystem accounting, using entry points that are easy to understand and follow.

Audience: The audience for this document / guidance would be statisticians or researchers in countries that would like to get started with ecosystem accounting. The materials should therefore have entry points which are useful for this audience, aligned with the SEEA EEA. The guidelines should also develop advise depending on availability of national data, GIS capabilities of the country etc. (a bit like the decision trees that are part of the CI guidance)

A lot of materials have been developed recently on assessing all sorts of biophysical modelling approaches, notably:

- "Biophysical Modelling of Ecosystem Services in an Ecosystem Accounting Context" – Lars Hein, commissioned as part of the EU project;
- Tools for measuring, modelling, and valuing ecosystem services provided by Key Biodiversity Areas, natural World Heritage Sites, and protected areas (IUCN)
- Measurement and Modelling for the SEEA-EEA (report from ANCA project, by Bethanna Jackson, Emil Ivanov, Michael Bordt)
- Guidance for the Biophysical Modelling and Analysis of Ecosystem Services in an Ecosystem Accounting Context (ANCA project).
- World Bank commissioned reports on Evaluating Approaches to Global ES Modeling;
- Online database of ES tools & methods such as: http://aboutvalues.net/method_navigator/
- Work as part of the EU MAES process. The book on mapping ecosystem services is freely available here: https://ab.pensoft.net/article/12837/ as well as the MAES explorer: http://www.maes-explorer.eu/
- WRI guide to selecting ES models: https://www.wri.org/sites/default/files/guide-selecting-ecosystem-service-model-decision-making_0.pdf

Most of the materials to develop guidance is already there, it is a matter of putting all materials together in a useful format for the target audience.

Process / planning (tbd)
1st Editorial Board Meeting 30th April – discuss draft outline, audience, scope
2nd Editorial Board Meeting (end of May) – discuss revised outline, some draft content
Glen Cove 26-29 June Forum – session to present guidelines and obtain feedback from participants
3rd Editorial Board Meeting – Summer (end of August) – discuss first full draft
(after start consultation process with revised draft – SEEA EEA TC + additional experts)
4th Editorial Board Meeting October - review final draft

Editorial board
Rosimeiry Portela / Daniel Juhn (CI – chair), Glenn Marie Lange (World Bank), Justin Johnson (University of Minnesota), Ken Bagstad (USGS), Francois Soulard (Stats Canada), Michael Bordt (UNESCAP), Bethanna Jackson (VUW), Lars Hein (WUR), Stephanie Tomscha (VUW) – editor, Bram Edens (Project management / secretariat)

OUTLINE

Below are two sections from the proposed paper. Their location within the document are highlighted in grey in the outline (above).

SEEA-EEA tiers

A "tiered" approach to initiating SEEA-EEA is a strategic approach, which allows nations to build from their current context. A tiered approach mirrors IPCC approaches for carbon accounting (IPCC 2006) , highlighting three broadly defined tiers (Figure 1) (Martínez-López et al. 2019). Each tier advances in spatial detail, computational complexity, and local accuracy. A Tier 1 SEEA-EEA relies on globally available datasets and pre-constructed ecosystem service models using freely available tools, requiring very little user input. A Tier 2 SEEA-EEA models ecosystem services using national datasets, requiring some customization and validation of ecosystem service models. A Tier 3 SEEA-EEA would draw on the best available local data using bespoke models, parametrized for local contexts. A Tier 3 SEEA-EEA ideal for accuracy, however, rough estimates based on global models and global datasets are a first step towards locally parametrized models, and many organizations may choose to initiate SEEA-EEA using a Tier 1 approach.

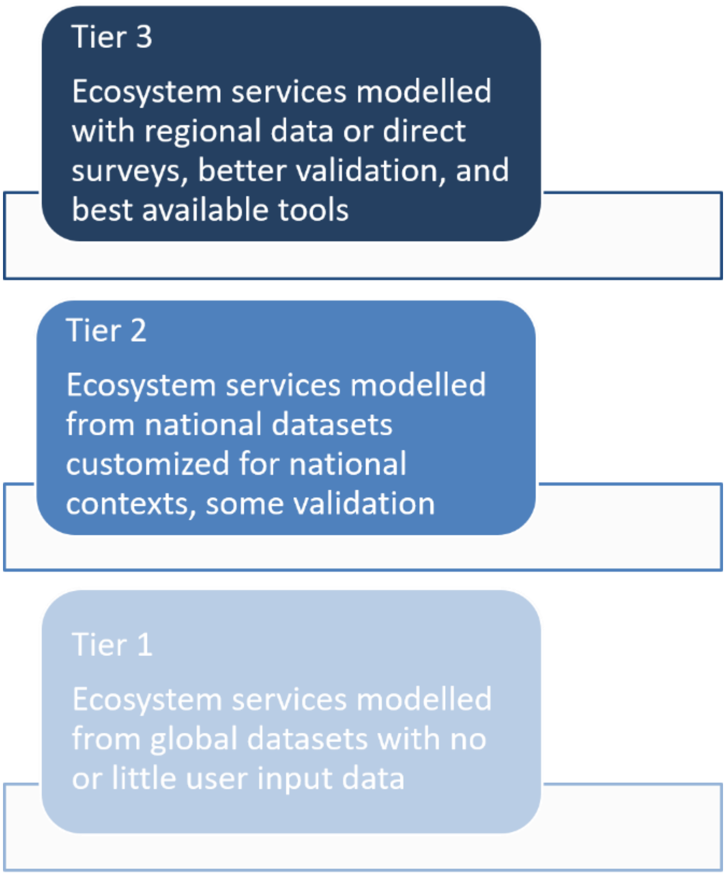

Figure 1 Diagram of SEEA-EEA tiers, each tier with varying levels of comprehensiveness. A tier 1 SEEA is a basic assessment of ecosystem services using freely available models and little to no additional input data. A tier 2 SEEA would include national datasets and some validation. A tier 3 SEEA uses the best available tools and draws on regional data, direct surveys, and includes better validation.

Provisioning of crops

The value of agricultural production is part of the SNA. In the SEEA, the harvested biomass is included in the material flow accounts that describe the total flows from the environment to the economy in physical units.[1] The contributions of SEEA-EEA distinct from the SNA (and SEEA-AFF) are twofold. First, SEEA-EEA aims to disentangle the nature's contributions to crop production from human contributions to crop production, while also capturing spatial variability in these contributions. Second, and in part because discussions around how to best represent nature's contributions to crop production are still active, SEEA-EEA aims to provide spatially explicit estimates of crop production (e.g., volume/hectare). The dominant approach within SEEA EEA is to use harvest as proxy for the service, but then for valuation, use a resource rent or production function approach to isolate the contribution from the ecosystem from human inputs. Finally, frameworks and methods for incorporating intermediate services linked to agricultural production are an aspiration for SEEA-EEA. For example, these intermediate services may include pollination, which links habitat for pollinators with the production of pollinated crops, and pest and disease regulation, which is the capacity of an area to buffer against pest and disease outbreaks. Clearly, a large number of services, such as pollination, pest prevention, nutrient inputs from soil as well as flows of green water are used together with human inputs (e.g. fertilizers) for agricultural production. However, due to a lack of data, these services (with the exception of pollination) are usually not modelled separately.[2]

Biophysical modeling can play several roles in achieving the interrelated aims of SEEA-EEA for crop provisioning. For example, biophysical modeling provides approaches for spatializing census data, where spatially explicit data are scarce. Data coverage of environmental quality needed to support agricultural production is patchy, and modeling may help fill these gaps. Furthermore, spatially explicit maps of crop production provide the landscape context needed to understand natural inputs into crop production from surrounding habitats. Thus, biophysical modeling provides the potential to expand our understanding of nature's contributions to crop provisioning by facilitating connections to ecosystem condition, as well as reporting on intermediate services for crop production. Biophysical modelling may provide approaches to expand reporting on the capacity of an area to produce livestock, especially through the inclusion of other ecosystem services in agricultural production functions (FAO and UNSD 2018). Because of biophysical modeling's potential to facilitate SEEA-EEA agricultural production accounts, clear guidelines on suitable models and possible are needed (FAO and UNSD 2018), we suggest how to approach modeling crop provisioning for SEEA-EEA using the "tiers" perspective outlined in the introduction of this document.

[1] Approaches to clarify nature's contributions to agricultural production in SEEA-EEA build on approaches from SEEA-AFF (System of Environmental-Economic Accounting for Agriculture, Forestry, and Fisheries) (FAO and UNSD 2018).

[2] An alternative approach has been proposed by the EU-JRC (2019) in which emergy (embodied energy content) is used to isolate the input from nature viz-a-viz human inputs. This essentially yields spatially explicit fractions, which are then used to multiply with the market values of crops to obtain estimates of crop provisioning by nature in monetary terms.

A tiered approach to Agricultural production in SEEA-EEA

Tier 1 Coarse estimates using global data

The most basic SEEA-EEA account for agricultural production can be produced using global models. A first step to agricultural production models for SEEA-EEA involves producing spatially explicit maps of different crops and estimating the volume of production. There are several global models that can be used to get started. For example, the InVEST Global Crop Model uses statistical approaches to map and estimate crop yields for 12 crops (Sharp et al. 2018).[3] Very coarse estimates of yield based on percentile models is also possible in InVEST for 175 world-wide crops. Models are based on FAO data as well as global data sources on climate and irrigation and are mapped at an unspecified spatial scale. The outputs provide maps of yield (ss well as nutritional content), and tables which can be converted into standardized SEEA-EEA tables. One of the main limitations of this approach is that it does not account for variation in yields based on landscape position, such as differences in slopes or valley bottoms, as the model only includes climate, fertilization, and irrigation (Sharp et al. 2018).

Tier 2 Spatialized official statistics or global models with national data

Most countries conduct an agricultural census supplemented by regular agricultural farm-level surveys on arrange of variables. Sometimes administrative data sources are used. Tier 2 approaches would use existing official statistics and spatialize them using biophysical modeling techniques.

In the most basic approach, there is only information on agricultural land use – not which types of crops are grown where (or for what rotation cycles). Under these circumstances, average yield factors can be computed and used to spatialize the information. Using this basic approach, it would be difficult however to depict this in maps, as some crops will only be grown in certain areas.

In an intermediate variant, more information on which crops are grown where or could the ability to deduce this information from other data sources (e.g. soil maps) allows for the development of maps, with the computed yield factors, which will differ based on the granularity of the survey data. In a third approach, information on crops (e.g. a detailed land use maps) is available, but no information yield. In this case, a look-up table approach using yield factors from the literature could be applied.

A slightly more sophisticated approach may include using modeling approaches such as look up tables or regression and linking these to land cover or extent accounts. Models such as LUCI or ARIES may produce these more sophisticated estimates of potential crop production. For example, LUCI estimates the potential of a location to produce crops, based on soil fertility, aspect, and climate, which could be linked to estimates of yield. The advantage of this approach is that it could rely on freely available data to create more accurate linkages to yield, without relying on farm-scale data. However, this is a custom approach requiring additional steps beyond outputs provided by modeling platforms.

[3] The 12 staple crops are: barley, maize, oil palm, potato, rapeseed, rice, rye, soybean, sugar beet, sugar cane, sunflower, and wheat. For 175 crops worldwide, InVEST models include percentile models (i.e., identifying yields that are considered to be in 5th, 50th, 75th, and 95th percentiles by climate bin).

Tier 3 Sophisticated country specific models

More accurate yield models may be designed using national data. Custom models may include yield data parameterized using national data or detailed micro data or farm-scale surveys. Tier 3 account should aim for high-resolution outputs. ARIES modelling platform has infrastructure for taking a wide range of input data into account, through using Bayesian networks including soil fertility, irrigation, water availability and soil management to estimate crop yield. Furthermore, LUCI models potential agriculture production, and outputs from LUCI may link to other models to provided more sophisticated estimates of local yield, taking tillage techniques, fertilizers, and landscape context into account.

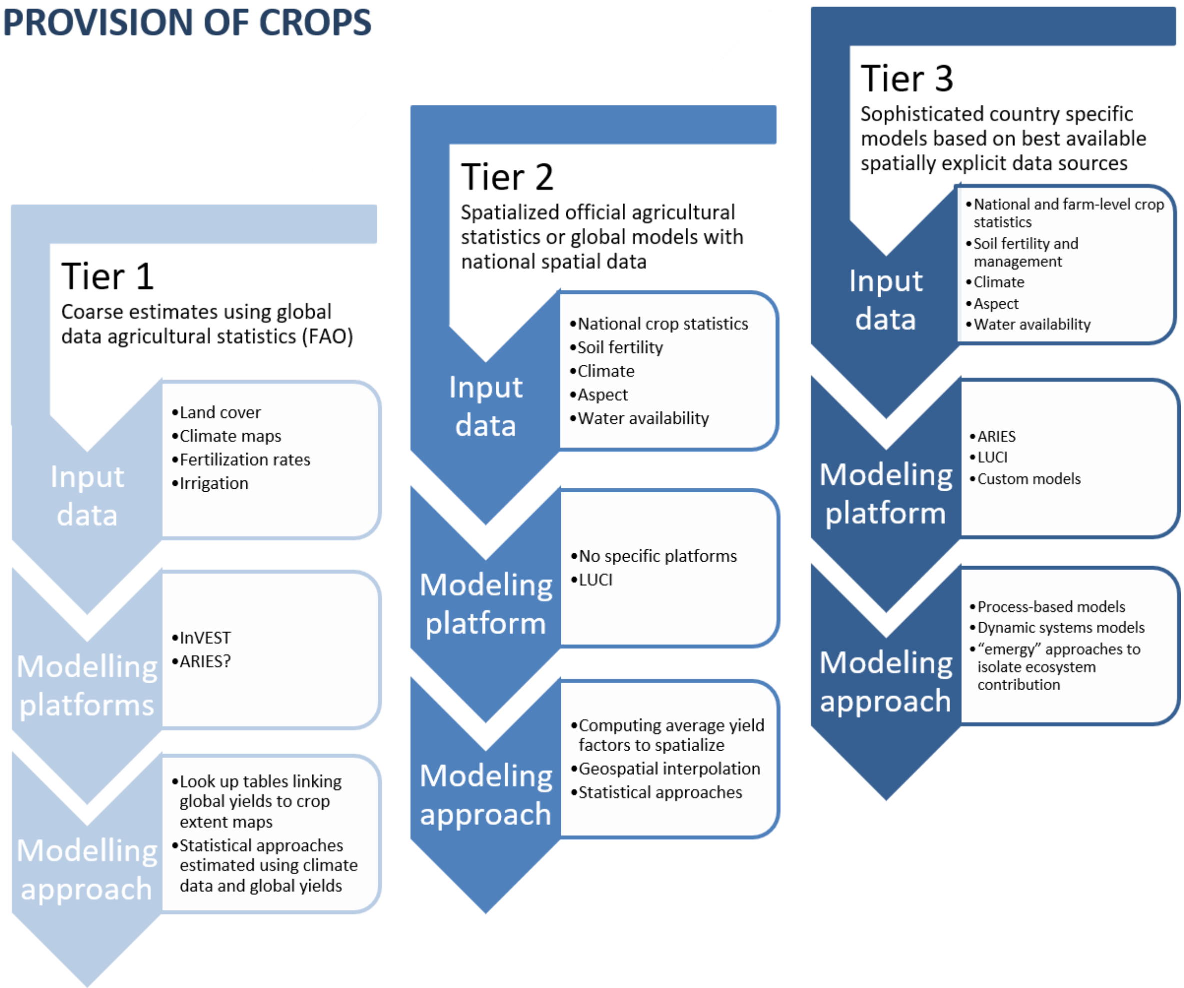

Figure 2 Tiers for agricultural production/provision of crops models. Modeling approaches, platforms, and input data increase in spatial resolution and complexity from tier 1 to tier 3.

Examples of agricultural production accounts

Two approaches to crop production in SEEA-EEA are exemplified below, each representing variations on approaches to reporting agricultural production for SEEA-EEA. These examples come from the Netherlands and the EU. The SEEA-EEA in the Netherlands provides an example of how to report agricultural production, which focuses on spatializing crop yields (which we highlight here) alongside fodder production, as well as crop pollination (Remme et al. 2018). For the EU, we highlighted their approach to isolating environmental inputs to crop production.

The Netherlands – Tier 3

The Netherlands has detailed land parcel data for farms, as well as detailed information from their agricultural surveys (a rolling sample of farms), that allows for crop-specific accounts of yields (see Remme et al. 2018). The scope of the Netherland's crop provisioning accounts included all relevant crops for human consumption.[4] From the registry of agricultural parcels, both the geographical location and the type of crop grown on each parcel (at a specific date) are known.[5] Another data source used was harvest projections, based on annual surveys to crop producers (Statistics Netherlands 2017). Linking these two datasets, data on average production (in kg) per ha per province are published for the majority of crops. A look-up table (LUT) approach is used to obtain maps for these individual crops. Many results in the Dutch SEEA-EEA are reported with a 10 m resolution, which lends well to local-scale decision making, while also allowing for national-scale aggregation for broad policy perspectives. Having the combination of high spatial resolutions and spatially explicit yield data positions this account as a Tier 3 account. One of the main sources of uncertainty in this approach is linking the harvest projections to the appropriate spatial locations, as harvest projections are registered to the farm business address, while farm parcels are registered to locations.

[4] 24 different cops (or crop categories) were distinguished. For some crops e.g. produced in smaller quantities or those that are not a separate category in the projections other estimations are used.

[5] A selection of relevant parcels lead to a total of 137 thousand parcels taken into account in the analysis.

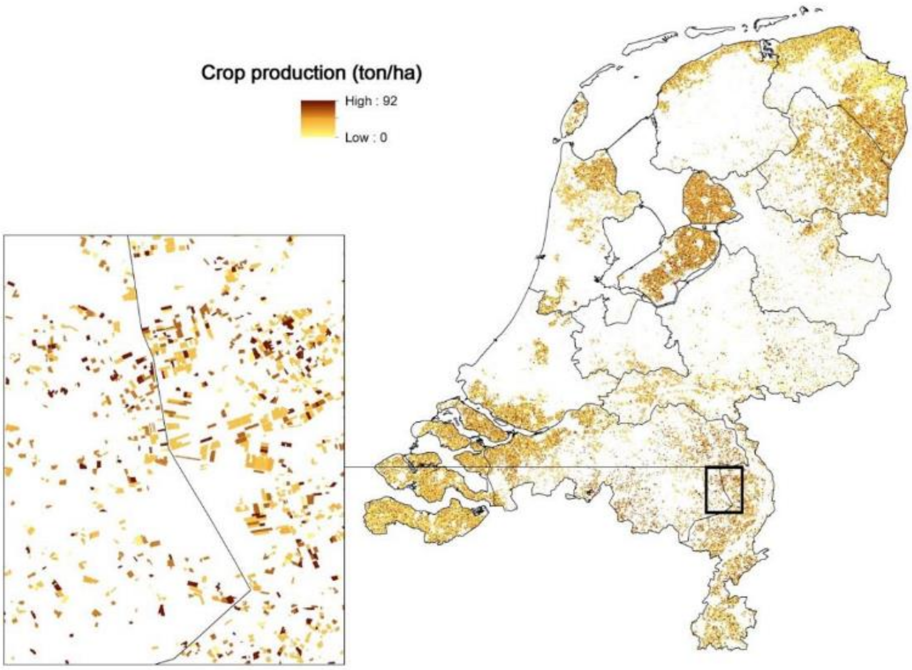

Figure 3 Total crop production (ton/ha) in the Netherlands 2013. These maps were produced by linking harvest projections to spatially registered farm parcels (from (Remme et al. 2018)*).*

The EU JRC "emergy" approach

A primary goal of SEEA-EEA is disentangling human versus nature's contributions to crop production. In the EU, one approach used to disentangle these inputs is called "emergy" approach (derived from terms 'emergent energy') (Vallecillo et al. 2019). Natural inputs include sunlight, rain, soil, etc, while human inputs include planting, irrigation, and chemical products and result in the production of crops (Figure 4). These data are collected as part of Common Agricultural Policy Regionalised model, a European program. To facilitate the comparison of these distinct inputs with different unites, they were transformed into solar equivalent Joule (seJ), using a transformity coefficient. Next, the ratio of natural to human inputs were calculated to determine the relative input of the ecosystem.

One key outstanding issue is how to represent an ecosystems contribution to crop production in physical terms (Hein L., Turpie J., Cerilli S. 2018). The dominant approach is to use harvest as proxy for the service, but then for valuation, use a resource rent or production function approach to isolate the contribution from the ecosystem. For example, agricultural production accounts will provide spatial estimates of harvest volumes, while also isolating the contributions of the environment by creating spatially explicit indices. To create these indices, natural versus human inputs to crop production have been distinguished. Agricultural production is a function of renewable natural input such as sunlight, rainfall and evapotranspiration, non-renewable natural input such as soil organic matter, and anthropogenic inputs including mineral fertilizers, pesticides, seeds, and human labor (Vallecillo et al. 2019). These indices are subsequently used to determine the benefits of ecosystems provided by crop production. Attempts to isolate the environment's contribution to crop yields have thus far been static, which is an important limitation.

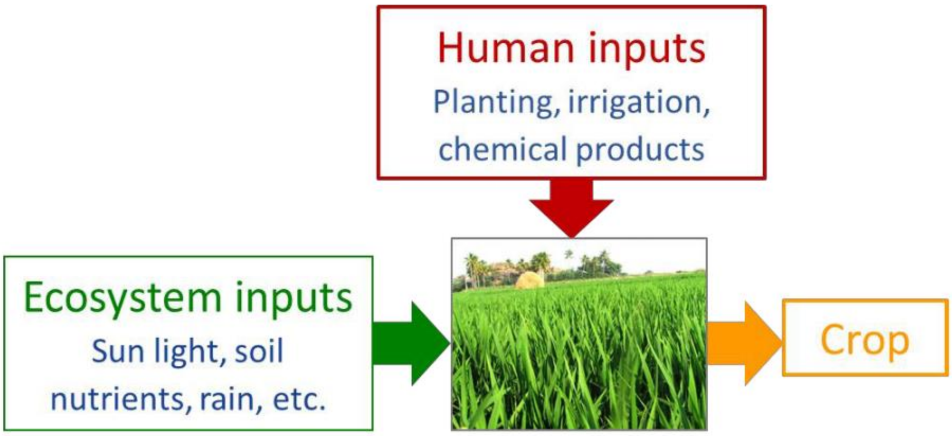

Figure 4 Diagram showing the distinct inputs from humans versus ecosystems. The "emergy" approach adopted by the EU aims to isolate these inputs to better understand how nature contributes to crop production.

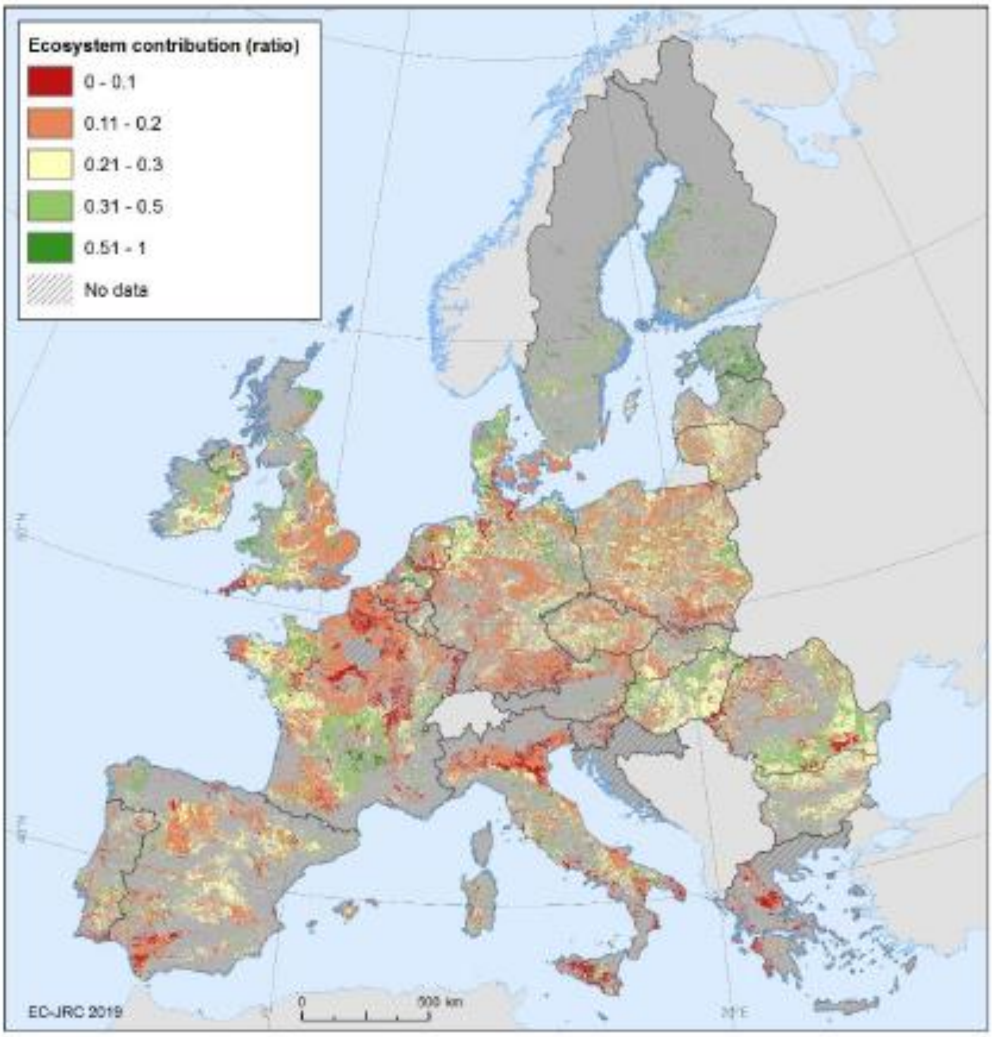

Figure 5 Shows spatial variability in the ratio of ecosystem contribution to crop production across Europe (From (Vallecillo et al. 2019))

References

FAO, and UNSD. 2018. System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries: SEEA AFF White Cover version:138.

Hein L., Turpie J., Cerilli S., C. G. 2018. Discussion paper 1: Towards a definition and classification of terrestrial provisioning services related to crop cultivation and forestry. New York.

IPCC. 2006. GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES. Page (W. I. (USA) Jim Penman (UK), Michael Gytarsky (Russia), Taka Hiraishi (Japan) and and T. K. (Brazil), Eds.). Kanagawa, Japan.

Martínez-López, J., K. J. Bagstad, S. Balbi, A. Magrach, B. Voigt, I. Athanasiadis, M. Pascual, S. Willcock, and F. Villa. 2019. Towards globally customizable ecosystem service models. Science of the Total Environment 650:2325–2336.

Remme, R., M. Lof, L. de Jongh, L. Hein, S. Schenau, R. de Jong, and P. Bogaart. 2018. The SEEA EEA biophysical ecosystem service supply-use account for the Netherlands:113.

Sharp, R., H. T. Tallis, T. Ricketts, A. D. Guerry, S. A. Wood, E. Chaplin-Kramer, R., Nelson, D. Ennaanay, S. Wolny, N. Olwero, K. Vigerstol, D. Pennington, G. Mendoza, J. Aukema, J. Foster, J. Forrest, D. Cameron, K. Arkema, E. Lonsdorf, C. Kennedy, G. Verutes, C. K. Kim, G. Guannel, M. Papenfus, J. Toft, M. Marsik, J. Bernhardt, R. Griffin, K. Glowinski, N. Chaumont, A. Perelman, M. Lacayo, L. Mandle, P. Hamel, A. L. Vogl, L. Rogers, W. Bierbower, D. Denu, and J. Douglass. 2018. InVEST 3.6.0 User's Guide.

Vallecillo, S., A. La Notte, G. Kakoulaki, J. Kamberaj, N. Robert, F. Dottori, L. Feyen, C. Rega, J. Maes, S. Vallecillo, A. La Notte, G. Kakoulaki, J. Kamberaj, N. Robert, F. Dottori, L. Feyen, C. Rega, and J. Maes. 2019. Ecosystem services accounting Part II Pilot accounts for crop and timber flood control. Publications Office of the European Union, Luxembourg.