Utilizing Physical Input-Output Model to Inform Nitrogen related Ecosystem Services

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Short summary:

Nitrogen management is a critical issue facing the society today because of its indispensable need along with negative impacts that occur due to nitrogen losses to environment. In this work, PIOTs are used to inform strategy for nitrogen management that can reduce the external impacts of nitrogen use.

Extended abstract:

The global nitrogen (N) cycle has been significantly altered during the past century by anthropogenic activities [1]. While benefiting society through enhanced agricultural production and the manufacturing of goods such as nylon and explosives, human modification of the N cycle has also led to an overabundance of reactive forms of N in the environment, harming human health, altering ecosystem function, and contributing to global climate change [2] . Optimizing N use efficiency while at the same time minimizing the effects of increased environmental N loading is therefore an important challenge facing society in the 21st century**.** Thus, developing such strategies form an important focus of the research efforts at EPA [3] and National Academy of Engineering [4].

To be able to develop and apply strategies for nitrogen management that can help identify the trade-offs among various ecosystem services impacts, it is important to understand the flow network of nitrogen dependence. One of the tools to analyze and gain insights about physical flows is the Physical Input-Output Table (PIOT) which is the physical analogue of economic input-output tables [5, 6]. Physical Input-Output Tables (PIOTs) have been developed for several countries to understand material flows and related environmental impacts [7, 8, 9]. When applied in conjunction with economic accounts, these tables can be used to understand the life cycle demands of raw-materials or waste generation associated with consumption activities. This model gives the ability to capture the direct and indirect consumption of all the commodities that are required to support consumption of a given unit of production demand, thus bringing the life cycle perspective in ecosystem services management related to material flows. Despite the capabilities of PIOTs to show detailed material flows account, it has been rarely used in informing the policy decisions regarding sustainable ecosystems management & economic benefits in US. This is due to the challenges related to data availability and efforts required to construct a PIOT which has led to some work on methods for PIOT compilation [10, 11, 12]. It can also be used to study the impact of change in policies or introduction of new technology on the life cycle scale for the economy for various materials flows and related environmental impacts [7].

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In this work we aim to develop a physical input-output model of nitrogen commodity flows which can then be used with the biophysical models NEWS [13] or SPARROW [14] to calculate the region specific impact of commodity use on water quality and other related ecosystem services. Using PIOT framework will help quantify the life cycle impact of strategies on ecosystem services. The relationship between nitrogen-based drivers and ecosystem services is based on EPA's ongoing work on ecosystem services [2]. The nitrogen PIOT is developed using data from the Bureau of Economic analysis [15], the USDA NASS dataset [16], an EPA nitrogen inventory [17], and process life cycle inventory where necessary. Further, regional models will be connected to study one region's impact on the ecosystem services provided by other regions utilizing the physical flows as the drivers.

Here we describe the development of nitrogen PIOTs for the midwestern US state of Illinois with large inputs of nitrogen from agriculture and industry. The PIOTs are used to analyze the relationship between regional economic activities and ecosystem services in order to identify activities that enhance or negatively impact ecosystem services. In addition, the effect of inter-region trade on ecosystem services is enumerated. Ultimately, this model identifies mitigation strategies for nitrogen and their relationship to ecosystem services. Along with informing specific ecosystem services decisions related to nitrogen, this work contributes to the development of more complete physical accounts which can be used together with economic IO data for economy-wide analyses [18].

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