Quantification of ecosystem services flows to Israel

Key findings

- This study compares two watersheds in the USA (Iowa and Kansas) and one in the Ukraine with respect to three ecosystem services (ES) and calculates indices to quantify virtual ES flows to Israel.
- All three watersheds have a low freshwater provisioning service. The USA watersheds have a slight advantage in terms of erosion regulation and are clearly superior in food provisioning compared to the Ukraine watershed.

Motivation

Global trade in crop commodities enables countries with limited water and land resources to maintain food security, but it also makes them reliant on ecosystems abroad. Ecosystem services (ES) are benefits people obtain from ecosystems. Examples are food provisioning, freshwater provisioning, and erosion regulation. This study focuses on these three services that are considered key to maintaining food and water security. It looks at Israel as a case study, focusing on staple crops – wheat, maize, soybean – that are imported to Israel from the USA and Ukraine. Similar to the concept of virtual water, or water footprint, we view ES as virtually imported or the importing country having an ES footprint in the exporting country. The provision of ES varies in different countries and within countries, and some regions can be considered more suitable to produce certain crops than others. This study looks at crop production within specific watersheds and compares them using a set of ES indices.

Methodology

Over the last few decades, Israel has imported significant quantities of wheat, corn, and soybean from the USA and Ukraine. We compare three watersheds in terms of provided ES and virtual ES flows to Israel (Koellner et al., 2019). We modeled two watersheds in Iowa and Kansas (USA) and one watershed in Ukraine using the Soil and Water Assessment Tool (SWAT; Arnold et al., 1998). These watersheds represent a range of production systems from a relatively low-precipitation climate with wheat and irrigated corn production in western Kansas, to rainfed corn and soybean production in Iowa, and rainfed corn, soybean, and wheat production in Ukraine. Monthly streamflow is used to calculate a freshwater provisioning index based on minimal environmental flow requirements, defined as 30% of long-term streamflow. The biomass and yield of the relevant crops are used to calculate the food provisioning service based on the average multi-year yield across all watersheds. The sediment yield is used to calculate the erosion regulation service based on a maximum tolerable soil loss rate per year (Logsdon & Chaubey, 2013). More indices for other ES will be added in the following months.

Quantification approach

The Soil and Water Assessment Tool (SWAT; Arnold et al., 1998) is a watershed-scale hydrological model capable of producing outputs that can help to quantify various ecosystem services. For this analysis, we used outputs on streamflow (freshwater provisioning), crop and biomass yield (food provisioning), and sediment yield (erosion regulation) to compare three watersheds in the USA and Ukraine. Each ES index is normalized to a value of 0 to 1 to enable a direct comparison of the watersheds.

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Results

When comparing the three watersheds in terms of freshwater provisioning, the calculated index is relatively low in all three cases, meaning that streamflow is below the 30% threshold for large parts of the year (Figure 1a). Figure 1b shows the erosion regulation index, indicating a slight difference between the watersheds, with erosion regulation in the Iowa and Kansas watersheds being slightly higher. This is likely due to heavy implementation of contour farming and terracing. When we look at the food provisioning service (Figure 1c), Iowa and Kansas stand out significantly over the Ukrainian watershed. This is primarily driven by lower yields in the Ukraine, which means that the USA watersheds are more efficient food producers. Based on these results, it appears that crop production in the USA is advantageous over production in the Ukraine, at least with respect to the investigated watersheds and ES.

Application

Analyses of virtual ES flows enable policy makers to identify countries and watersheds that have high ES indices and from which they could import crops while reducing environmental impacts. The concept of virtual ES provides an additional lens through which to investigate the reliance of importing countries on ecosystems abroad and identify non-linear trade-offs. Rather than using a simple indicator such as tons per hectare or cubic meters per second, we opted to use indices with normalized unitless values between 0 and 1. This enables us to compare watersheds of different sizes and with different streamflow quantities. On the other hand, indices introduce an extra layer of complexity and therefore uncertainty. An additional watershed in Brazil will be included in further analyses, as well as indices for additional ES. A more comprehensive analysis can also be made by including energy requirements and emissions related to Israel's crop imports.

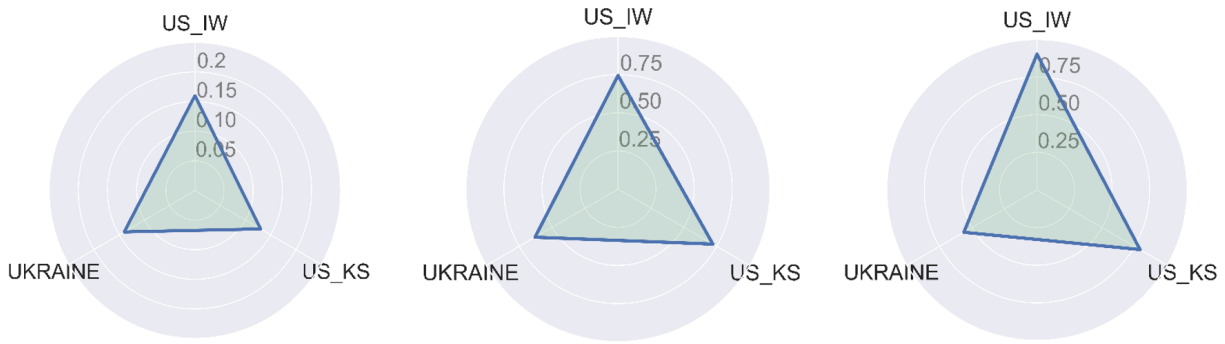

Figure 1: Comparison of a) Freshwater provisioning service, b) Erosion regulation service, c) Food provisioning service for the watersheds in Iowa and Kansas (USA) and Ukraine

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