Applied Geography 96 (2018) 16–28

Contents lists available at ScienceDirect

Applied Geography

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

The Telecoupling GeoApp: A Web-GIS application to systematically analyze telecouplings and sustainable development

Paul McCord*, Francesco Tonini, Jianguo Liu

Center for Systems Integration and Sustainability, Department of Fisheries and Wildlife, Michigan State University, Manly Miles Building, 1405 S. Harrison Rd., Room 115, East Lansing, MI 48823, USA

ARTICLE INFO

Keywords:
CHANS
Land-use change
Sustainable development
Telecoupling
International trade
webGIS

ABSTRACT

Global challenges, such as chronic hunger in developing and developed regions, loss of wildlife habitat, and the continuing rise of greenhouse gas emissions from human activities, can be addressed only through an integrated approach. The telecoupling concept is one such approach: it explores socioeconomic and environmental interactions among coupled human-natural systems over distances. The telecoupling framework is therefore well-positioned to provide new insights to persistent global sustainability challenges. To operationalize the framework, we have developed the Telecoupling GeoApp, a new web-based component of the Telecoupling Toolbox that provides researchers and practitioners with a useful platform to address globally important issues such as international trade, species invasion, biodiversity conservation, and land-use change. The *GeoApp* features mapping and geospatial analysis tools to visualize and quantify the five major interrelated components of the telecoupling framework (systems, flows, agents, causes, and effects). In this paper, we demonstrate the GeoApp's functionality by applying it to a case study in which distant systems interact across space and time: the Brazil-China soybean telecoupling. We conclude by highlighting the advantages of the Telecoupling GeoApp in addressing global sustainability challenges. It is our hope that this web application will be valuable to a range of users exploring telecouplings and outcomes across distant coupled human-natural systems for achieving sustainable development goals.

1. Introduction

The world is increasingly connected through flows of materials and information across vast distances, the emergence of new networks linking actors, and the presence of spatial externalities joining localized processes to global systems (Foley et al., 2005; Liu et al., 2015a; Peters et al., 2008). These interconnections can be beneficial: sustainable globalized food systems can improve food security (Godfray et al., 2010), cell phone proliferation and short message services offer remote rural farmers valuable climatic and planting information (Car, Christen, Hornbuckle, & Moore, 2012; Singels & Smith, 2006), and tourism and trade potentially allow ecosystem services to be provided to areas where the supply of such services fails to meet demand (Liu, Yang, & Li, 2016; Zeppel, 2008). Yet increased connectivity may also result in greater damage to global systems from human activities due both to anthropogenic manipulation of geophysical processes, e.g., climate change, and the accumulation of environmental damage at multiple discrete sites, e.g., biodiversity loss and land use change (Stern, 2008; Vitousek, 1992; Vörösmarty et al., 2010). These processes of global environmental change - and the human dimensions of such change - have been well-documented (e.g., Adger, Barnett, Brown, Marshall, & O'Brien, 2013; DeFries, Rudel, Uriarte, & Hansen, 2010; Geist & Lambin, 2002; Kramer et al., 2017; Lambin & Meyfroidt, 2011; Turner et al., 1990; Turner, Lambin, & Reenberg, 2007).

Concern about the effects and implications of global environmental change as well as efforts to better understand how to meet humanity's needs while maintaining the integrity of environmental systems led to the field of sustainability science (Kates et al., 2001). Fundamentally, global sustainability (and the obstacles posed to it) is shaped by complex and multi-scale human-environment interactions (Komiyama & Takeuchi, 2006; Liu et al., 2015a; Turner et al., 2003). Many efforts have emerged to understand these interactions and to assess progress toward global sustainability. For instance, the Sustainable Development Goals, adopted by the United Nations (UN) General Assembly in 2015, provide a set of seventeen global goals and targets for all countries, including goals related to addressing climate change and sustainably using terrestrial and aquatic resources (Sachs, 2012; United Nations, 2016). Other efforts to confront global sustainability challenges have

* Corresponding author.
E-mail addresses: mccordpa@msu.edu (P. McCord), ftonini@anr.msu.edu (F. Tonini), liuji@msu.edu (J. Liu).

https://doi.org/10.1016/j.apgeog.2018.05.001
Received 21 December 2017; Received in revised form 27 March 2018; Accepted 5 May 2018

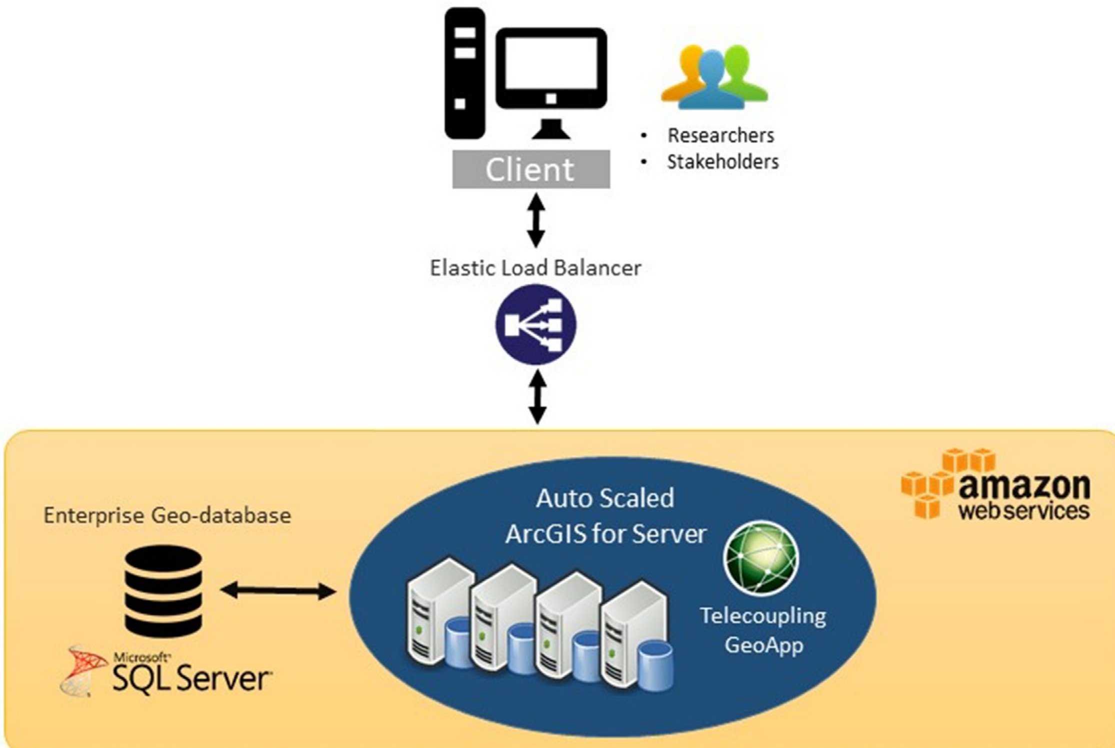

Fig. 1. Architecture of the Telecoupling GeoApp deployment with ArcGIS Server on Amazon Web Services (AWS). Users (researchers, stakeholders) interact with the GeoApp via a computer and a modern browser. Behind the scenes, the Amazon Elastic Load Balancer (ELB) directs incoming and outgoing traffic between the client and the Amazon cloud servers. Both the web server hosting the GeoApp and the ArcGIS Server site are hosted on the same virtual server. The ArcGIS Server site is load-balanced with auto scaling to automatically route incoming web traffic across a changing number of Elastic Compute Cloud (EC2) instances that increase or decrease based on user demand. Data behind the GeoApp are pulled from an enterprise geo-database in Microsoft SQL Server.

included crafting frameworks to investigate the components, processes, and multi-scalar dimensions of sustainability topics (e.g., Millennium Ecosystem Assessment, 2005; Ostrom, 2009), frameworks to interrogate the vulnerability of coupled human-natural systems (e.g., Polsky, Neff, & Yarnal, 2007; Turner et al., 2003), and frameworks particularly oriented toward understanding system interactions across space (Liu, 2017; Liu et al., 2013, 2015b).

The telecoupling framework, which we focus on in this paper, was developed to provide an integrated understanding of socioeconomic and environmental interactions between coupled human and natural systems over distances (Liu et al., 2013). The framework consists of five interrelated components: coupled human and natural systems; flows between systems, which can include flows of materials, energy, and information, among others; agents enabling flows; causes behind the flows; and the effects of interactions. Systems are classified as either a sending system (e.g., resource exporter), a receiving system (e.g., resource importer), or a spillover system (e.g., a country that is affected by trade between the sending and receiving systems).

Multiple studies have employed the telecoupling framework to analyze various components of distant socioeconomic and environmental interactions (e.g., Carter et al., 2014; Deines, Liu, & Liu, 2016; Gasparri, Kuemmerle, Meyfroidt, de Waroux, & Kreft, 2016; Liu, 2014; Liu et al., 2015b; Silva et al., 2017; Sun, Yu-xin, & Liu, 2017). To support this research, a suite of desktop-based software tools have been developed to allow researchers to operationalize the framework and systematically explore complex interactions (Tonini & Liu, 2017). Following the deployment of these desktop-based tools, the next step has been to develop a web-based application to provide greater flexibility in visualizing and quantifying telecoupling components and their outcomes.

This paper introduces the Telecoupling GeoApp (hereinafter, the GeoApp), a web-based application that operationalizes the telecoupling framework through a suite of spatially explicit geoprocessing tools while avoiding desktop-based software installation procedures and licenses. In this way, the GeoApp is an example of a web GIS application where a range of simple-to-complex mapping and geospatial analysis operations can be completed with the primary preconditions being an internet connection and a modern browser (Fu & Sun, 2010). It offers a fully interactive platform to explore the systems, flows, agents, causes, and effects of a telecoupling. To demonstrate its functionality, we apply the GeoApp to a case study with global sustainability implications: the Brazil-China soybean telecoupling wherein Brazil exports millions of tons of soybeans to China every year (more than 30 million metric tons were exported in 2014; see Silva et al. (2017)). It is our hope that this web application will be valuable to a range of users exploring various telecouplings and outcomes between distant systems.

2. The Telecoupling GeoApp

2.1. The Telecoupling Toolbox

The GeoApp is part of a larger collection of software tools and applications called the Telecoupling Toolbox (Tonini & Liu, 2017). At present, the Telecoupling Toolbox consists of two main products: the ArcGIS Toolbox and the GeoApp. The ArcGIS Toolbox features a collection of custom geoprocessing tools to be used with ESRI's ArcGIS Desktop, while the GeoApp offers a dynamic, interactive web GIS platform along with a large collection of mapping and analysis tools to systematically study telecoupling.

Both the GeoApp and the ArcGIS Toolbox have been developed in a modular fashion to facilitate the integration with existing third-party tools, e.g. InVEST (Kareiva, Tallis, Ricketts, Daily, & Polasky, 2011; Sharp et al., 2017), and to accommodate the development of custom tools and models as the demand for additional telecoupling applications