Ecosystem Services xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

# An integrated biophysical and ecosystem approach as a base for ecosystem services analysis across regions

Dor Fridman *, Meidad Kissinger

*Department of Geography and Environmental Development, Ben Gurion University, Israel*

ARTICLE INFO

*Article history:*
Received 17 August 2017
Received in revised form 14 November 2017
Accepted 10 January 2018
Available online xxxx

*Keywords:*
Systems-integration
Trade-offs
Food systems
Interregional-sustainability
Tele-couplings
Dis-services
Ecosystem service indicators
Biophysical and ecosystem assessments

ABSTRACT

In an interconnected world, the 'food system' sustainability of any given region is increasingly dependent on ecosystem services originated from supporting regions in different parts of the world. However, commonly used research approaches, such as place based ecosystem service assessments and interregional biophysical accounting, have limited capacity to capture the complex interactions across regions. This research addresses this gap by integrating a global biophysical accounting of food crops with its related local ecosystem dis-services. It combines agricultural and ecosystem indicators to describe different classes of biophysical pressures and potential dis-services from growing 4 key agricultural staples exported to Israel from different agricultural areas around the world. Each class stands as a 'functional region' in which either a trade-off or a synergy exists between agricultural efficiency and environmental impact. The research finds that over half of Israel's crops supply was produced in areas with high soil loss potential, and almost 15% of it originates from areas with high water scarcity. It implies that changes to Israel's supply sources have the potential to reduce consumption related impacts on ecosystem services. The functional regions typology may be used as a global road map mediating interregional flows assessments with place-based ecosystem service assessments.

© 2018 Elsevier B.V. All rights reserved.

## 1. Introduction

For most of human history societies' food security and sustainability was mainly attributed to their local environment. However, growing populations, technological developments, changing material standards of living and global economic integration have fundamentally changed global food systems, to an extent that most societies worldwide are at least partially dependent on remote world regions for their food supply (Fader et al., 2013; Kastner et al., 2014; Kastner et al., 2012; Weinzettel et al., 2013).

The world's agricultural systems mostly benefits humans through provisioning ecosystem services (i.e., food production), yet they rely on a suite of other ecosystem functions and services, such as: soil conservation, structure and fertility, water provision, nutrient cycling, pollination, pest control and genetic biodiversity (Power, 2010; Zhang et al., 2007). Agricultural systems may be negatively affected by flows of ecosystem dis-services (or environmental disruptions), and may produce such dis-services that affect other ecosystems, as well. For example: intensive cropping systems may increase land degradation by increasing soil erosion, which may affect soil fertility by both reducing its organic carbon content and by modifying its structure (Zhang et al., 2007). Additionally, sediment yields from agricultural basins may alter a water flow regime, degrade riparian wetlands, and increase sediment and nutrient loadings to fresh water ecosystems (Swallow et al., 2009).

International trade of agricultural commodities shifts dependence and environmental pressures from regions of consumption to remote agricultural systems. These linkages are accounted for by two analytical frameworks, developed in recent years – the tele-coupling (Liu et al., 2007, 2013) and the interregional sustainability (Kissinger et al., 2011; Kissinger and Rees, 2010a). The first is mainly used to measure and analyze material, financial and information flows from sending regions to remote receiving regions. The latter focuses on the interdependence of different regions and on the implications of such interdependence to sustainability.

Two relevant research approaches advanced in recent years for exploring the global agricultural systems and its environmental implications are the biophysical and the ecosystem. By 'biophysical' we refer to studies that accounted for reliance on various inputs such as: land, water, and fertilizers, embodied in the life cycle of various food crops. Various studies have focused on resources and material embedded in international trade of food crops and related processed products as indicators of

* Corresponding author.
*E-mail address:* fridmand@post.bgu.ac.il (D. Fridman).

https://doi.org/10.1016/j.ecoser.2018.01.005
2212-0416/© 2018 Elsevier B.V. All rights reserved.

Please cite this article in press as: Fridman, D., Kissinger, M. An integrated biophysical and ecosystem approach as a base for ecosystem services analysis across regions. Ecosystem Services (2018), https://doi.org/10.1016/j.ecoser.2018.01.005

environmental pressure (Dalin et al., 2017; Kastner et al., 2014; Lassaletta et al., 2016; Mekonnen and Hoekstra, 2014). The ecosystem approach on the other hand focuses on the state of the environment and its processes, and analyzes their spatial and temporal variation. It focuses on properties, structures and functions including for example analysis of habitat change and loss of biodiversity (Chaudhary et al., 2016), soil degradation (Nachtergaele et al., 2010) and other environmental components. Individually each approach contributes to science and policy in a variety of ways, yet integrating both would form a robust link between natural and social systems, while advancing the science of sustainability, and providing better insights to policy makers (Eisenmenger et al., 2016). However, to date only very limited numbers of studies have attempted to integrate both approaches (Chaudhary and Kastner, 2016; Dalin et al., 2017; Kissinger and Rees, 2009, 2010b; Würtenberger et al., 2006).

Ecosystem service assessments are an important subset of the ecosystem approach, which focus on ways in which humans benefit from ecosystems (Haines-Young and Potschin, 2010; Millennium Ecosystem Assessment, 2005). Ecosystem service assessments vary in scope, but are mostly restricted to a landscape scale. For example, some studies focused on one or more hydrological basins (Queiroz et al., 2015; Swallow et al., 2009), while others used national or sub-national administrational boundaries to scope their analysis (Gimona and van der Horst, 2007; Leh et al., 2013; Raudsepp-Hearne et al., 2010; Turner et al., 2014). Some have attempted to conduct a global ecosystem services assessment (Costanza et al., 1998; Millennium Ecosystem Assessment, 2005; Naidoo et al., 2008; Turner et al., 2007). However, spatial explicit and temporal datasets required for such assessments are highly limited (Leh et al., 2013), and global consistent datasets are particularly less available (Naidoo et al., 2008). Nevertheless, global assessments are important in an era in which global decision making is required to tackle some of the most urgent environmental challenges humanity is going through (Naidoo et al., 2008; Turner et al., 2007).

The global nature of our food system and the increasing dependence of societies on remote production regions challenge place-based ecosystem service assessments with respect to their suitability for sustainability assessments. Further, while biophysical accounting proved as suitable at modeling the interconnections between consumer and producers across space, it mostly focuses at flows between nations; ignoring the variability of the ecological, technological and economic conditions across different producing regions. Therefore, integrating biophysical and ecosystem approach requires finer scale biophysical accounts and cross border ecosystem services assessments. It can help relating the flow of provisioning services from one region to another to ecosystem dis-services generated in growing regions, and to the sustainability of both producing and consuming regions.

A growing number of recent studies have estimated environmental stress and land displaced by food consumption and trade (Dalin et al., 2012; Kastner et al., 2014, 2012; Kissinger and Rees, 2009, 2010b; Lassaletta et al., 2014; Yu et al., 2013). Nevertheless, most biophysical analysis studies focus on the national political boundaries and therefore cannot identify the specific region in exporting country in which the studied commodity was grown. This approach ignores the variability of the ecological and human-related conditions across different producing regions. Therefore it neglects the notion that similar environmental pressures may lead to different ecological consequences. For example, a cropland footprint of 1 squared-km in Brazil probably has different implications to soil degradation than a similar footprint in North America. Similarly, an equal pressure on different production regions in one country may result in different environmental impacts.

Recently, some studies have advanced a sub-national analysis of biophysical flows (Godar et al., 2015, 2016). In addition, few studies have also attempted to determine the linkage between land/water dependence and ecosystem changes in exporting/supplying regions (De Baan et al., 2013; Kissinger and Rees, 2009; Koellner and van der Sleen, 2011; Schütz et al., 2004; Würtenberger et al., 2006). Some have focused on implications for biodiversity (Chaudhary and Kastner, 2016; Lenzen et al., 2012; Sandström et al., 2017), on embodied $CO_2$ (Karstensen et al., 2013; Ståhls et al., 2011), and on underground water depletion (Dalin et al., 2017). These studies demonstrate how interregional flows of provision ecosystem services result in increasing ecosystem dis-services flows to global, regional and local communities.

This manuscript contributes to this effort by linking global provision to Israel of rice, maize, soybeans and wheat with ecosystem dis-services from agricultural producing regions at a resolution of a 5 arc-min ($\sim$10 km around the equator). It characterizes both agricultural and environmental systems in production regions, and integrates them to describe different classes of biophysical pressures and potential dis-services from agriculture. Each class stands as a 'functional region' in which either a trade-off or a synergy exists between agricultural efficiency and environmental impact. Doing so, this manuscript presents an analysis framework that links environmental pressures related to food consumption with potential environmental impact of agriculture across space. In a globalizing increasingly interconnected world, the approach developed and illustrated here for the case of Israel is relevant and can be applied to any other country and to the entire global system.

## 2. Methods and materials

The primary objective of this manuscript is to present an initial step of the integration of a global biophysical assessment of food crops (provisioning services) with its related local environmental impacts and ecosystem dis-services. To do so, this manuscript presents an analytical framework that integrates the agricultural and environmental systems into a coupled indicator system (Fig. 1). The agricultural system measures environmental pressures posed by crop production, and plays a key role in linking these pressures to remote consumers. The environmental system uses environmental state indicators to indicate on how different pressures potentially affect the environment. For example, land used to provide a fixed quantity of wheat (measured by wheat yield) may be situated in an area with either high or low tendency for soil loss. This coupled indicator system balances human derived pressures against nature capacity to function under pressures, and can be used to characterize production regions as unique areas with different functionalities, which are referred here as "functional regions".

This paper presents the identification and demarcation of such functional regions, and the application of this concept to a case study of Israel's national supply of 4 main staple crops. This was achieved by two main stages: (a) Integrating a global agricultural dataset with a few ecological datasets to produce crop-specific functional regions map; (b) Conducting a sub-national assessment of biophysical flows to Israel and estimating flows from each functional region.

### 2.1. Producing crop-specific functional regions map

A functional region is a spatial-explicit production class defined by its relative agricultural performance and environmental state measured by different indicators. In this study the agricultural system is described by two spatial explicit indicators for each crop: yield and water intensity. Two additional indicators are used to

Please cite this article in press as: Fridman, D., Kissinger, M. An integrated biophysical and ecosystem approach as a base for ecosystem services analysis across regions. Ecosystem Services (2018), https://doi.org/10.1016/j.ecoser.2018.01.005

Download English Version:

https://daneshyari.com/en/article/6556291

Download Persian Version:

https://daneshyari.com/article/6556291

Daneshyari.com