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User-centric SDI: Addressing Users Requirements in Third-Generation SDI. The Example of Nature-SDIplus

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Today, Spatial Data Infrastructures (SDIs) play a key role in spatial information sharing. Since their beginning, SDIs underwent tremendous changes. Product-based (first-generation) models evolved to process-based (second-generation) SDI models. Now we face shift to user-centric, third-generation SDI. Compared to former SDI concepts, the development of third-generation SDI is increasingly driven by users. It is argued that to unfold its full potential, a SDI needs to fulfill user requirements. Therefore, SDI core components (spatial data, metadata, services and geoportals) need to be designed focusing on users and their requirements. But, who are today's SDI users? Can we distinguish different types of users groups? What are user requirements in terms of spatial data handling? How can we address the user requirements? And ultimately, which approaches, procedures and methods can be applied to design a user-centric SDI? Within the framework of the EU project Nature-SDIplus, we proposed the application of the interdisciplinary and wide-ranging concept of usability relating to commonly known software development processes as solution to design a user-centric SDI. Based on the results of a Europe-wide user survey, the status quo on nature conservation's spatial data use was described, user requirements were specified, target user groups of a domain specific SDI were identified, and recommendations made to contribute to user-centric Nature-SDI.

1 Setting the scene and research questions

Spatial data has become omnipresent in our everyday lives (Puri 2006; Rajabifard et al. 2006). A wide range of human activities requires access to a multitude of reliable spatial datasets at different spatial and temporal resolution and thematic granularity. By using spatial data, activities and workflows performed within different areas such as resource management, spatial planning, nature conservation, environmental impact assessment, or disaster management, become more efficient and effective (Maguire & Longley 2005; Rajabifard 2008). Hence, a great variety of users from both private and public sectors increasingly demands for spatial data and adequate handling methods (McDougall 2010). To meet these requests, Spatial Data Infrastructures (SDIs) are considered crucial instruments nowadays. These initiatives support users in performing different tasks such as to acquire, to process, distribute, use, maintain and preserve spatial data. SDIs provide a consistent approach to share spatial data between and within organizations, across local, regional, national and international levels (FGDC 2003; Maguire & Longley 2005; Nedović-Budić, Pinto & Warnecke 2004; Rajabifard et al. 2006).

Since their beginning in the 1990s, SDI concepts have been constantly evolving in response to social changes and technological advancements. In the past, SDI initiatives concentrated mainly on technological issues such as data harmonization, standardized metadata models, standardized web services for data discovery, vizualization, download. Problems arising from users and their requirements were not seen very pressing (Delgado Fernández & Castellanos 2006). Nevertheless, it is the people who will make SDI efforts a success or failure (e.g. Rajabifard, Feeney & Williamson 2002). Maguire & Longely (2005) underline, that even though technology enables SDIs, a dominant technological focus hampers user acceptance and can sabotage SDI initiatives. De Man (2011) highlights, that SDIs are more than technological i.e. they embrace non-technological elements as well. Thus, the current SDI vision is to provide an environment where users can cooperate to handle spatial data in an efficient,

	1st SDI generation Product-based	2nd SDI generation Process-based	3rd SDI generation User-centric
Level/Focus	Explicitly national	National; including hierarchical context	Cross-scale
Driving forces	Integration of existing data, data management Gov.agencies	Establishing the linkage between people and data; Spatial data application	User-driven Private sector organizations & individuals
Expected results	Linkage into a seamless database	Knowledge infrastructures, interoperable data and resources	Platform for a spatially enabled society
Development participants	(Mainly) data producers	Cross-sectors: provider, integrators, users	Users: producers, consumers
Funding/ resources	Mainly no specific or separate budget	Mostly include in national mapping program, or having separate budget	Incorporating governmental, private initiatives, including crowd-sourcing
Involved actors	Mainly national mapping organizations	More independent organizational committees, partnership groups	Consortia, representing the target user groups
Number of SDI initiatives	low	increasing number	Numerous initiatives
User domain	government	Various stakeholders	everyone
tasks	Mainly administrative	Different applications	Different applications
GI Expertise	GI experts	GI experts	Every level, GI expert to laymen
Rel. between SDI initiatives	Low	Increased cooperation	Integrated SDIs
Measuring SDI value	Productivity, savings	Holistic socio-cultural value, expense of not having an NSDI	Usability criteria

Tab 1. Selected characteristics on the three SDI generations (based on Budhathoki, Bruce & Nedović-Budic 2008; McDougall 2010; Rajabifard et al. 2006; Sadeghi-Niaraki et al. 2010)

effective, and satisfactory way (Rajabifard, Feeney & Williamson 2002). Sadeghi-Niaraki et al. 2010 emphasize that only SDI approaches being centered on user requirements can unfold their full potential in supporting users in spatial data sharing. Within the outlined development framework, SDI concepts proceeded from first-generation to second-generation, i.e. from product-based to process-based, and currently towards user-centric, i.e. third-generation models (Craglia & Annoni 2006; Rajabifard & Williamson 2002). To highlight SDI evolvement selected characteristics on the three models are presented in Tab. 1.

Despite important progress and experience gained, current user-centric SDIs do not yet completely meet anticipated purposes and expectations (Nedović-Budić, Pinto & Budhathoki 2008). It is argued that these frameworks are still not fully centered on user preferences. To deal with this matter, user community, i.e. users in a domain for which a SDI is intended to operate for, needs to be well understood, and their needs deeply analyzed (Rajabifard, Feeney & Williamson 2002; Sadeghi-Niaraki et al. 2010). For turning the concept of a user-centric SDI into practice, user requirements must not only be specified, but also must find their way into SDI development. Therefore, the following open issues need to be addressed adequately: (1) what approaches, processes, and methods can be applied to support user-centric SDI development? (2) Who are today's SDI users? (3) Can we distinguish different types of users groups? (4) What are user requirement in terms of spatial data handling? (5) Which open recommendations can be made to foster user-centric SDI development?

In this paper, the above questions are discussed by the example of the EU-project Nature-SDIplus (URL1), EU eContentplus project, which aims at contributing to the strategic development and implementation of INSPIRE Directive in Europe. With its specific reference to a cluster of data themes on nature conservation, Nature-SDIplus considers four INSPIRE Annex themes: Protected Sites (Annex I/ 9), Biogeographical Regions, Habitats and Biotopes, and Species Distribution (Annex III/ 17, 18, 19). The project consists of 30 partner institutions from 18 EU-countries. These partners form together the Nature-SDIplus Best-Practice Network that aims to involve new stakeholders, to share data and best practices, to improve and stimulate exploitation and to enable re-use of information on nature conservation.

2 User-centric SDI concept and development approach

Sustainable SDI development requires a deep understanding of its underlying concepts and components (Rajabifard & Williamson 2002). Although actors from different disciplines conceptualize SDI differently (Rajabifard & Williamson 2002; Wytzisk & Sliwinski 2004), the majority of definitions agrees on a number of SDI core components such as spatial data, metadata, web services and geoportals, a formal framework on standards, policies, technological specifications, as well as people and their capabilities (e.g. Nedović-Budić & Budhathoki 2006; Portolés-Rodríguez et al. 2005, Rajabifard, Feeney & Williamson 2002; Rajabifard et al. 2006; URL 2).

To serve as guiding principles for SDI development and implementation, several models exist. These models arrange and describe the specified SDI core components as well as (dynamic) relationships, i.e. interdependencies and interactions, between them (Budhathoki, Bruce & Nedovic-Budic 2008; Rajabifard et al. 2003; Rajabifard et al. 2006). Based on the existing models, Fig. 1 presents a modified approach that particularly targets at user-centric SDI development. It emphasizes SDI core components being designed and organized above all user-centrally. The users and their needs are highlighted being placed at the center of each SDI initiative. Their requirements essentially determine the nature of the SDI and. its core components spatial data, metadata and data access tools (web services and geoportals). These components are embedded in the above mentioned formal framework (Hennig, Wallentin & Hörmanseder 2010). Thus, for implementing a user-centric SDI, both technological components and the formal framework need to be well-orchestrated and user-centered designed.

"Like any construct, (…)" SDI "(…) comes out of a development process" (De Man 2011: 262). Hence, like any software construct, any SDI development relies on software engineering concepts and methods. Accordingly, SDI creation generally follows well known software development processes consisting of several steps (Fig. 2): requirements analysis, application design, implementation, and validation (Balzert 2000; Sommerville 2008). Specified user requirements (requirements analysis) will guide the whole process of SDI development, and provide essential input to the other development steps. However, even though software

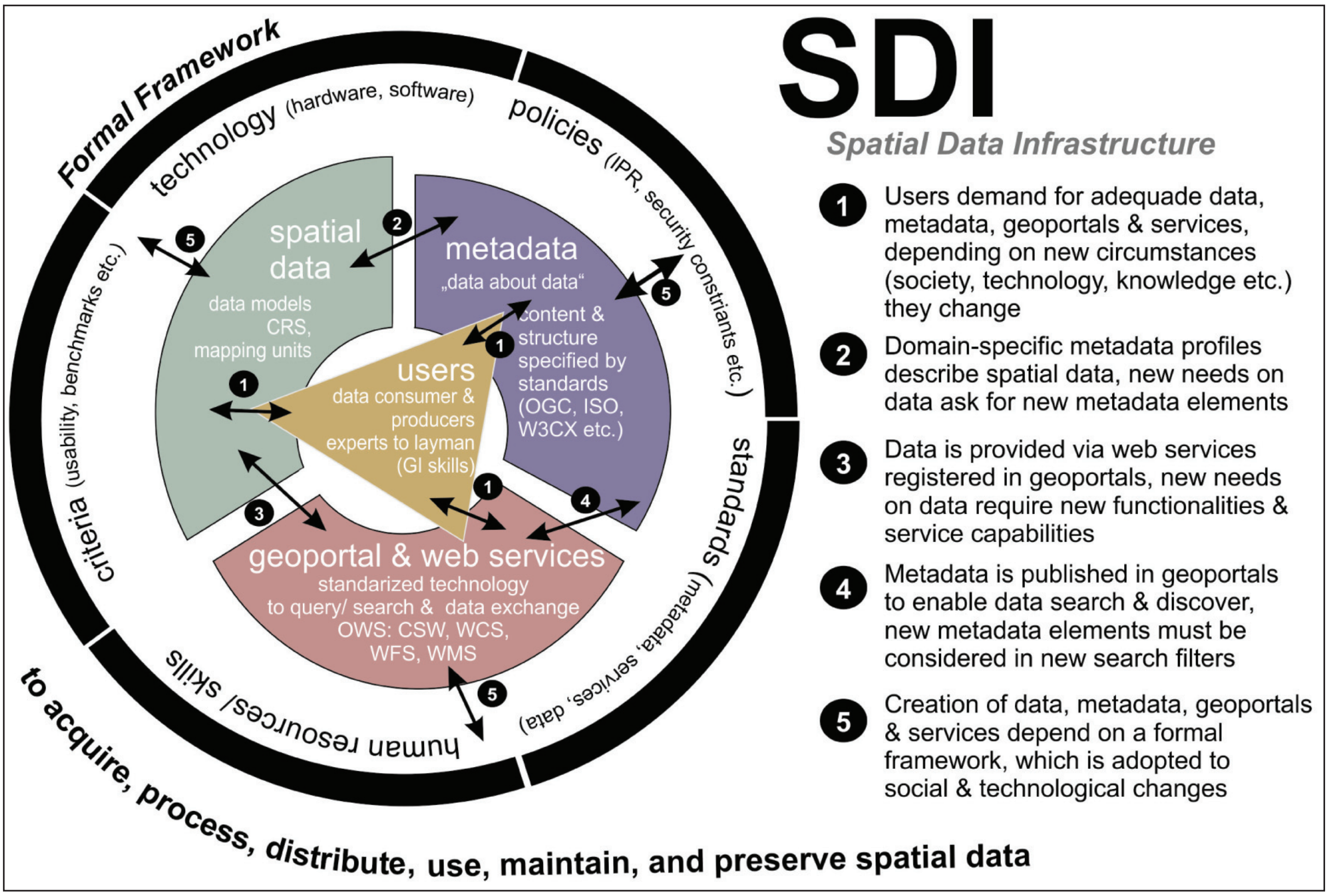

Fig. 1. User-centric SDI development model (adapted from Hennig, Wallentin & Hörmanseder2010).

development processes and methods provide valid tools for SDI creation, some of them must be adapted to a certain degree to the SDI context. Thus, SDI development process must focus on conceptualization, implementation, and validation of spatial data models, metadata profiles, web services and geoportals (Rajabifard & Williamson 2002) under the general regulations of the formal framework. The whole process is challenged by the necessity to include user requirements in each development phase and to apply identified requirements to each of the SDI components by paying attention to the relationships between the individual components. Normally, the development activities occur as continuous and concurrent, providing feedback loops, rather than being a step-by-step procedure (Coleman, McLaughlin & Nichols 1997).

Within software engineering the widely used concept of usability can be considered to be specifically suitable to facilitate the creation of a user-centric SDI. It provides a framework of methods, tools and criteria to systematically integrate and to adequately respond on user requirements (Richter & Flückinger 2007). The interdisciplinary concept of usability is extensively used in a wide spectrum of industries for different products (e.g. software application, website, book, tool, machine, process, or anything with which humans interact). It is understood to be the ease of use and learnability of a human-made object. In ISO 9241 usability is defined as the extent to which a product can be used by specified users to achieve intended goals with effectiveness (how well the users achieve their goals they set out by using the system), efficiency (the resources consumed in order to achieve their goals), and satisfaction (how the users are pleased by using the system) in a certain con-

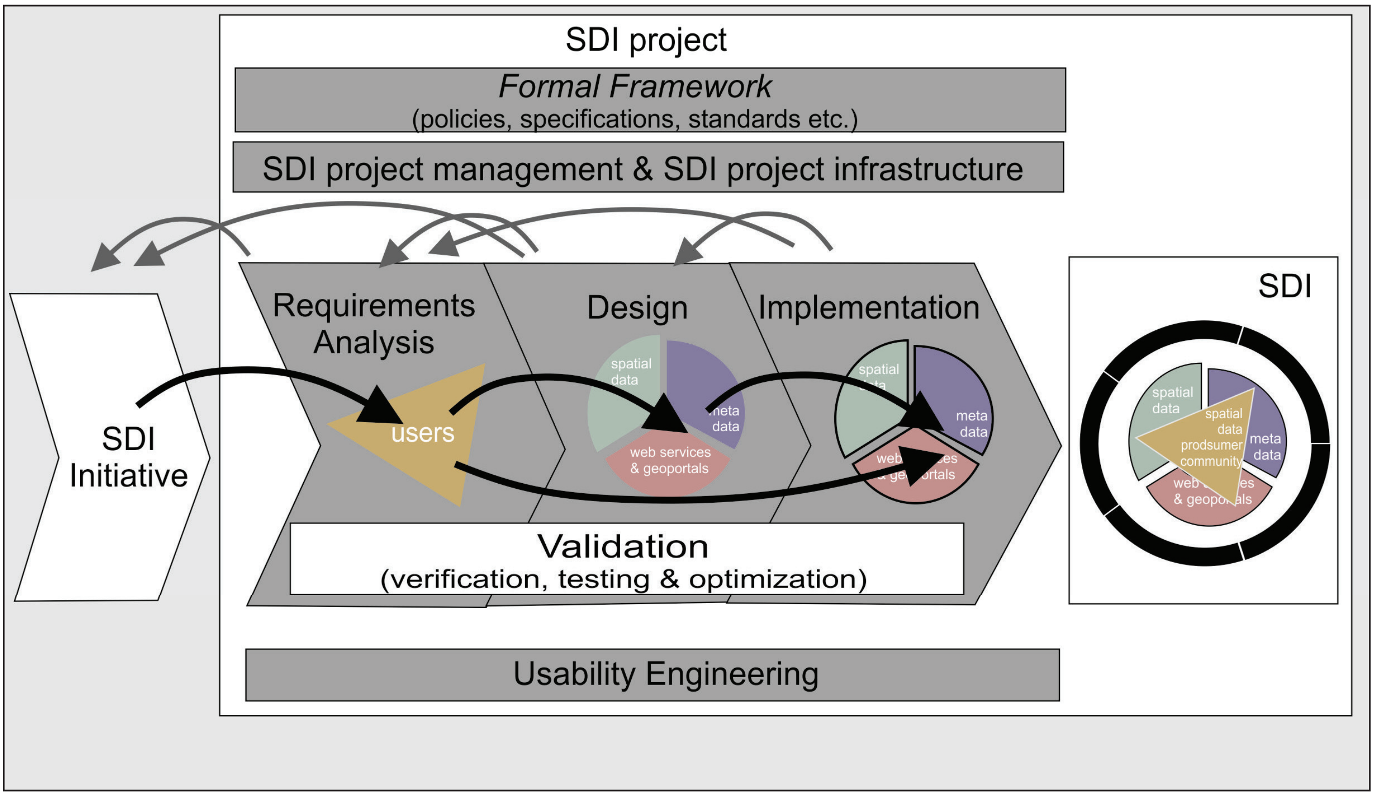

Fig. 2. Schematic (and simplified) user-centric SDI development process model

text of use. Following Nielson (1994) usability is traditionally associated with different attributes such as learnability, efficiency, memorability, error prevention, satisfaction. Consequently, usability has multiple assessment components.

Usability engineering is the design process that aims at understanding and systematically addressing usability demands of a customer. It accompanies the software development process at all process steps to guarantee the suitability of the final product. For all stages of development processes a variety of methods exists which originate from different fields such as empirical social sciences, software engineering or web design (Horn 1998; Nielson 1994; URL 3; URL 4; URL 5; URL 6):

- Requirements analysis: user survey, interviews, contextual inquiry, target groups, evaluating existing systems, card sorting, scenarios of use, task analysis etc.
- Application design: design guidelines, paper prototyping, heuristic evaluation, parallel design, storyboarding, evaluate prototype, interface design patterns etc.
- Application implementation: style guides, rapid prototyping etc.
- Application validation: diagnostic evaluation, heuristic evaluation, user survey, remote evaluation etc.

3 Nature-SDIplus user requirements analysis

Within Nature-SDIplus project, several of the above proposed methods were used for specifying user requirements: user survey, interviews, definition of target groups, and task analysis. Particularly, a Europe-wide user survey was considered as most valuable information source on user requirements and Geographic Information use. It was conducting as online questioning using SurveyMonkey (URL 7). The survey, set up according to the principles of empirical social research, consisted of 64 questions arranged in different sections focusing on: (1) the user himself and his/her company/ organization; (2) use and production of nature conservation's spatial data (above mentioned INSPIRE Annex themes); (3) use of GI software and methods; and (4) geoportal use. The questioning, carried out in 2009, resulted in 314 interviews from 17 European countries. The collected data was statistically analyzed, interpreted, and correlated with existing knowledge and further relevant research findings. This served as information input to describe use/ user context on nature conservation's spatial data and metadata, GI tools and methods. It revealed the context where nature conservation SDI is intended to operate for. Different types of target user groups were distinguished, and user requirements specified.

4 User requirements and open recommendations

To accommodate user requirements, a number of approaches exist. Apart from already existing activities generally involved in SDI development (e.g. data and metadata harmonization, provision of web services) we suggest some further open recommendations (Tab. 2)

4.1 Education and capacity building

User requirements gained relevance not only because of SDI evolution over the years, but also because of considerable changes in today's GI community. For instance, the last advancements in Information and Communication Technologies, including online mapping applications like Google Earth, Google Maps, and navigation systems, led to "GI democratization" (McDougall 2010). GI became available to everybody, both professionals and laymen.

Due to this GI democratization, particularly in a multifaceted domain like nature conservation, we are dealing today with an increased number of diverse people who produce, hold, and use nature conservation's spatial data. In terms of performed tasks and working environment, nature conservation community can be divided into seven target user groups: (1) Public Sector Authorities; (2) Basic Education Institutes; (3) Institutes on Higher Education & Research; (4) Research Facilities; (5) Commercial Sector Companies; (6) Nature Conservation Authorities; and (7) NGOs & Citizens (Araujo & Bronze 2004; Hennig, Wallentin & Hörmanseder 2010; Kanellopoulos 2005). Regarding spatial data use, GIS and SDI expertise, community members can be characterized as basic (~25%), advanced (~50%) and expert (~25%) users. The high percentage of users self-assessed as basic and advanced users conforms to the low use of GI tools (varying between 34 and 57%), geoportals (43%), and metadata use for data search (28%) and metadata creation (43% respond to not generate metadata).

For responding to the above outlined situation, education and capacity building are pivotal elements (Rajabifard & Williamson 2004). Activities such as training programs, workshops, or e-learning initiatives (see for instance NatureSDIplus project e-learning platform URL 8) should focus on improving users' skills on spatial data handling and on raising awareness on SDI concepts, components, and technologies. While users belonging to research and public administration target user groups have the required expertise to find, access and use spatial information, members of the other target user groups are less experienced. This conforms to the results obtained by Crompvoets et al. (2005). They found that geoportal are accessed largely in areas such as research (universities, public/ private institutes), governments and administrations. Accordingly, considerable efforts must be dedicated to users activating in education (high-school education) and commercial sector as well as on NGOs and citizens. Education and capacity building activities will be successful only if they take into account the characteristics of the particular target groups, their GI background, tasks and working environment.

4.2 Data documentation

As stated in our survey, 52% of the respondents produce spatial data. So the nature-conservation community can further be divided into data consumers and data produ-

		User Open Requirements & Recommendations						
			User	Meta-data		Geoportal		
			Education & Capacity building	Data documentation	Semantic annotations	Easy-to-use applications	Social webbing	Multi-functinalties & web services
Use/User Situation on using nature conservation's spatial data	User	Diverse user community (private & public sector)	•	•	•	•	•	•
		Data consumer (100%) & *prosumers* (52%)	•	•	•	•	•	•
		Different GI skills (basic/ advanced: 75%)	•	•		•		•
	Spatial data	Manifold use purpose: monitoring (36%), research (35%), management/ planning/ public administration (32%), consulting/ education (19%), lobbying (8%)		•	•			•
		Data types: raster & vector data are equally relevant (75% & 73%)						•
		Use of analogue data (paper maps: 30%)	•			•		•
		Temporal data (multi-temporal data: 61%; time ranges: 58%)		•				•
		Ancillary spatial data themes (altitude & topography, actual land use, hydrology, land use change, soil, transportation etc.)				•	•	•
		Additional attributes for Annex themes required		•				•
		Mainly regional (76%), local (74%), national (71%), International-neighboring (55%), EU-wide (45%), i.e. Europe-wide (41%) and international datasets (39%)				•		
		Data access/ processing problems (property rights, technical aspects)	•			•		•
	Metadata	Reduced (conscious) use of metadata (28%)	•	•	•	•	•	•
		Problems caused by no/ little (complete, high-quality) metadata available	•	•	•		•	•
		Barriers: terminology & language	•		•	•		
		No metadata production (43%)	•	•		•		•
		Use of metadata standards: No (60%), project specific (28%), national (28%), international (9%)	•	•	•	•	•	•
		Additional metadata elements for Annex themes required	•	•	•	•	•	•
	GI tools & methods	High diversity on data handling: view (71 %) & map data (69 %), searching in datasets (65 %), identifying objects (64 %), classifying data (62 %), statistical analysis (61%), measuring (59 %), spatial analysis (51 %), modeling (53 %) etc.	•			•		•
		No great use of GI tools (Desktop GIS/ Server GIS: 57%, Web Clients: 34%)	•			•		•
		Reduced geoportal use (43%)	•			•		•
		Technological obstacles in using geoportals	•			•	•	•
		Demanded services: view (57%), query (42%), mapping (44%)	•			•		•
		Demand for further comprehensive information: projects (24%), contact details (21%), (additional) statistical data (17%), glossaries (11%), further (relevant) links (11%), help including FAQs (6%) etc.	•			•	•	•

Tab. 2. Excerpt of Nature-SDIplus use/user context, user requirements and open recommendations (based on 314 returned surveys)

cers, i.e. prosumers (having in mind that data producer most probable also use/ consume data). This differentiation needs to be taken into account across the entire process of SDI conceptualization, implementation and maintenance, because use context and user requirements on data, metadata, geoportals, and web services differ fundamentally in accordance with the task of consuming or producing data.

This gets obvious by analyzing for instance nature conservation's metadata use. Only 28% of data consumers use metadata for data search and only a minority states to face no problems in using metadata. They are mainly complaining about metadata completeness and quality. From the point of view of data producers, 43% answered to not create any metadata at all (43%). Even if metadata is provided, 60% of the respondents answer to not use any metadata standards (60%) at all. If used, data producers prefer project-specific (28%) and national metadata standards (28%) instead of internationally recognized ones, used by merely 9% of the respondents. This complies with other, still valid, research findings. Tulloch & Fuld (2001) figured out that a large number of data producers did not document their data assets. They pointed out that we still lack a mature culture in metadata publishing. Nedović-Budić, Pinto & Warnecke (2004) underline that the most commonly used standards tend to be those developed locally (66 %), rather than national, federal, or international standards (ISO 19139, ISO 1915, ISO 19119, INSPIRE Metadata Implementing Rules). To enable interoperability, data producers have to describe their geographic assets following the specifications of international standards. These standards guarantee consistency and integration of multi-sourced spatial datasets and enable reliable query and discovery. Although these standards generally fulfill data consumer's demands for complete and high-quality data, data producers complain about their complexity. Metadata producer have to face even more complex metadata models, because nature conservation's datasets have an inherent specificity (e.g. temporal aspects, spatial and thematic accuracy, acquisition methods, and lineage) that needs to be comprised within particular metadata profiles as stated by survey respondents (Hennig, Wallentin & Hörmanseder 2010).

To overcome this problem, education and capacity building initiatives on both metadata use (data consumer) and metadata generation (data producers) must be intensified. Additionally, easy-to-use and intuitive metadata editors (online or desktop editors) should be available. To familiarize publishers with metadata elements and to assure truth in labeling, comprehensive help information should be provided on each metadata elements. Further, the GI community must work on simplifying metadata standards, supporting their immediate application by finding innovative ways on data documentation.

4.3 Semantic Annotation

Geographic Information sharing is hampered also by semantic heterogeneity problems. These problems are challenging both data harmonization processes and searching tasks. Semantic heterogeneity is caused by difference in information meaning or context information (Nowak et al. 2008). It involves two dimensions: cognitive heterogeneity and naming heterogeneity. First dimension refers to different domain concepts conceptualization. This means different perspectives upon the same reality. For instance, the concepts habitat or biotope may be conceptualized differently, depending on applied legislation, rules and conservation practice. The second dimension refers either to multilingual problem or to terminology problems. Crompvoets et al. (2004) agree that the terminology used in data and metadata is too discipline specific; and also survey respondents named language and terminology barriers as major problems hampering SDI's efficiency.

To overcome these semantics barriers, controlled vocabularies or ontology services can be used. A controlled vocabulary supports users in sending queries and retrieving the appropriate spatial data or services. An example of this approach is GEMET Thesaurus. It is addressing the multilingual and semantic related problems specific to European Countries, "an extremely diverse, segmented, multilingual and multifaceted environment" (Strobl 2008). To cover intrinsic specificity of nature conservation domain, existing GEMET Thesaurus has been extended with relevant nature conservation concepts. Although the existing solutions prove to be efficient in overcoming semantic heterogeneity, additional work is required for achieving semantic interoperability. We need to take advantage of the concepts and solution developed within Semantic Web framework (e.g. Linked Data Initiative).

4.4 Easy-to-use applications

Geoportals represent the interface of SDIs. Its good functionality and well design influence SDI use, popularity, and sustainability. There is a need for user-friendly, easy-to-use applications. The poor use of geoportals by the nature conservation community (43%) can result either from not knowing these platforms or from user's refusal. The first point asks for spreading awareness; the second point demands on the one hand for education and capacity building, and on the other hand for improving applications usability. It must be emphasized that the majority of respondents complain about technological obstacles in using geoportals. This reflects findings from Crompvoets et al. (2004) featuring, that geoportals are not always user friendly and too complicated for the users.

In information system building, software developers often adopt a standardized approach regardless intended user category, even though individualized and contextualized user requirements of target user groups exist. Thus, different strategies need to be deployed in design, implementation and use of information systems to fit each of the defined user categories and to achieve effective, efficient, and satisfactory use. Here, guidelines and principles for designing GUI and web sites can be used to support the process of designing and implementation easy-to-use geoportal applications. Solutions on such user-friendly geoportals in respond to user needs (Tab. 2) include (1) implement comprehensive help content and functions (including web-based training components); (2) multilingual GUIs in response to barriers imposed by foreign languages and technical terms; (3) integration of spatial and non-spatial information within a common platform; and (4) integrating the geoportal within a content-management system to provide up-to-date and additional information on data (contact information, further links, project descriptions, partner etc.) This conforms with Maguire and Longley (2005) findings who describe geoportals as websites with a collection of pages including content, search, navigation instructions, as well as information of general interest to the SDI community. Geoportals implemented in this way act as a gateway to a collection of information resources, including datasets, services, news, tutorials, tools and an organized collection of links to other sites.

As mentioned above, SDI users can be data consumers or data producers, i.e. prosumers. Hence, geoportal users belong to one of following categories: (1) consumers (being authenticated or not) performing data search and access tasks, and (2) metadata publishers (data producers) as authenticated users who can document their self-produced spatial datasets by using different mechanisms such as metadata editors accessible within geoportals, or uploading metadata generated using other editors. The requirements of these two user groups on geoportals differ substantially. While data producers are granted with publisher role which enables them to edit, validate and publish metadata, data consumer can only find, and use published datasets.

The authentication mechanism can be used to track and understand user behavior in terms of query formulation, discovery, and accessibility. This supports validation and optimization of the SDI (Fig. 2)

Since respondents mostly indicate to work in a local and/ or regional context, and require spatial data on local, regional and national themes, local and/ or regional geoportal applications should be implemented. These geoportal applications can be fed as node within a European geoportal application (by harvesting automatically the content of existing catalogue service). As a result, the European geoportal can represent an entry point to all member states geoportals as well as local and/ or regional geoportals.

4.5 Social Webbing

Information access network like SDI involves building up technological architecture, institutional frameworks as well as dynamic partnerships between different stakeholders (Maguire & Longley 2005; Rajabifard & Williamson 2002). Particularly, user-centric SDIs aim at levering SDI advantages by developing a sense of community, establishing social networks and thereby encouraging social interaction. It enables communication within spatial data community, between data consumers and data producers, and thereby represents a milestone in the transition from spatial information silos to information sharing (McDougall 2011). Further advantages for SDI developers and users are (Craglia & Annoni 2006; Maguire & Longley 2005; McDougall 2010; Rajabifard, Feeney & Williamson 2002; Rajabifard & Williamson 2002):

- enable cooperation and partnerships of stakeholders and users at different levels (political, administrative etc.) and between different countries that helps leveraging investments and reduce duplication;
- getting user feedback and thus enabling deep understanding of changing user behaviour
- building communities around data categories to serve as data stewardship leaders and responsible persons for portal maintenance, enabling SDI long-term sustainability and use;
- connection between individuals will increase their interest to participate in SDI initiative with a higher level of motivation; and
- provide better (real-time) communication channels for sharing and using data assets instead of aiming only toward the linkage of available databases.

Geoportals provide the appropriate environment for building GI communities and consistent sharing networks. They represent the communication platform between data consumers and providers and actually bring SDI to live (Strobl, Belgiu & Nazarkulova 2010). Based on principles, concepts and methods of Web 2.0, social webbing functions and constructs (manage users via user profiles, search and contact users, manage and maintain contacts, establish specific groups, communicate and exchange by different channels such as email, chats, forums) can easily be implemented. Forums and blogs covering community relevant themes (published data, provided metadata, implemented services etc.) can be rated in accordance with users' comments. This supports integrated evaluation of SDI and geoportal (Fig. 2).

4.6 Multi- functionalities and web services

In the past, geoportals capabilities were mostly reduced to data documentation, search and discovery (George 2010), serving mainly as data or metadata pool. Today, their complexity is continuously increasing. Nevertheless, geoportal applications do not fulfill entirely user demands for an interactive online environment that supports standardized, operative applications. For instance, only several geoportals facilitate services to further analyze spatial data (Crompvoets et al. 2005). This is an issue that needs to be tackled carefully as our respondents expressed their need of sophisticated spatial data handling mechanism (Tab.2). They need web services (including web processing services) helping them to extract, access and use required information. For nature conservation community, viewing and mapping data in geoportals play an important role – as indicated by a high number of respondents (57%, 44%). Accordingly, existing datasets have to be published online following the specification of existing web services specifications (Web Map Service) and Styled Layer Descriptor.

An additional issue could be the integration of search results into different applications (such as GEORSS, HTML or mapping environments like Google Earth). Social sharing capabilities enable dissemination of retrieved information by quick links to existing online platforms such as Facebook, Twitter, Messenger, MySpace. This offers great support to the lay users who are mostly familiarized with these environments and enjoy using them.

In conclusion the following open recommendations on geoportals functionalities can be considered as paramount for user-centric solutions: (1) online metadata editors accompanied by comprehensive help content; (2) ontology services; (3) web map services; (4) social webbing sharing functionalities (authorization mechanism) and online mapping integration; and (6) computer-based training components.

5 Conclusion and outlook

In today's user-centric SDIs, user requirements have become a crucial issue (Crompvoets et al. 2004). Commitment to user requirements ensures successful SDI implementation, leverage and maintenance (Nedović-Budić, Pinto & Budhathoki 2008). Therefore, SDI main components (spatial data, metadata, geoportals, and web services) must be designed and implemented to conform to user requirements following the steps involved in common software engineering processes: requirements analysis, application design, implementation, and validation. Involved process steps can be supported and guided by the concept of usability providing several usability engineering methods, tools, and criteria.

User requirements specified within Nature-SDIplus project show that data consumers and data producers are operating within a wide range of application areas (planning, management, monitoring, research, education etc.) mirroring a diverse spatial data use context. Further, it has been revealed, that the number of basic and advanced users regarding spatial data handling, GIS and SDI is surprisingly high. Therefore it can be concluded, that a user-centric SDI asks for intensive education and capacity building programmes and for simplified approaches following usability criteria. To meet these demands, several open recommendations have been highlighted: easy-to-use (geoportal) applications, support for multi-functional geoportal applications including capabilities for social sharing and social webbing, user-supported data documentation, and semantic annotations.

Nevertheless, there are still many open issues challenging the development of user-centric SDIs. As SDI is a dynamic system, rather than a static system, conceptual models used to create SDI frameworks need to accommodate user requirements which are changing as new environmental, societal or economic conditions and technological improvements appear (Maguire & Longley 2005). To respond to these changes, user requirements specifications need to be paralleled by user integration in SDI development processes as proposed by Budhathoki, Bruce & Nedović-Budić (2008); Goodchild (2008), and Rajabifard et al. (2006). Users` involvement ensures identification and capture of their still unfulfilled and unknown requirements (Nedović-Budić, Pinto & Budhathoki 2008) and might help to pave the way to a spatially enabled society as stated by Sadeghi-Niaraki et al. (2010).

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Om forfatterne

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