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A visualization and data-sharing tool for ecosystem service maps: Lessons learnt, challenges and the way forward

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ABSTRACT

A plurality in methods, models, terminologies is used to assess, quantify, map and communicate ecosystem services (ES). The Thematic Working Groups on Mapping (TWG4) and Modeling ES (TWG5) of the Ecosystem Service Partnership (ESP), recent literature and expert workshops, have highlighted the need for developing a platform that systematically organizes, visualizes and shares ES maps and related information. This led to the development of the Ecosystem Services Partnership Visualization Tool (ESP-VT), an open-access interactive platform that hosts a catalogue of ES maps with information on indicators, models and used data. Users can upload or download ES maps and associated information. ESP-VT aims at increasing transparency in ES mapping approaches to facilitate the flow of information within the ES community from academics to policy-makers and practitioners. Populating the ESP-VT with ES maps from different geographic locations, across different spatial scales, using different models and with various purposes, leads to a diverse and heterogeneous ES map library. The scientific community has not yet agreed on standards for ES terminology, methodologies and maps. However we do believe that populating and using the ESP-VT can set a basis for developing such standards and serve towards achieving interoperability among the varying ES related tools.

1. Introduction

Maps are powerful means to visualize spatial information and communicate complex phenomena (McInerny et al., 2014). Maps can be used to support decision-making in policy, spatial planning and management and they facilitate dialogue among science, policy and practice. Hence, a wide variety of spatial information and map sharing systems on land and natural resources have been developed (Bagstad et al., 2013; Pagella and Sinclair, 2014). The data presented in maps are derived in many different ways, including traditional field survey methods, remote sensing data interpretation, modeling and interpolation, and online or participatory mapping (e.g. Toillier et al., 2011; Palomo et al., 2013), resulting in a broad range of map types with varying complexity used to address different user needs.

Ecosystem services (ES) have a strong geospatial component. A wealth of studies has quantified and mapped the supply and demand of different ES at different spatial and temporal scales (Naidoo et al., 2008; Chen et al., 2009; Deng et al., 2011; Burkhard et al., 2012; Schulp et al., 2014), resulting in a diverse array of ES maps. The growth in popularity of the ES approach has seen the emergence of a number of spatial tools addressing different target audiences' needs. All these tools have the common aim of supporting end users in the decision-making process. Such tools range from standalone mapping applications (e.g. Norman et al., 2010; Pert et al., 2013) to online tools or tools tightly coupled to GIS or other software types (Roberts et al., 2010). Yet the exponential increase of the number of these tools allows users to create maps "easily" with all the risks such an approach entails, like not considering errors or uncertainties, when using this information for decision making (Jacobs et al., 2014).

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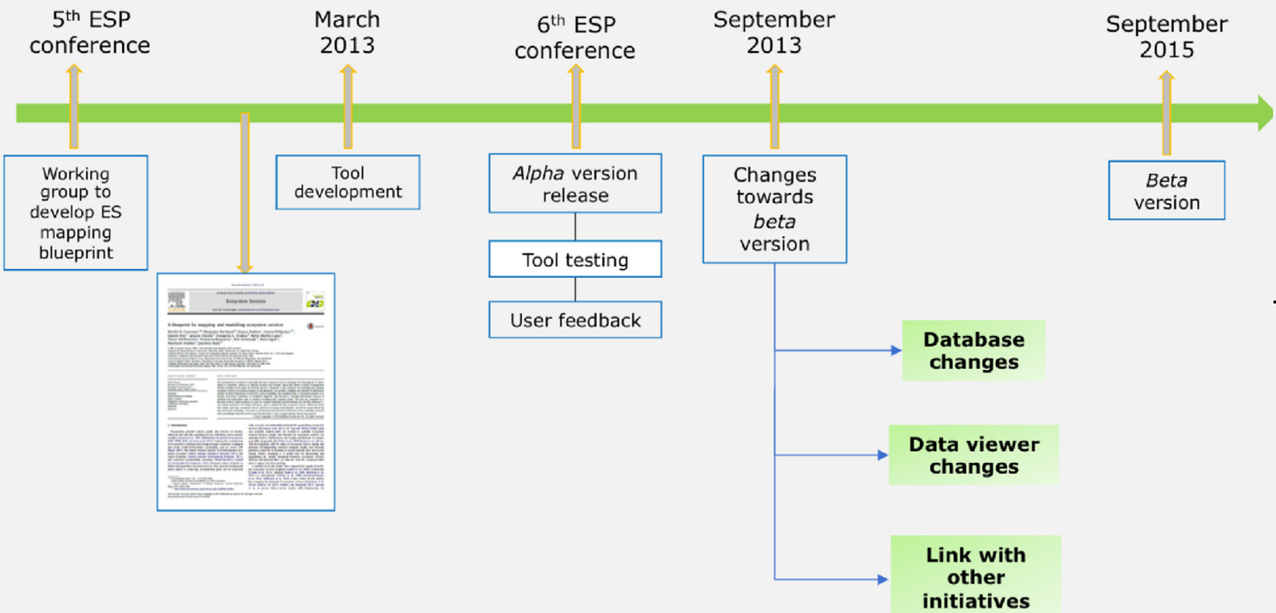
Box 1–Timeline of the ESP-VT development

The development of the '*blueprint for modeling and mapping ecosystem services*' (Crossman et al., 2013) during the 5th ESP Conference by the members of the Thematic Working Groups (TWG) on Mapping and Modelling ES (TWGs 4 and 5) of the Ecosystem Services Partnership (ESP) followed by its publication, initiated an effort to make ES maps and relevant information freely accessible to interested users. ESP Visualisation Tool (ESP-VT) was developed based on this effort. The Joint Research Centre of the European Commission (JRC-EC) led the technical development of the tool. The *alpha* version of the tool was published under the http://esp-mapping.net/Home/ web address and was released in August 2013 during the 6th ESP Conference, where it was tested by ES scientists and practitioners. The participants worked in six groups of four and tested the ESP-VT functions and gave feedback to the provided forms for each of the tool functionalities. The feedback received was then used to improve the functions and structure of the tool and will lead to its *beta* version (see Box Figure). The ESP-VT is a work in progress and in this development phase users can upload maps, consult example entries and send their feed-back through the webpage.



On the other hand when dealing with decision-making one should consider that not all types of ES information can be or need to be presented in the form of maps and this should be made explicit, especially if such tools are used by non-experts. A detailed review of ES quantification and valuation tools was conducted by Bagstad et al. (2013).

The growing popularity of ES within the scientific, policy and practitioner communities (Egoh et al., 2012) creates a demand for standard and consistent presentation of information to ensure common understanding and application within and across these communities (Boyd and Banzhaf, 2007; Seppelt et al., 2012). To this end the ES Mapping[1] and Modelling[2] Working Groups of the Ecosystem Service Partnership (ESP) developed a blueprint for mapping and modeling ES (Crossman et al., 2013), that proposes such a documentation scheme for ES maps. The aim of the blueprint is to serve as a basic framework to structure and share ES spatial information within the science-policy-practice community, as the ES concept becomes mainstream. Providing a method for documenting ES spatial data produced by the many existing online, standalone and GIS-coupled ES modeling tools can set a basis to facilitate the communication between ES "mappers" and "map users". This communication and sharing of ecosystem service maps has been acknowledged as a need for moving forward the field of ecosystem services (De Groot et al., 2010; Hauck et al., 2012; Maes et al., 2012).

In this paper we present the Ecosystem Services Partnership Visualization Tool (ESP-VT), an online platform to collect, publish and share ES maps. The tool is currently available as an *alpha* version (i.e. work in progress), meaning that the content is subject to modifications according to user requirements and suggestions that keep emerging through the ESP community and beyond.

In this paper we give a brief overview of the existing tools and databases for quantifying and mapping ES. We then present the basic structure and functions of the Ecosystem Services Partnership Visualization Tool (ESP-VT). Finally we discuss the challenges encountered in developing the ESP-VT and provide suggestions for a way forward in ES mapping and data sharing to facilitate the development of best mapping practices for ES.

2. Overview of ES tools

Building on Bagstad et al. (2013), we discuss ES related tools into three major categories: (i) those serving as data catalogues; (ii) those serving as toolkits, allowing the users to enter their own input data to map or model ES; and (iii) those combining both, but tailored to the needs of a specific region or a specific ES category. *Data catalogue tools* are mainly listings of available ES assessments (e.g. IPBES catalogue of assessments) or ES valuations (e.g. Marine Ecosystem Service Partnership-MESP database). Such tools serve as data repositories and are useful sources of information especially when dealing with large-scale assessments or gap analyses (e.g. at global, regional levels). Among the identified data catalogue tools, there is indeed no

[1] http://www.es-partnership.org/esp/79222/5/0/50.
[2] http://www.es-partnership.org/esp/79026/5/0/50.

Table 1
Examples of ecosystem service related tools.

Tool name	Tool type	Link	Access	Spatial scale
Digital Observatory for Protected Areas (DOPA)	Toolkit	dopa.jrc.ec.europa.eu/explorer	Open	Global
Ecosystem Service Valuation Toolkit	Toolkit	http://esvaluation.org/	Demo available	Global
InVEST (Integrated Valuation of Environmental Services and Tradeoffs)	Toolkit	http://www.naturalcapitalproject.org/InVEST.html	Open	Global
ARIES (Artificial Intelligence for Ecosystem Services)	Toolkit	http://ariesonline.org/	Open	Global
MIMES (Multi-scale Integrated Models of Ecosystem Services)	Toolkit	http://www.afordablefutures.com/services/mimes	Not available yet	Global
Catalogue of Assessments on Biodiversity and Ecosystem Services	Data catalogue	http://ipbes.unepwcmc-004.vm.brightbox.net/	Open	Global
Marine Ecosystem Service partnership database (MESP)	Data catalogue	http://www.marineecosystemservices.org/explore	Open	Global
BioCarbon Tracker	Combined	http://tracker.biocarbontracker.com/login/?next=/interface/	Open	Global
Capturing Coral Reef Ecosystem Services (CCRES)	Combined	http://www.worldbank.org/projects/P123933/capturing-coral-reef-ecosystem-services-ccres?lang=en	Open	Global
Ecosystem Services mapping gateway	Combined	http://www.nerc-bess.net/ne-ess/	Open	UK

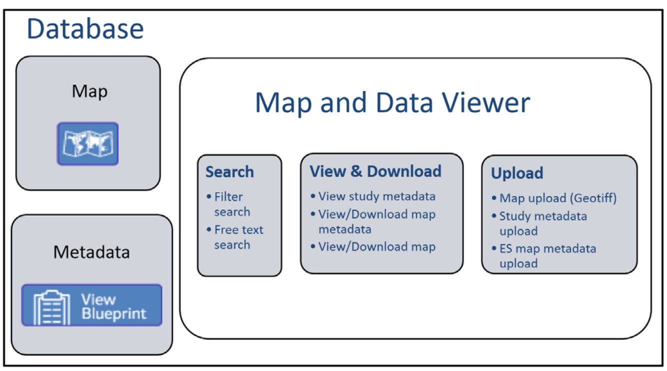


Fig. 1. Graphic representation of the basic tool structure and functions. The tool consists of the database and the map and data viewer. The database (outer rectangle) consists of two major components, the map and the relevant metadata, including study metadata. The Map and Data Viewer (inner rectangle) consist of three components: search, view and download and upload. The functionalities of each of these three components are listed within each rectangle.

data standard regarding ES in terms of terminology or classification systems followed. *Toolkits* allow users to use web services to query (e.g. DOPA) or generate new information in different formats, like maps or values (e.g. InVEST). They usually address different types of end-users, from researchers to policy makers. The ES Valuation Toolkit (Table 1) is an exemplary tool, as it provides an adapted interface according to the user type (e.g. researcher, policy maker). Lastly, the *tools combining both* functionalities are usually tailored to the needs of specific ecosystem types or specific regions like the CCRES for coral reef ecosystems or the BESS gateway for the UK. Table 1 gives an overview of some of these tools. Most of them are open access and users are able to download most or all, available data.

3. The Ecosystem Services Partnership Visualization Tool (ESP-VT)

ESP-VT is an online tool that stores, organizes, visualizes and shares ES maps and associated documentation and metadata. In a broader sense the ESP-VT also supports communication within and beyond the community of ES mappers by providing a common framework that could be used to set standards for cataloguing and displaying ES spatial data. The ESP-VT is unique among the current ES-related tools because it visualizes, compares and makes ES maps available for sharing within the ES community. The *alpha* version of the ESP-VT is available through the http://esp-mapping.net/Home/ web address. The original concept for establishing this tool was inspired by the collaborative research work of the members of the ESP TWGs on Mapping and Modelling ES. The technical development is coordinated and hosted by the Joint Research Centre of the European Commission (JRC-EC). For a detailed timeline of the tool development please see Box 1.

Below we describe the basic structure and functions of the ESP-VT (see Fig. 1 for a graphical abstract).

3.1. ESP-VT structure

The ESP-VT consists of: (i) a *database* in which maps and associated metadata are stored, and; (ii) the *map and data viewer*, comprising a database search engine, a map and metadata viewer and a map upload section. The database structure as already mentioned is based on the ES blueprint (Crossman et al., 2013) with slight adjustments and modifications to improve ESP-VT functionality (see Table 2). Certainly this is not a standard for structuring ES map databases, but it could serve as a basis to develop standards whose applicability could then be tested to the rest of the ES databases.

We used PostgreSQL9 (Obe and Hsu, 2012) for the database setup while all maps are stored in the GeoServer (Deoliveira, 2008). The database has two basic entities: (1) background information about the mapping study and (2) the ES maps with specifications about the mapping methodology, objective and data sources. In Fig. 2 we give a brief overview of the database structure. There is virtually no limit to the number of spatial datasets, nor are there any constraints on spatial and temporal scales of data, that ESP-VT users can upload.

The map and data viewer is a user interface which has been developed using the *JavaScript* language (Flanagan, 2002). The data viewer, under the *Data* page, contains a search engine to search the database. The map viewer, under the *Map* page, contains a basic view window for visualizing the data (Fig. 3).

The *map viewer* projects the ES maps on a global map. The user can change the background layers (satellite, terrain and land cover) and/or overlay the ES maps with layers giving relevant information. The ESP-VT currently allows users to overlay ES maps with layers of: protected areas (UNEP-WCMC. Cambridge U, 2014), terrestrial ecoregions (Olson et al., 2001), marine ecoregions (Spalding et al., 2007) and exclusive economic zones (EEZs) (version 8, 2014). The *data viewer* allows the user to view a list of database map entries and the relevant metadata following the blueprint structure.

Table 2
Ecosystem Service blueprint fields and definitions as currently used for the ESP-VT (adapted from Crossman et al. (2013)).

Blueprint field(as it appears on the ESP-VT)	Definition
Mapped ecosystem service	The type of ecosystem service for which the map is provided, according to the CICES classification system (Haines-young and Potschin, 2013).
Ecosystem service indicator	The indicator used to map the ecosystem service. It could be more than one per ES.
Accounting definitions	The type of ecosystem services according to: ● ***Accounting type***. The maps are characterized on whether they represent ES Stock, ES Flow or a Process/Function underpinning ES supply ● ***Beneficiary***. The maps are characterized on whether they represent ES supply, Demand or an ES providing or benefitting area.
Quantification unit	The units of the ES indicator map. They are presented as composites of: ● Quantity (e.g. monetary, density, counts) ● Quality (e.g. score, ranking) ● Area (e.g. ha, m) ● Time (e.g. 1/yr).
Input data source and reference	The type of input data to quantify the indicator is mentioned with the associated reference, when available.
Quantification method	The method used to quantify the ES indicator is referred as: ● Collection of primary data (e.g. tourist counts, species observations) ● Proxy method (e.g. land cover lookup table) ● Empirical model (e.g. regression models, MaxEnt) ● Process model (e.g. biophysical models) ● Participatory method (e.g. community mapping).
Spatial details	The basic spatial information of the ES maps are referenced here: ● ***Scale***. Classified as local, sub-national, national, supra-national, continental or global ● ***Extent***. The extent of the ES map ● ***Resolution***. The map resolution.
Mapped year or period	The temporal scale of the map.
Study objective met	A 1 to 5 evaluation of whether the map has achieved its objective, as provided by the user who uploaded the map.
Comments	Additional comments to the ES maps that users referring to it must know.

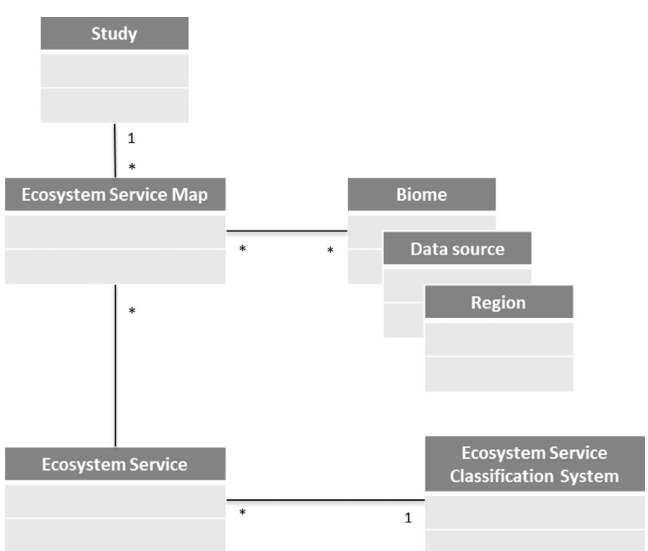


Fig. 2. Graphic representation of the database structure. Asterisk (*) represents multiplicity. Two asterisks in a line represent a "many-to-many" relationships, while an asterisk and a 1, represent a "one-to-many" relationship. Each box is an abstract representation of a database table with all fields removed for brevity.

Under the *upload* page of the map viewer the users can upload the maps and relevant information. This part is structured by the map upload, map metadata upload and study metadata upload component.

Two additional pages are *About* and *Help*. The former provides background information on the ESP-VT, and the latter provides access to a quick user guide, a glossary of the basic terms, relevant publications, the technical guide of the tool and a FAQ section.

3.2. Tool functions

The tool has three major functions: (i) map and data upload; (ii) map and data search; (iii) map and data view and download.

The *map and data upload* allows registered users to upload ES maps with relevant metadata to the database. Currently, users can login using their personal Google, Yahoo, myOpenID or Stack Exchange account, which is approved for membership by the system administrator (at the JRC-EC). Then, through a stepwise procedure, the users can create or modify a new workspace (study) to upload ES maps and all the relevant information to the blueprint components (Table 2). The ESP-VT allows users to customize the way their maps are visualized in the viewer. The fields the users complete during the data upload are predefined (where possible) to allow for consistency and standardization within the database. All uploaded data are protected under the European Commission's licensing agreement on the reuse of EC's documents following open access data sharing (Commission Decision, 2011/833/EU).

The *map and data search* engine uses four different filter criteria to search the database and a free text search function. The search criteria are the *ecosystem service*, the *biome* for which the ES has been mapped, the *spatial scale* of the ES map and the *purpose of the study*.

A number of different ES classification systems are followed when quantifying ES, from more general (e.g. TEEB, 2010; Haines-young and Potschin, 2013; Landers and Nahlik, 2013) to ecosystem or region specific systems (Hicks, 2011; Gómez-Baggethun and Barton, 2013; Liquete et al., 2013). The ESP-VT uses the Common International Classification of Ecosystem Services (CICES[3]) (Haines-Young and Potschin, 2013) to label ES in the database. CICES is used because it is the most recent, updated and comprehensive

[3] http://cices.eu/.

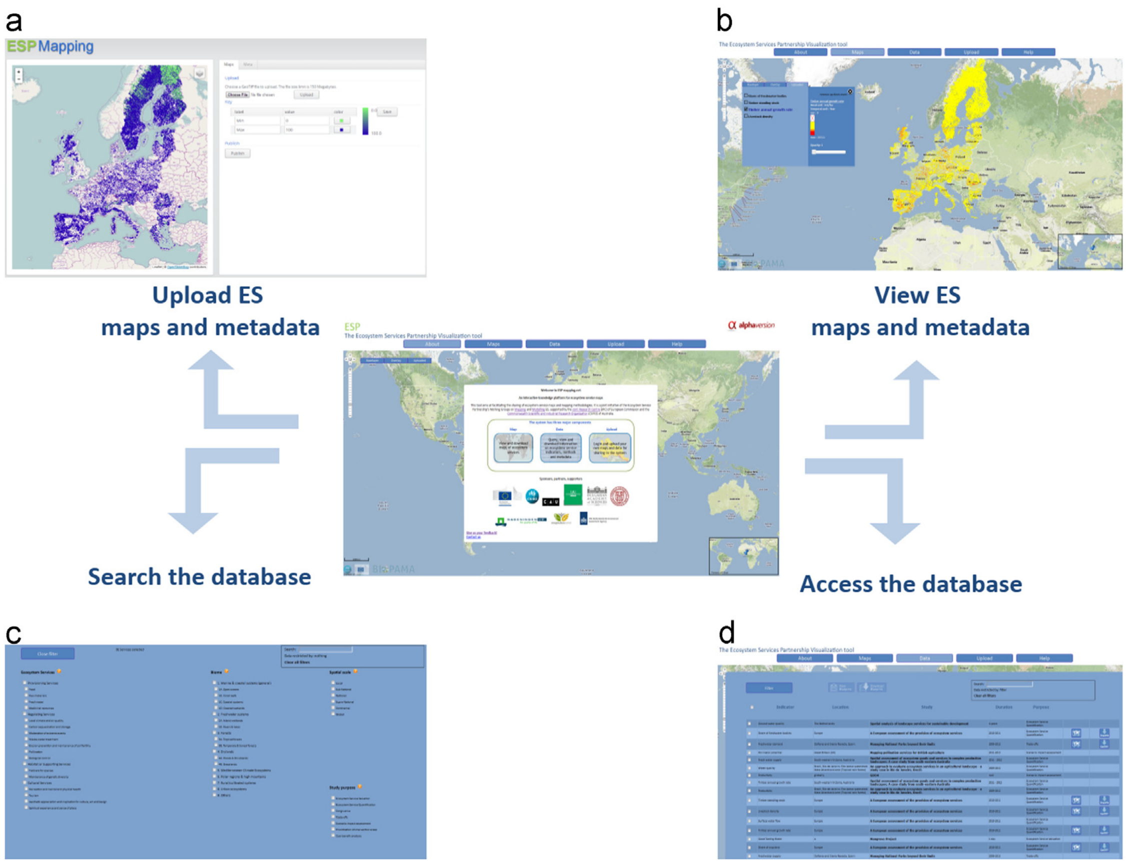


Fig. 3. Web interface of the major tool components. The central figure is the ESP-VT starting page. On the four corners the captions of the different interfaces appear: (a) Upload ES maps and metadata, (b) View ES maps and metadata, (c) Search the database and (d) Access the database.

classification system. Certainly it is not possible to identify one ES classification system that will be used to capture all ES at all spatial and temporal scales (Costanza, 2007) and that would make sense for all types of end users. When carrying out an ES assessment and producing ES maps, everything is scale-dependent and end-users of the generated information need to be considered, while the regional specificities should definitely be acknowledged. However given the necessity to keep the ESP-VT as simple as possible, we need to stick to one system that can be used and understood within the ES community. CICES is easy to use also because other common ES classification systems can be translated to it through a Bayesian Belief Network provided to the users via the OpenNESS project[4].

To label the ES data according to the biome types, we use the biome classes suggested by the TEEB (TEEB, 2010), since this classification was tailored to ES studies. We use a 6-level classification of spatial scales, from local to sub-national, national, supra-national, continental and global. The ES maps are also labeled according to the *ES study purpose*. The different types of purposes are those identified by Egoh et al. (2012) as: (i) ES valuation, (ii) ES quantification, (iii) congruence, (iv) trade-offs, (v) scenario impact assessment, (vi) prioritization of intervention areas and (vii) cost–benefit analysis. Maps are made to serve different purposes; users can search maps per study objective to learn more about used approaches and mapped outcomes. For a detailed documentation of the ESP-VT data standards, please refer to the tool Technical Guide (Drakou et al., 2012, *draft V.1*).

All user queries return database records as a list in the *map viewer*, describing the basic characteristics of the ES maps. The user can view or download the map and associated metadata for one or more of the records fulfilling the search criteria. Most importantly the user can view and overlay different maps that are available for the region of interest.

4. Lessons learnt and future prospects

The need for open access data sharing is evident in all types of information systems, as it facilitates the scientific process itself as well as the usability of information for different needs (Schofield et al., 2009; Tenopir et al., 2011). Also, the need for a tool that allows ES practitioners to share ES information and the variety of tools available (see also Section 2; Table 1) giving ES practitioners access either to large ES databases or allowing them to use models and toolkits to quantify or map the ES of interest keeps growing. The ESP-VT comes to complement this “tool landscape”, by providing a database that systematically organizes ES maps. ES maps, due to their visual nature, facilitate the science-policy dialogue and allow scientists and other ES practitioners to present complex data in a simple form (e.g. Burkhard et al., 2013; Crossman et al., 2013; McInerny et al., 2014). This visual information once combined with non-spatial ES data can increase efficiency in communication and incorporation of ES information into decision-making processes and raise awareness within the ES community and beyond.

Developing ESP-VT is an ongoing dynamic process. The tool is still on its *alpha* phase where it has been tested by a limited group of users, either via online forms or during workshops. The major challenge faced so far in the tool development process is compiling spatial ES data and systematically organizing it in a database. However, we foresee several advantages for data sharing, among which the

[4] http://openness.hugin.com/example/cices.

possibility of data-verification, as well as a higher impact of ecosystem service maps being exposed to larger audiences. Since ecosystem service maps usually have a predefined end user, the ESP-VT could also serve as a transitional node between researchers and practitioners. The plurality of methodologies, tools, approaches used and the different spatial scales assessed created a highly heterogeneous landscape of ES maps. Organizing this information in one database requires a standardized system to host this and continuous observation that keeps coming up through the submitted feedback forms.

In this process we faced the following paradox; one the one hand there is a clear lack of a standardized nomenclature within the ES community (Nahlik et al., 2012; Herrando-Perez et al., 2014), while there is a common understanding within the same community that a plurality of typologies is needed to address different user needs (Costanza, 2007). Even if ES assessments vary significantly among practitioners, a standardized ES nomenclature could serve as a basis to formulate data standards for ES maps and relevant information. The advantage of data standards is that by using them we can "*avoid repetition in scientific research and expand our domains of knowledge*" (Herrando-Perez et al., 2014, p. 311), while using them as a common language understood by both the scientific community and policy makers. Contrarily, developing commonly agreed data standards might be considered to over-simplify or generalize ES assessments, especially when this information is planned to be used for decision making. Using a plurality of ES classification systems, each of which is specifically designed for certain ecosystems or policy requirements, seems to be a more accurate approach tailored to the purpose it was developed for. This diversity may have limited transferability and created confusion among ES practitioners though. We argue that there is a strong need for both approaches to work in parallel and make sure that in all steps of the process, there is an "interpreter" allowing the ES practitioners to find their niche within the system. A good example of such a work is the one provided by the OpenNESS project using Bayesian belief networks to define the correspondence among major ES classification systems[4]. The generation of such a concept is urgent at an era in which the rate that new tools are released, increases exponentially.

The ESP-VT can serve as a platform to set the basis to develop standards for ES maps through its dynamic development process and its collection and sharing of ES spatial information. The process of achieving standards is not easy and is time consuming. Therefore, such vision needs a well-designed infrastructure and data design to support it. Yet the technological advances cannot be used, unless the basic concepts are agreed within the tool developing community. The molecular genetics community (MGC) example could be used as a source of inspiration for the ES practitioners and tool developers. The MGCin 1982 created the GenBank[5] "*in response to a critical scientific need for a timely, centralized, accessible repository for genetic sequences*" (Bilofsky and Burks, 1988, p. 1861). Since its inception, the Genbank has grown at an exponential rate, becoming "*the most important and most influential database for research in almost all biological fields, whose data are accessed and cited by millions of researchers around the world*". The process of collecting, collating, and making available through open-access such a huge amount of data, involved advances in many scientific fields, from genetics and shot-gun sequencing, to specialized powerful algorithms for searching DNA sequences or fine-tuned ontologies. Although the first steps towards this direction have started happening within the ES community (e.g. Villa et al., 2014), it is relatively early to envisage a similar situation. Still the platform of the ESP-VT can serve to open the dialogue among the ES community working with spatial data. The option of developing commonly agreed data standards within the ES community is the next step towards making the existing tools interoperable thus allowing users to navigate among them (i.e. by generating results in one tool and publishing them to another one in an automated way).

[5] https://www.ncbi.nlm.nih.gov/genbank/.

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