Maps of Ecosystem Services - Supply and Demand

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In this article, the need for appropriate quantification and related spatial visualization of ecosystem services is discussed. The supply of multiple goods and services by nature on the one hand should match the demands of society on the other hand, if a self-sustaining system is to be achieved. Depending on production schemes and various other factors, self-sustaining systems have a higher capacity for a sustainable use of natural capital than import-dependent systems. As land use and resulting land cover changes are among the main effects induced by human activities on landscapes and their capacities to provide ecosystem services, assessments in a spatial manner using maps seem to be appropriate. Moreover, a simple but efficient approach to produce maps of ecosystem services supply and demand based on an integrating assessment matrix is presented.

Background

The concepts of ecosystem services and Natural Capital have become very popular tools in science within the last decades. Due to their integrative and problem-focused character, ecosystem services have a high potential for application in resource and environmental management. Therefore, the conceptual framework has been adapted by numerous research projects, e.g. the Millennium Ecosystem Assessment. Within these studies, one problem seems to be that they remain on a rather conceptual level when it comes to concrete numbers regarding the broad range of possible ecosystem services. Various evaluation approaches exist, including economic valuations, purely ecological function analyses or value-based social assessments that have been applied at diverse spatial and temporal scales. All these approaches have their advantages and disadvantages and the solution might not be an either-or but an integration of different methods and their potentials. Supply and demand of ecosystem services is a very important issue for if the demand exceeds the supply, the system is not self-sustaining and depends on imported goods and services, which often results in ecological degradation of distant regions. This means that impacts of human actions are delocalized and the system itself cannot be managed in a sustainable way. However, one has to differentiate between the different ecosystem services’ suitability for trade, as the spatial scale at which the supply has to meet the demand varies between them. For some ecosystem services, as for example for the carbon sequestration service, supply and demand have to be balanced only at the global scale, allowing trading schemes such as the clean development mechanism. At whichever scale, both sides can be influenced by political measures, the supply as well as the demand of ecosystem services, the latter being mainly determined by population dynamics, economic factors and people’s behavior. Thus, the comparison of supply/demand ratios of ecosystem services can help decision makers in landscape management when striving for a sustainable balance between resource supply and demand.

Various approaches exist to set the ecosystem service supply into relation with the ecosystem service demand. One of the first was the concept of carrying capacity, which aims at quantifying the number of individuals of a given species that a defined habitat can support infinitely. It was followed by the ecological footprint approach that focuses on the demand side by calculating the resource consumption of a population, expressed in biologically productive area with global average hectares as measurement unit. Another approach to indirectly link the supply with the demand is the monetary valuation of ecosystem services.
This approach necessitates the replacement of low or missing market values for ecosystem services by estimated values of people’s willingness to pay or accept. Any monetary valuation requires a previous assessment of ecosystem services in biophysical units as a basis. If the demand as well as the supply is quantified for a specific region in biophysical units, they are directly comparable enabling the assessment of the region’s sustainability. For this purpose, maps are an appropriate instrument to illustrate spatial phenomena, distributions and their interrelations. With focus on landscape management, they can be a powerful tool by e.g. showing areas where action is needed or not needed, respectively. In order to map the distribution of ecosystem services' supply and demand, appropriate indicators and data for their quantification are needed, including quantitative and qualitative assessments.

**Mapping Ecosystem Services’ Supply**

The supply of ecosystem services is strongly linked to natural conditions, e.g. land cover (vegetation), hydrology, soil conditions, fauna, elevation, slope and climate. All this information should be as detailed as possible, in a relevant resolution and at an appropriate scale when defining the capacities of different ecosystems to supply services. At the beginning of the ecosystem services’ chain of supply, there are processes and structures in ecosystems, which often are referred to as supporting services or ecological integrity. Based in their integrity, ecosystems are able to provide regulating, provisioning and cultural ecosystem services. Using land cover information from e.g. remote sensing, simulation models, GIS and statistics, the state of ecosystems and their capacities to supply ecosystem services can be assessed and transferred to maps of different spatial and temporal scales. The results reveal patterns of natural conditions and human activities over time and the capacities of different ecosystems to provide ecosystem services under changing use.

We suggest a matrix linking 29 ecosystem services (on the x-axis) to 44 different land cover types (on the y-axis). This selection of ecosystem services is based on most recent research, the land cover classes originate from the European CORINE land cover project. At intersections (altogether 1276), different land cover types’ capacities to provide particular services were assessed qualitatively on a scale consisting of: 0 = no relevant capacity, 1 = low relevant capacity, 2 = relevant capacity, 3 = medium relevant capacity, 4 = high relevant capacity and 5 = very high relevant capacity (Figure 1).
Figure 1: Matrix for the assessment of different land cover types' capacities to provide ecosystem services. Value 0 = rosy colour = no relevant capacity of the land cover type to provide this particular ecosystem service, 1 = grey green = low relevant capacity, 2 = light green = relevant capacity, 3 = yellow green = medium relevant capacity, 4 = blue green = high relevant capacity and 5 = dark green = very high relevant capacity. In the rows between the assessments (yellow colour), sums for the individual ecosystem services groups were calculated.

The matrix numbers are based on experience from different case studies in different European regions and have to be considered as a suggestion of possible capacities of ecosystem services provision. They should be checked carefully and substituted by numbers from respective research if available. Once the matrix is filled with data, map compilation is rather easy.
Mapping Ecosystem Services’ Demand

By definition, an ecosystem service is only a service, if there is a benefit. This means, there must be a certain demand by people to use a particular service. In order to assess these demands, data on actual use of ecosystem services are needed. They can be derived from statistics, modeling or interviews. By transferring them to a scale similar to the one used for ecosystem services supply, respective maps of ecosystem services demands can be produced. In order to analyze source and sink dynamics and related flows of goods and services, the information in the maps of ecosystem services’ supply and demand can be merged.

Figure 2 shows exemplary maps of energy supply and demand for an eastern German region including the two cities Leipzig and Halle. The maps have been compiled by incorporating land cover data and statistical data on land use, energy consumption of households, industries, commerce, mining, agriculture and forestry. The energy supply map (top left) uses the five classes described in the assessment matrix above, but links them with real data in biophysical units. The same classification is used in the demand map (bottom left), showing high energy consumption in the two cities and low consumption in the surrounding agricultural and forest areas. The balance between supply and demand is visualized in the map on the right revealing areas of energy surplus (in green color) as well as areas with an energy deficit (in red color). Although the green areas dominate in this map, the whole region had to face an energy deficit of $44 \times 10^6$ GJ in 2007 due to the high energy consumption in the two cities.
Figure 2: Provisioning ecosystem service "Energy"; supply (top left) and energy demand (bottom left) in the Eastern German region Leipzig-Halle in the year 2007 as an example for ecosystem service maps. The map on the right shows the balance of energy demand and supply (Data sources: German Federal Environmental Agency, DLR, Ministry of agriculture and environment Saxony-Anhalt, Saxon State Ministry of the environment and agriculture, Institute for Energy and Environment, Saxon State Department of the Environment and Geology, Statistical Office of the Free State of Saxony, Statistical Office of Saxony-Anhalt, German Federal Statistical Office).

Conclusion

Mapping ecosystem services and especially quantifying information behind these maps are an important contribution towards the applications of the ecosystem services’ approach in science as well as in practice. One main problem is the lack of appropriate data. If data are available, they have to be aggregated based on suitable units (e.g. kg, Joule, monetary values), spaces (e.g. per ha) and time (e.g. per year) in order to make them comparable. Starting with a matrix (as presented above) provides a rather easy tool to begin the ecosystem service assessment with, the level of complexity and data accuracy can be increased successively. By using a rather "neutral" scale (0 to 5), value-laden units (such as monetary terms) can be avoided and a variety of data sources (e.g. monitoring, statistics, expert judgment, literature review, on-site assessment) can be harmonized. Besides this data issue, the selection of appropriate temporal and spatial scales seems to be very crucial for the quality of the assessment. Moreover, the system analysis' complexity and limit have to be defined carefully. For mainly imported ecosystem services (e.g. in city regions), a concept of ecosystem services’ footprint, comparable to the concept of the ecological footprint, should be developed. Therefore, the development of corresponding education, research projects, monitoring schemes and national ecosystem services assessments would be a big step towards implementing the concept of ecosystem services as a solution for real problems.

Further reading


