Computers, Environment and Urban Systems 65 (2017) 79–92

Contents lists available at ScienceDirect

Computers, Environment and Urban Systems

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

Review

A review of the emergent ecosystem of collaborative geospatial tools for addressing environmental challenges

Jenny Palomino [a,b], Oliver C. Muellerklein [a], Maggi Kelly [a,b,c,*]

[a] Department of Environmental Sciences, Policy and Management, University of California, Berkeley, Berkeley, CA 94720-3114, United States
[b] Geospatial Innovation Facility, University of California, Berkeley, United States
[c] University of California, Division of Agriculture and Natural Resources, United States

ARTICLE INFO

Article history:
Received 30 December 2016
Received in revised form 17 April 2017
Accepted 17 May 2017
Available online xxxx

Keywords:
Spatial Data Science
Collaboration
Tools
Multi-user
Workflows

ABSTRACT

To solve current environmental challenges such as biodiversity loss, climate change, and rapid conversion of natural areas due to urbanization and agricultural expansion, researchers are increasingly leveraging large, multi-scale, multi-temporal, and multi-dimensional geospatial data. In response, a rapidly expanding array of collaborative geospatial tools is being developed to help collaborators share data, code, and results. Successful navigation of these tools requires users to understand their strengths, synergies, and weaknesses. In this paper, we identify the key components of a collaborative Spatial Data Science workflow to develop a framework for evaluating the various functional aspects of collaborative geospatial tools. Using this framework, we then score thirty-one existing collaborative geospatial tools and apply a cluster analysis to create a typology of these tools. We present this typology as a map of the emergent ecosystem and functional niches of collaborative geospatial tools. We identify three primary clusters of tools composed of eight secondary clusters across which divergence is driven by required infrastructure and user involvement. Overall, our results highlight how environmental collaborations have benefitted from the use of these tools and propose key areas of future tool development for continued support of collaborative geospatial efforts.

Contents

* Corresponding author at: Department of Environmental Sciences, Policy and Management, University of California, Berkeley, Berkeley, CA 94720-3114, United States.
E-mail address: maggi@berkeley.edu (M. Kelly).

http://dx.doi.org/10.1016/j.compenvurbsys.2017.05.003
0198-9715/

1. Introduction

Environmental challenges such as biodiversity loss, wildfire management, climate change, and rapid conversion of natural areas due to urbanization and agricultural expansion are recognized as "wicked problems" (Allen & Gould, 1986; Balint, Stewart, & Desai, 2011; Carroll, Blatner, Cohn, & Morgan, 2007; Temby, Sandall, Cooksey, & Hickey, 2016), or "complex social-ecological systems" (Akamani, Holzmueller, & Groninger, 2016). Many of these challenges can be described as global in scale, at the nexus of interdisciplinary approaches, and/or part of coupled processes. Research teams have also become larger, more distributed, and multi-disciplinary (Elwood, Goodchild, & Sui, 2012; MacEachren & Brewer, 2004). To address these challenges, researchers have called for collaboration not only in the environmental management and decision-making processes (Daniels & Walker, 2001; Frame, Gunton, & Day, 2004; Selin & Chevez, 1995), but also in the knowledge production process, including the sharing of data, methods and tools (Cravens, 2014; Head & Alford, 2015; Temby et al., 2016). Consequently, understanding how various technologies, including geospatial tools, can support collaborative efforts for environmental problem-solving is a critical area of ongoing research (Cravens, 2014; Cravens, 2016; MacEachren & Brewer, 2004; Wright, Duncan, & Lach, 2009).

Contemporaneous to the emergence of these complex and large-scale research challenges has been a rapid expansion in the sources of geospatial data from mobile devices, environmental sensors, and Unmanned Aerial Vehicles (Miller & Goodchild, 2015) as well as from increased public access to administrative data through cloud/web-based Application Programming Interfaces (APIs; Anselin, 2015). In addition, Volunteered Geographic Information (VGI; Goodchild, 2007) as well as data captured by citizen scientists continue to increase in volume (Dickinson, Zuckerberg, & Bonter, 2010; Dickinson et al., 2012), both complementing and challenging the anonymity and centralized nature of traditional geospatial data produced by large organizations (i.e. governments and proprietary companies). Available data are now more detailed, with changes in scale from local to global extents, from coarse spatial resolutions in 2D planimetric to fine grain sizes with 3D and 4D options, and from seasonal/monthly temporal scales to daily or real-time capture. As such, researchers working on environmental challenges are increasingly leveraging large, multi-scale, multi-temporal, and multi-dimensional geospatial data in search of solutions (Goodman, Parker, Edmonds, & Zeglin, 2014; Miller & Goodchild, 2015).

Complementing this explosion in data has been the development of diverse array of geospatial analytical tools (i.e., scripting libraries, open source and cloud/web-based mapping options) and increased functionality to support multi-user workflows (i.e. standardized working environments, code-sharing, data exchange, status updates). Through advances in Web 2.0 technologies (Haklay, Singleton, & Parker, 2008) and Free and Open Source Software for Geospatial (FOSS4G; Steiniger & Hunter, 2013), the primary use of geospatial data is evolving from proprietary desktop software and data formats used to create static cartographic products toward the leveraging of open source and cloud/web-based tools, open data format and standards, and APIs to create dynamic web visualizations shared by collaborative teams across technology, science, and the public.

These intertwined evolutions in available geospatial data and tools also highlight the ongoing discussion regarding the role of technology within collaborative projects and how to best leverage technology to support collaborative tasks. Successful collaboration is dependent on many things including dynamics of negotiation, equity in knowledge and power, inclusion and access, and trust, which have been explored by various researchers (Elwood, 2006; Sieber, 2000; Wright et al., 2009). In addition to these social dimensions, collaboration is also dependent on the technology used to complete and achieve the desired tasks and outcomes (Cravens, 2014; Cravens, 2016). In their seminal work on "geocollaboration", MacEachren and Brewer (2004) identify four "stages of group work" as "explore, analyze, synthesize, present" (pg. 7) and explain that these stages represent "collaborative tasks for knowledge construction" (pg. 19) that can be accomplished using technology, especially those for geovisualization.

MacEachren and Brewer (2004) also offer a definition of collaboration that applies well to the context of leveraging geospatial data and technology for environmental problem-solving: "a committed effort … of two or more people to use geospatial information technologies to collectively frame and address a task involving geospatial information" (pg. 2). MacEachren and Brewer (2004) categorize these multi-user collaborations into four types: same place-same time, same place-different time, different place-same time, and different place-different time, stating that these last two (different place) were still primarily in the prototype phase at the time of their publication and were being driven by advances in database and web technology.

Since then, as these technological advances have progressed further, there has been a rise in technologies that support all of these collaborations, most notably for different place-different time collaborations. In particular, the logistics and mechanisms provided for collective work by technology in general, and geospatial ones in particular, have been identified by other researchers in varying descriptions of collaborations between scientists, non-scientists, and the general public: "collaboratories" (or collaboration laboratories; Pedersen, Kearns, & Kelly, 2007; Wulf, 1993) and "geocollaboratories" (specifically "work by geographically distributed scientists about geographic problems" MacEachren et al., 2006, pg. 201), participatory planning and management (Jankowski, 2009; Kelly, Ferranto, Lei, Ueda, & Huntsinger, 2012; Voss et al., 2004; Wright et al., 2009), citizen science efforts (Connors, Lei, & Kelly, 2012; Dickinson et al., 2010; Dickinson et al., 2012), observatory networks such as National Ecological Observatory Network (NEON; Goodman et al., 2014), virtual networks for collaboration such as Geosciences Network (GEON; Gahegan, Luo, Weaver, Pike, & Banchuen, 2009) and Human-Environment Regional Observatory (HERO; MacEachren et al., 2006) and "action ecology" (White et al., 2015). Through these collaborative efforts, researchers highlight how advances in geospatial data and tools provide technical support for collaborations through facilitation of: (i) group use and development of technology (i.e. field data collection at broad and long scales; dispersed responsibility of tasks); (ii) sharing and peer reviewing of data and results (i.e. crowdsourcing of data validation; data editing by multiple users); (iii) communication between stakeholders (i.e. ability for stakeholders to share their different representations of space and project outcomes); and (iv) integration of complementary tools (i.e. combining geospatial and communication-oriented tools; integration of big data tools and open data formats). Hence, the technical capabilities of geospatial tools can provide the practical mechanisms and infrastructure that allow people to successfully work together on tasks and goals, despite their distributions across time and space.

While it is evident that geospatial tools can support collaboration through providing the technological infrastructure needed for collaborative tasks, existing literature does not yet provide a clear framework for evaluating geospatial tools based on how well they support completion of these collaborative tasks. Furthermore, as projects can differ greatly in their requirements, there is no single tool that fulfills all needs and often, multiple tools must be integrated into workflows. As such, in addition to features that support workflows across multiple users, geospatial tools also need to support interoperability between tools (i.e. transfer of data, methods and results between tools). Consequently, successful navigation of the ever-expanding list of collaborative (i.e. multi-user) geospatial tools requires an understanding of their strengths, synergies, and weaknesses, specifically regarding functionality for collaborative tasks and capabilities for tool interoperability.

A typology of geospatial tools can provide a roadmap for these explorations by focusing on technical infrastructure for collaborative tasks such as setting up common working environments and shared data exploration, analysis, and visualization. This typology would also