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Technical assessment of GeoSUR and comparison with INSPIRE experience in the context of an environmental vulnerability analysis

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Technical assessment of GeoSUR and comparison with INSPIRE experience in the context of an environmental vulnerability analysis

by

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Abstract

The use of spatial information has become an important resource for decision support making at national and regional levels. In this respect, several private and public organizations are continuously collecting and producing geospatial data. However, there are still problems that affect the usage of spatial information. As a response to these problems, several spatial data sharing initiatives have been implemented at national, regional and global level. This is also the case of the Infrastructure for Spatial Information in the European Community (INSPIRE) and the Integrated Geospatial Information Network for South America (GeoSUR), both created in 2007.

GeoSUR works together with the PAIGH, the Geocentric Reference System for the Americas (SIRGAS) and the Permanent Committee on Geospatial Data Infrastructure for the Americas (PC-IDEA) to consolidate the Spatial Data Infrastructure of the Americas. In this context, the role of GeoSUR is to provide the distribution platform for the SDI and develop geoservices and applications based on institutional spatial databases.

This research performs a technical assessment of GeoSUR to identify the extent to which the spatial resources provided by the network area accessible, applicable and usable for decision making processes at regional (multinational) level. In order to do so, this study is conducted in the context of a real case study that implements Spatial Multicriteria Evaluation to assess the environmental vulnerability of the Amazon IIRSA region.

Results show strengths at finding spatial resources, and regarding the accessibility to regional datasets in GeoSUR. However several obstacles still limit accessibility, applicability and usability of spatial data to perform regional analysis. In this respect, elements considered by INSPIRE such as common implementing rules and technical guidelines are identified as useful to tackle these obstacles and make the spatial services and datasets of the participant institutions compatible to perform regional analysis.

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List of Acronyms

CAF:	Development Bank of Latin America
EEA:	European Environment Agency
EID:	Integration and development Hub (for its acronym in Spanish)
EVI:	Environmental Vulnerability Index
GeoSUR:	Integrated Geospatial Information Network for South America
GSDI:	Global Spatial Data Infrastructure Association
IGAC:	Geographic Institute Agustín Codazzi
IGN:	National Geographic Institute of Spain
IIRSA:	Initiative for the Integration of the Regional Infrastructure in South America
INSPIRE:	Infrastructure for Spatial Information in the European Community
IPCC:	Intergovernmental Panel on Climate Change
ISO:	International Organization for Standardization
JRC:	Joint Research Centre
LAC:	Latin America and the Caribbean
LAMP:	Latin American profile of Geographic Metadata
OGC:	Open Geospatial Consortium
PAIGH:	Pan American Institute of Geography and History
PC-IDEA:	Permanent Committee on Spatial Data Infrastructure for the Americas
SDI:	Spatial Data Infrastructure
SIRGAS:	The Geocentric Reference System for the Americas
SMCE:	Spatial Multicriteria Evaluation
SOPAC:	South Pacific Applied Geoscience Commission
UNEP:	United Nations Environment Programme
UN-GGIM-Americas:	Regional Committee of the United Nations Global Geospatial Information Management for the Americas
UN-GGIM-AP:	Regional Committee of the United Nations Global Geospatial Information Management for Asia & The Pacific
UNISDR:	United Nations International Strategy for Disaster Reduction

Chapter 1. Introduction

1.1. Background

The use of spatial information has become an important tool for decision support making at national and regional levels. Several private and public organizations are continuously collecting and producing geospatial data. Despite high production volume of spatial data sets, there are still challenges regarding availability, quality, organization, accessibility and sharing of spatial information (European Commission 2007).

In response to these challenges, many spatial data sharing programs have been implemented as national, regional and global initiatives. An example of such an initiative is the Integrated Geospatial Information Network for South America (GeoSUR) created in 2007. GeoSUR is a spatial data clearinghouse led by the Development Bank of Latin America (CAF) and the Pan American Institute of Geography and History (PAIGH). It aims to generate, disseminate, and exploit geospatial data useful for decision-making in Latin America and the Caribbean (Van Praag et al. 2012a).

GeoSUR works together with the PAIGH, the Geocentric Reference System for the Americas (SIRGAS) and the Permanent Committee on Geospatial Data Infrastructure for the Americas (PC-IDEA) to implement the action plan for development of the Spatial Data Infrastructure of the Americas. This joint plan aims to consolidate distributed responsibilities: the PAIGH as a facilitator of regional processes and as a capacity builder; SIRGAS as the supplier of geodetic reference frames for the region; the PC-IDEA as promoter of regional and institutional policies and direct liaison with the United Nations and GeoSUR as developer of geoservices and applications based on institutional spatial databases (Borrero et al. 2012).

The Infrastructure for Spatial Information in the European Community (INSPIRE) is considered one of the most successful data sharing approaches at the regional scale. INSPIRE was established in 2007 to support European Community environmental policies, and policies or activities which may have an impact on the environment. It is based on common infrastructures for spatial information established and operated by the European Union Member States (European Commission 2015).

Differences exist between an SDI such as INSPIRE and a spatial data clearinghouse network as GeoSUR. These differences occur mainly due to the existence of a legal framework in Europe which is not available in Latin America. Yet similarities also arise from the aims and objectives of the "Joint Action Plan to Expedite the Development of Spatial Data Infrastructure of the Americas" which seeks to develop GeoSUR services into an SDI for the Americas, primarily by setting it as the central provider and distribution platform for facilitating access to and use of regional geospatial information for the region (Borrero et al. 2012). In the absence of studies to deal with the current function and capabilities of GeoSUR, this current research seeks to establish its technical characteristics in order to then facilitate a comparison with the experiences available from the consideration of INSPIRE.

Because GeoSUR already constitutes a formidable program with wide-ranging information capacity, this study proceeds via an illustrative case study in which a particular environmental vulnerability assessment for the IIRSA Amazon region is performed. The limitation to a specific environmental vulnerability study provides a reasonable example from which to assess accessibility, applicability and usability of spatial resources provided by GeoSUR for a relevant context of its intended primary use, and it's comparability to INSPIRE. Environmental vulnerability is a main factor determining consequences and success of development projects.

Assessments of environmental vulnerability rely heavily on spatial data and models of interconnectedness that exist between different geographic areas and locals of a considered political region. In South America, the IIRSA initiative (Integration of Regional Infrastructure in South America) is involved in the development of regional interconnection infrastructure in South America. The IIRSA approach for development projects consolidates analysis of physical connectivity networks at the regional level to establish characteristics and dynamics of different sub regions in South America (e.g. 'the Amazon' region). In its efforts, IIRSA considers a goal of "sustainable social and economic development criteria, and preserving the environment and the balance of ecosystems" (UNASUR 2013, p. 3), which in pursuit of South American integration relies critically on suitably organized geospatial information.

GeoSUR aims to support regional initiatives such as IIRSA (CAF 2009), where environment vulnerability assessment plays an important role to identify those areas that are more susceptible to be degraded when planning infrastructure projects and/or stablishing mitigation and conservation strategies.

1.2. Objectives

The aim of this research is to perform a technical assessment of spatial resources provided by GeoSUR in the context of a real case study of an environmental vulnerability assessment for the IIRSA Amazon region.

This assessment seeks to get an insight about the current status of GeoSUR and identify how the experience gathered by INSPIRE can be helpful to improve its performance.

There are three specific objectives:

- Assess the accessibility, interoperability and usability of the spatial resources provided by GeoSUR to perform regional analysis.
- Perform an environmental vulnerability assessment for existing roads in the IIRSA Amazon hub using spatial resources offered by GEOSUR and Spatial Multicriteria Assessment.
- Identify which elements from the INSPIRE Directive can be helpful to improve GeoSUR capabilities at performing regional decision making processes.

1.3. Thesis Structure

This thesis is structured in five main chapters. Chapter 1 describes the general outlines of the document, giving a brief description of the two regional data sharing initiatives that will be considered within the research frame.

Chapter 2 , Literature review, describes the goals as well as the technical and institutional issues associated with INSPIRE and GeoSUR and contains a ‘state of the art’ regarding spatial data sharing initiatives as well as methods and indicators commonly used in environmental vulnerability assessments, including those considered in studies in South America.

Chapter 3, Methods, describes the methods and enumerates the criteria and indicators considered to assess the spatial resources offered by GeoSUR. It also presents the methodology and criteria used to perform the ex-post environmental impact assessment conducted as a case study, including the data pre-processing techniques required to access the data into the SMCA.

Chapter 4, Results, describes the results of the GeoSUR spatial services assessment and the case study. The assessment of the spatial services offered by GeoSUR is expressed in terms of accessibility, applicability and usability, it considers the characteristics of the network as a whole and those associated to individual resources. The results of the distribution of environmental vulnerability and the differences among countries are also described here.

The analysis of the assessment performed on GeoSUR services is discussed in Chapter 5. Based on the results obtained for the technical evaluation, a linkage is established between the problems in terms of accessibility, applicability and usability found in GeoSUR and strategies adopted by INSPIRE that can be useful to overcome them.

Chapter 6 contains conclusions obtained from the assessment performed to GeoSUR and link them to elements from INSPIRE. It describes how elements contained in the INSPIRE directive can improve the spatial services provided by GeoSUR in the process of construction of a SDI in Latin America.

Chapter 2. Literature Review

This study is constituted by two main elements: a technical assessment of spatial resources offered by GeoSUR and an environmental vulnerability assessment as a case study. Thus, the literature review is structured in 2 main parts: Sections 2.1 up to 2.5 will consider literature regarding SDI, and the sections 2.6 and 2.7 will be focused on literature about the case study, such as the description of the study area and previous studies performed in the area of Spatial Multicriteria Evaluation and Environmental vulnerability Assessment.

2.1. Spatial data issues

The importance of geographic data in decision making processes has risen with the development of new technologies and techniques to collect, interpret and process spatial data. There are several applications of spatial data on local, national and international scales such as logistics study and planning, environmental management and protection, society planning, crisis management and road network design among others (Williamson 2003; Toomanian 2012).

However the usage of spatial data is limited by problems regarding availability, accessibility, applicability and usability of spatial information (Nedovic-Budic et al. 2004; Mansourian et al. 2006; European Commission 2007; Toomanian 2012). These problems are the consequence of different technical and non-technical factors. Non-technical factors refer for instance to the lack of agreements and frameworks to share spatial data among organizations. Technical factors include missing or incomplete spatial data, lack of proper description of spatial resources, heterogeneity among datasets and concepts, and lack of network services to share data. Figure 1, shows the relationship between the user requirements for spatial data.

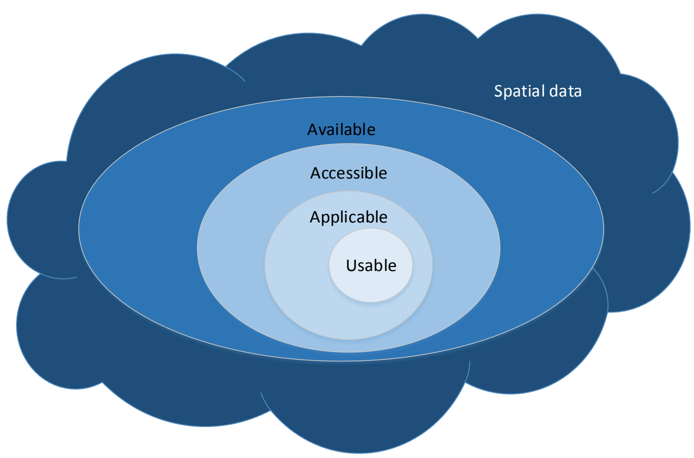


Figure 1. User requirements for spatial data, adapted from Toomanian (2012)

Availability is the existence of spatial data with the specifications required by the user. Accessibility refers to limitations regarding data access to the end user, thus, the dataset may exist, but the user cannot access it. In this context, technical factors such as poor dataset and services descriptions, inappropriate interfaces and services for data discovery and data download limit users' accessibility to existing data. Non-technical factors such as administrative constraints, inappropriate announcement of existing data, cultural and security issues as well as data pricing can also affect accessibility (Toomanian 2012).

Applicability is the amount of accessible spatial datasets compatible with current standards and end user needs (Feeney et al. 2002; Toomanian 2012).It is affected by the lack of common rules to describe, exchange and serve datasets. The lack of metadata for use and evaluation does not allow the user to identify the extent to which the data is applicable to its purposes. The availability of datasets information regarding to encoding formats, geometrical structure, coordinate reference systems and data quality gives the user elements to identify the extent to which the dataset fit to its needs and the processing operations to be performed (Toomanian 2012).

The term usability is associated to the amount of usage and the quality of use of spatial data for the end user. Even when data is available, accessible or applicable, it may not fulfil the needs of the final users, so they do not use these data in the analysis (Toomanian 2012). In this context, the low awareness of data characteristics or lack of information about the dataset regarding content, spatial and temporal dimension do not allow the user to evaluate if the data satisfies its requirements and limit their usage. Also the lack of skills, software, hardware and the lack of awareness on application of spatial data may limit spatial data usage.

Interoperability has emerged as a key concept to remove heterogeneities that bring problems for spatial data accessibility, applicability and usability. Interoperability refers to "the possibility for spatial data to be combined, and for services to interact, without repetitive manual intervention, in such a way that the result is coherent and useful to the final user" (European Commission 2007 p. 5). Standardized metadata is key for interoperability, it records the information necessary to ensure datasets discovery, evaluation and exchange. In this respect, the ISO/TC 2011 committee plays a fundamental role for Standardization in the field of digital geographic information. It establishes a structured set of standards for geographic information such as ISO 19115-1:2014 and ISO 19119:2005. ISO 19115 defines basic principles and requirements for standardized description of information resources, and ISO 19119 defines the architecture patterns for service interfaces and presents a taxonomy of geographic services based on their semantic characteristics (ISO 2010).

Two forms of interoperability are mostly recognized as to affect spatial data sharing and usage: semantic and syntactic. Syntactic interoperability is about the possibility to exchange spatial resources by using a common data format or structure, language, logic, registers and files. Standards or format specifications are a key factor to address interoperability. In the case of INSPIRE, technical guidelines specify how legal obligations could be implemented, making reference to existing standards such as those of OGC and ISO/TC211 (European Commission 2014).

Semantic interoperability is related to the use of common reference models for information exchange and interpretation of concepts to avoid inaccuracies or mix-ups when interpreting the meaning of terms. (Manso Callejo et al. 2009; Turnitsa and Tolk 2006).

INSPIRE addresses semantic interoperability through the "Interoperability of spatial data sets and services (ISDSSs) implementing rules". These rules define "common data models, code lists, map layers and additional metadata to be used when exchanging spatial data sets" (European Commission 2014 p. 12).

Figure 2 shows a summary of technical factors that affect the accessibility, applicability and usability of spatial data. The level of accessibility depends on the availability of friendly user interfaces to discover and download metadata as well as on the interoperability among services. Applicability depends completely on the syntactic and semantic interoperability among datasets, which is supported by the definition of common rules and standards. The decision to use or not a dataset depends on the level of interoperability among services and the own user preferences regarding datasets contents.

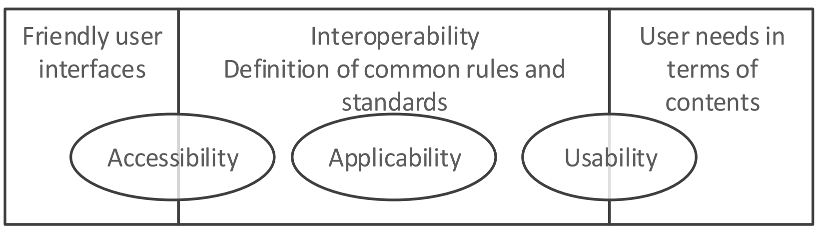


Figure 2. Elements that affect data accessibility, applicability and usability

2.2. Spatial Data Infrastructures

Spatial Data Infrastructures have emerged as initiatives to overcome the user requirement limitations mentioned above by facilitating the availability, accessibility, applicability and usability of spatial data (Toomanian 2012). The main aim of SDIs is to coordinate and facilitate spatial data management and sharing in a collaborative environment (Rajabifard and Williamson 2003; GSDI 2012; Toomanian 2012; PC-IDEA 2013; Crompvoets et al. 2004; Hjelmager et al. 2008; Hendriks et al. 2012; Rajabifard 2003). In this context, Spatial Data Clearinghouses play a key role at providing access to the SDI network and acting as a gateways to the data repositories (Crompvoets et al. 2004; Armenakis 2008; Toomanian 2012).

Several SDI have been created under the assumption of reducing unnecessary costs from duplicate production procedures and their benefits at supporting decision making processes in society, economy and environment (Executive Order 12906 1994; Crompvoets et al. 2004; European Commission 2007; Lance et al. 2009; Toomanian 2012; Rajabifard 2003; Morera Amaya 2011; Grus et al. 2011), as well as for their contribution to the quality and geographical coverage of spatial data (Rajabifard and Williamson 2003).

Rajabifard and Williamson (2003) indicates that SDIs have five main core components: people, access networks, policy, standards, and data. Figure 2, shows the interaction among these three components: producers and users of spatial datasets require an access network to interact, standards to facilitate the communication process, and a framework for cooperation and collaboration among them.

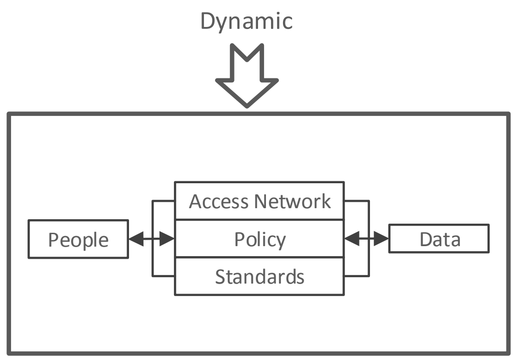


Figure 3. Components of an SDI (Rajabifard and Williamson 2003)

The concept of spatial data clearinghouse, also called Geoportal by some approaches like INSPIRE, refers to a distributed network that links geospatial data producers, managers, and users electronically (Executive Order 12906 1994). Figure 4 shows the general structure of a Geoportal as defined by Mansourian et al. (2011). It includes a gateway which allows to access catalog services linked to several metadata repositories to identify the available datasets and services. A group of data servers connected to spatial databases allow to deliver the resources to the client through the gateway.

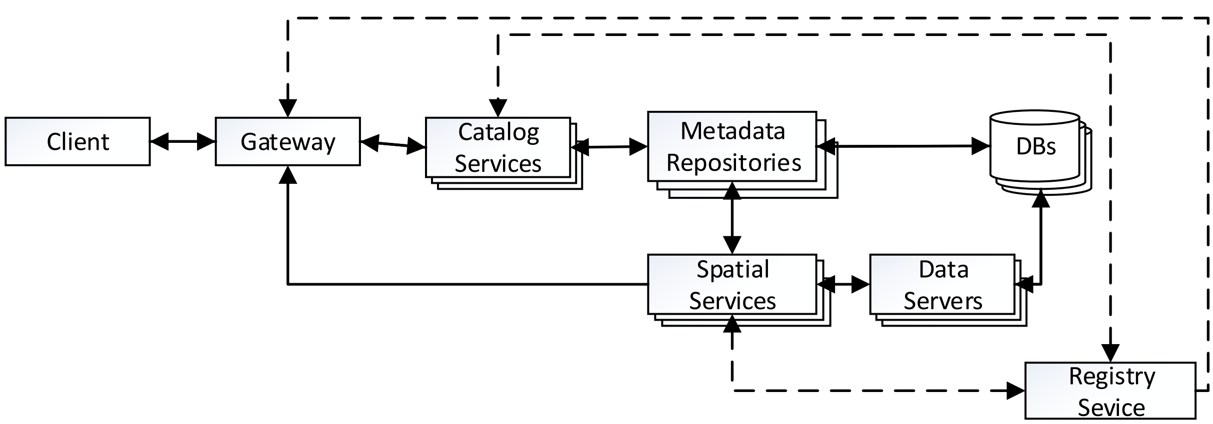


Figure 4. Structure of second generation clearinghouses or so called Geoportals by some researches, adapted from Mansourian et al. (2011)

As there are many SDI initiatives, also many assessment approaches have been developed to monitor and evaluate them (Morera Amaya 2011; Lance et al. 2006) considering technical and non-technical elements (Grus et al. 2011; Lance et al. 2009). SDI evaluation approaches vary depending on the perspective from where they are considered, the degree of clarity of SDI objectives and their potential impact, and the moment when the evaluation is performed (Georgiadou et al. 2006; Lance et al. 2006).

The performance and status of the elements of a geoportal are indicators of the performance of other technical and non-technical components in the SDI. In this regard, several evaluation approaches such as Toomanian et al. (2011), Crompvoets et al. (2004) or Morera Amaya (2011) have worked on monitoring and assessing the spatial data clearinghouse performance.

2.3. Regional SDIs

SDI comprises an “integrated, multi-levelled hierarchy of SDIs that are integrated based on partnerships at corporate, local, state/provincial,s national, regional (multi-national) and global levels” (Rajabifard 2003 p.1). When applying the hierarchy concept, an SDI at a global level consist of one or more SDIs from the lower level such as Regional SDIs. In the same way, a Regional SDI is part of the global one (Rajabifard and Williamson 2003), as shown in figure 5.

The need of consistent spatial data to support decision making at multinational level, and the lack of bodies responsible to coordinate existent national and sub-regional initiatives, led to consider a regional SDI perspective. This approach began with the establishment of the European Umbrella Organization for Geographic Information in 1993 and was followed by other initiatives in the Pacific and the Americas before the end of the 20th century (Borrero et al. 2003).

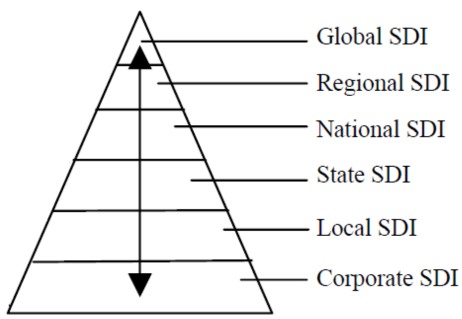


Figure 5. An SDI Hierarchy (Rajabifard and Williamson 2003)

Nowadays, the Global Spatial Data Infrastructure Association (GSDI), represents the top level of the SDI hierarchy as a Global SDI, aiming to further development of society by helping people to implement and develop spatial data infrastructures which build from local, national and regional to the global level (GSDI 2015). In the regional level, the Infrastructure for Spatial Information in Europe (INSPIRE), the Regional Committees of the UN Global Geospatial Information Management for the Americas (UN-GGIM-Americas), Asia and Pacific (UN-GGIM-AP) and Africa (UN-GGIM-Africa) are the most representative, among the 22 Regional SDI around the world reported by GSDI (GSDI Association). The Infrastructure for Spatial Information in Europe (INSPIRE) is one of the initiatives that has achieved higher progress, and has become a reference for other projects such as the Spatial Data Infrastructure of the Americas.

2.4. INSPIRE

The Infrastructure for Spatial Information in the European Community (INSPIRE) was established by the Directive 2007/2/EC of the European Parliament to support European Community environmental policies, and policies or activities that may impact on the environment (European Commission 2007). It was the result of a previous work of fact-finding and public consultations which aimed to identify those obstacles that limit the widespread use of spatial data needed for policies that may an impact on the environment. In that opportunity most of the participants identified 5 main obstacles, that are expected to be addressed by the INSPIRE Directive (European Commission 2014). The following paragraphs provide an overview of the main elements contained in the INSPIRE Directive (European Commission 2007).

Following hierarchy principles as indicated by Rajabifard (2003), INSPIRE is based on the infrastructures for spatial information created by the Member States that must follow common implementing rules in order to ensure that they are compatible and usable in a trans boundary context. In this respect, these national infrastructures should ensure appropriated data storage and management; allow to combine spatial data from different sources across the EU and share them between several users and applications; make spatial data easily available; make easy to discover available spatial data, to evaluate their suitability for the purpose and to know the conditions applicable to their use (European Commission 2007).

The INSPIRE Directive establishes the rights and obligations for all levels of government regarding the sharing of spatial data sets and services. They apply to all spatial data sets related to the 34 data themes listed in the INSPIRE Annexes I to III that are in electronic format, and refer to an area from any Member State. It also indicates that each Member State shall adopt measures for sharing of spatial data sets and services between its public authorities, including elements such as property rights, or charging.

Regarding coordination, Member States have to designate coordination structures and mechanisms, they can include users, producers, added value service providers and coordinating bodies. At the European Union level, INSPIRE is coordinated by a team consist of staff of the Directorate-General for the Environment and the Joint Research Centre (JRC) from the European Commission as well as the participation of the European Environmental Agency (EEA) (European Commission 2015).

The INSPIRE Directive in Europe has become into a model of spatial data sharing at regional level. It has defined common Implementing Rules (IR) in specific areas such as metadata, data specifications, network services, data and service sharing, monitoring and reporting to ensure that the spatial data infrastructures of the Member States are compatible (European Commission 2014):

- Metadata implementing rules that specify a number of common metadata elements to be provided for the resources related to the themes listed in Annexes I, II and III to facilitate their discovery within the INSPIRE infrastructure. Those common metadata elements include information regarding to access and use of, spatial resources; the quality and validity of spatial data sets; the authorities responsible of them; limitations on public access and the reasons for such limitations.
- The network services implementing rules specify common interfaces for web services for discovering, viewing, downloading and transforming spatial data sets. It also establishes a minimum combination of search criteria to be implemented.
- The interoperability of spatial data sets and services (ISDSSs) implementing rules specify common data models, code lists, temporal dimension, map layers and additional metadata required when exchanging spatial data sets. They provide the semantic interoperability layer and define in which cases the Member states may limit public access to spatial data sets and services, considering issues such as national defense, copyrights, among others.
- The data and service sharing implementing rules define the conditions under which Member States shall provide the institutions and bodies of the Union with access to spatial data sets and services.
- The monitoring and reporting implementing rules specify the rules to monitor the implementation and use of the Member Stats Infrastructures and to report on the implementation of the INSPIRE Directive.

INSPIRE directive establishes a continuous monitoring process in order to identify if the implemented actions are still on course to meet their objectives. This is performed using different information sources and methodologies, including reports from Member States (described in the following paragraph), a review of secondary sources (studies, reports, presentations at conferences), a study of the extent of implementation in the Member States; and a public consultation. The Implementing document related to monitoring and reporting, establishes a set of indicators to monitor the implementation of the INSPIRE Directive in each Member State. Those indicators are based on the implementing rules defined for metadata, interoperability of spatial datasets and network services. The common rules on monitoring and reporting also indicate the need to report on issues such as coordination and quality assurance, data sharing arrangements and cost and benefit aspects (European Commission 2014).

Spatial Data clearinghouses aim the facilitation of spatial discovery, access, and related services for users. Therefore the availability of user friendly interfaces is crucial for implementation in order to fulfil the current demands of the users. (Crompvoets et al. 2004).

2.5. GeoSUR

The Geospatial Network for South American Integration - GeoSUR is a program which aims to facilitate access to spatial information and support decision makers in planning of physical infrastructure, climate change adaptation, regional integration and other development goals in Latin America and the Caribbean - LAC (CAF and IPGH 2013). It was created in 2007, led by the Development Bank of Latin America (CAF) and the Pan American Institute of Geography and History (PAIGH). Its origins date back to the Condor Program developed by CAF in 2000, which aimed to identify the environmental and social impacts associated with infrastructure projects in the Andean region. Nowadays, Condor is part of the GeoSUR Regional Map Service (Van Praag et al. 2012b).

GeoSUR is constituted by four main components: a decentralized network of map services, a regional Geoportal, a regional Map Service and a Topographic Processing Service (Van Praag et al. 2012a). GEOSUR is based on a decentralized network of data providers responsible for generating and maintaining geographic and environmental information. During the first stage of the Program key national spatial data producers were invited to participate, such as geographic institutes, and environmental agencies. The regional geoportal allows access to metadata from the participating agencies, and it keeps an central metadata database that is periodically updated by an automatic harvesting mechanism from the participating agency´s catalogues. The portal also contains a map viewer that allows the user to pull, open and view layers available in partner map services. A Topographic Processing Service allows users to produce DEM derivative products for any point or region, and was used to perform Hydro-Electric Potential Assessments which results are also available in GeoSUR(Van Praag et al. 2012b).

GeoSUR is coordinated by representatives from PAIGH and CAF, and receives technical support from the US Geological Survey and the geographic institutes of Colombia (IGAC) and Spain (IGN) while the required funding is provided by CAF.

Although there is not a policy document such as the Directive 2007/2/EC, the Program Profile provides a description of the objectives, components, organizational structure and expected activities to be performed within the framework of GeoSUR. In order to maximize the compatibility among spatial data providers, existing SDI architectures were studied and standards and protocols to be used in GeoSUR were selected with support from the USGS/EROS (CAF 2009). GEOSUR does not define its own common technical implementation rules, but emphasizes the use of Open Geospatial Consortium (OGC) and ISO standards. Participants are free to choose the hardware and software platforms for sharing data with the Network, as long as they follow international recognized standards. In this way, GeoSUR provides training and technical assistance to all partner agencies (Van Praag et al. 2012b).

In 2011 CAF, the UNEP and the PAIGH conducted a survey in order to get users impressions about the services currently provided by the GeoSUR Program and ideas about its potential development. The survey includes results on the perception of participant organizations regarding GeoSUR strengths and weaknesses and about the use given to data and services (Van Praag et al. 2012b).

GeoSUR is recognized as one of the regional entities that play a key role in the consolidation of the Spatial Data infrastructure of the Americas. The 2013-2015 Joint Action Plan to Expedite the Development of Spatial Data Infrastructure of the Americas set the role of GeoSUR as developer of services and applications built on institutional and regional spatial databases (Borrero et al. 2012).

In the process of construction of the Spatial Data Infrastructure for the Americas, the purpose is to consolidate a widely distributed system of responsibilities among the four regional parties involved: the Pan American Institute of Geography and History -PAIGH, the Geocentric Reference System for the Americas -SIRGAS, the Permanent Committee on Geospatial Data Infrastructure for the Americas -PC-IDEA[1] and GeoSUR. Under this premise, these institutions are linked to one or more components of the SDI, and are required to complement each other at certain matters to achieve synergies based on individual contributions (Borrero et al. 2012).

In light of the above, GeoSUR Program is a complement to the sphere of action of the SIRGAS, PC-IDEA and the PAIGH. GeoSUR and PC-IDEA work together in fields such as training, making inventories of spatial information and implementing standards and protocols, as well as establishing the connections between national SDIs and regional SDIs. GeoSUR, gives the PC-IDEA mechanism to test and implement regional standards and protocols in geoservices and other spatial applications. Working together with the SIRGAS, GeoSUR can encourage the use of the continental reference system as a basic component of the implementation of tools and geoservices by the participating institutions. PAIGH as a coordination institution of GeoSUR was fundamental in its conceptualization, planning and start up, and has backed the participation of the geographic institutes of the region.

2.6. Integration Infrastructure Projects in South America

The need to develop regional interconnection infrastructure in South America led to the creation of the Initiative for the Integration of Regional Infrastructure in South America (IIRSA). In this frame a set of structured projects that consolidate physical connectivity networks at regional level have been proposed considering the characteristics and dynamics of different sub regions in South America.

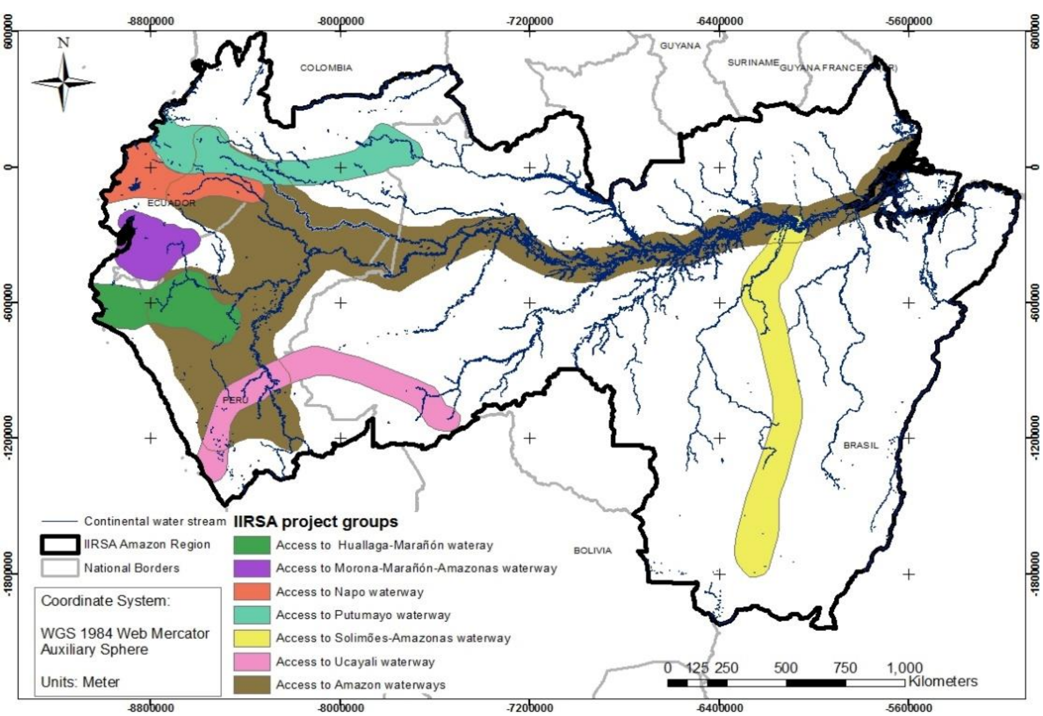
South America is a very diverse region. To manage this differences, IIRSA has defined the so called Integration and development Hubs (EID, for its acronym in Spanish) that are

[1] Replaced by the Regional Committee of the UN Global Geospatial Information Management Americas (UN-GGIM Americas) in August 2013.

multinational territories which involve natural spaces, human settlements, production areas, and trade flows. These regions distribution allows to identify the physical infrastructure requirements of each EID to articulate the territory with the rest of the region, and plan investments. Thus, each single project considered within this initiative have social, economic and environmental impacts along the whole EID.

There are three structured projects allocated in the Amazon area which main aim is to articulate 5 waterways: Huallaga, Marañón, Morona, Ucayali and Putumayo that connect the Amazon River basin with important coastal, rainforest and sierra regions in Perú, Ecuador and Colombia. Since the individual projects are planned to be integrated as part of big structured ones, the development of each one of them will affect the natural environment vulnerability of the whole EID. Establishing a base line of the vulnerability of the natural environment in the Amazon EID may allow to measure how the new individual infrastructure projects impact the vulnerability along the Region. Map 1 shows the groups of projects planned to facilitate the connection between the four countries involved by improving the access to waterways.

The vulnerability of the environment is a main factor that determines the environmental consequences of regional integration projects. The projects considered within IIRSA portfolio pursue a South American physical integration "considering sustainable social and economic development criteria, and preserving the environment and the balance of ecosystems" (UNASUR 2013, p. 3). Since GeoSUR aims to support regional initiatives such as IIRSA, environmental vulnerability assessment plays an important role to identify which areas are more susceptible to be degraded when planning infrastructure projects and/or stablishing mitigation and conservation strategies.



Map 1. Structured project groups in IIRSA Amazon Region (Spatial data provided by GeoSUR)

2.7. Vulnerability to natural environment degradation

The assessment of the environmental vulnerability also called natural environment vulnerability has been considered important by several ecological literature (UNEP and SOPAC 2005; Elbers 2011; Laurance et al. 2009; Wang et al. 2008; Kværner et al. 2006). It is recognized to provide useful information about ecological and environmental background information for environmental restoration (Wang et al. 2008) and to provide insights into the processes that can negatively influence the sustainable development (UNEP and SOPAC 2005). Kværner et al. (2006) consider it particularly important to include vulnerability assessment in the early stages of EIA, because the environment can be a more decisive issue for the creation of project alternatives. Vimal et al. (2012) highlight that the assessment of natural environment vulnerability facilitates the definition of conservation priorities based on their conservation value and their susceptibility of degradation. Even though the differences in definitions and approaches, most of scientist agree at pointing out the importance of the environmental vulnerability assessment as a valuable source of information in decision making processes that involve environmental management.

Vulnerability is a term used differently in many context and can be interpreted in many different ways (Wang et al. 2008; Kværner et al. 2006; UNEP and CUAS 2015). The United Nations International Strategy for Disaster Reduction (UNISDR) defines vulnerability as the "characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard" (UNISDR 2009 p.30). Hazard is described as "dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage"(UNISDR 2009 p. 17). The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as the propensity or predisposition to be adversely affected and also includes several concepts such as sensitivity or susceptibility to harm and lack of capacity to adapt (Field et al. 2014).

Several studies have developed methods for studies related to environmental vulnerability assessment. UNEP and SOPAC (2005) developed a natural environment vulnerability index to reflect the extent to which the natural environment of a country is susceptible to damage and degradation, where "natural environment includes those biophysical systems that can be sustained without direct and/or continuing human support" (p. 5). They define vulnerability as "the potential for attributes of any system, human or natural, to respond adversely to events" (UNEP and SOPAC 2005 p.4) and consider three aspects to calculate a vulnerability index for the natural environment (EVI) at country scale: the risks associated with hazards, resistance and acquired vulnerability (damage). This consideration differs from the most internationally accepted conception which considers a risk as the result of the interaction of vulnerability, exposure, and hazard (Field et al. 2014), and not a function of vulnerability.

Other methods have considered also the spatial dimension, such as Wang et al. (2008) and Li et al. (2006) who use remote sensing, GIS and the method of Spatial Principal Component analysis to analyze environmental vulnerability and its changes over time. Kværner et al. (2006) address vulnerability assessment through 3 approaches which depend on the discipline, and suggest that in the case of vulnerability analyses of Natural environment, segmentation of landscape into landscapes-ecological units is preferable. Etter et al. (2006) modeled forest spatial patterns of forest conversion for agricultural land uses in Colombia, which allowed to identify areas and ecosystem types that are vulnerable to deforestation. They considered data of remnant ecosystems, potential ecosystems, climate, rain, moist, slope, soil, distance to towns, rivers and roads, rural population growth rates and protected areas to model forest conversion using logistic regression and classification trees.

Multicriteria decision evaluation associated to geoinformation tools has been widely considered in environmental management and ecological evaluation in researches such as Chou et al. (2007) or Ying et al. (2007) and more recently in environment vulnerability assessment. Huang et al. (2010), for instance used the method of Analytical Hierarchy Process (AHP) to weight the factors and then the PROMETHEE II method to quantify the priority of environmental vulnerability

2.8. Indicators considered in environmental vulnerability assessments

There are many approaches to assess the vulnerability of the natural environment, they depend largely on how the researcher interprets vulnerability as well as the element of the environment to which the assessment is aimed to. The following paragraphs will describe some factors and indicators considered by some researchers as drivers of environmental vulnerability and those hazards that threat environmental degradation in the Amazon region.

Vimal et al. (2012) assessed spatial variability of the vulnerability of three biodiversity descriptors considering the threats due to intensive agriculture, building and road infrastructure, and effects of human population density on a wider scale. In this study, a coefficient was assigned to each type of road as well as to each kind of agricultural land based on the likelihood of turnover and levels of chemicals application. For each threat type, they weighted the threat values by their distance to a given cell within an arbitrary chosen zone of 2 km. The threats in relation to overall human population density were assessed on a larger scale considering an arbitrary buffer of 50 km from the centroid of each municipal district.

UNEP and SOPAC (2005) developed a vulnerability index for the natural environment (EVI) to estimate the overall vulnerability of the environment of a country considering indicators associated to hazards due to weather & climate, geology, geography, ecosystem resources & services and human populations. The biotic indicators, grouped as “ecosystem resources and services”, include indicators on endemic species, introduced species, endangered species, extinct species, natural and regrowth vegetation cover, change in land vegetation cover, roads, areas severely degraded, protected areas, intensive farming, fertilizers, pesticides, biotechnology, fishery, renewable water, air pollution, waste production, waste treatment, industry, spills, mining, sanitation and vehicles, among others. Those indicators are calculated based on the overall characteristics of each country and do not consider the spatial dimension. However, many of the themes agree with those considered by other studies, such as roads or land use/land cover. One weakness of this approach is the fact that it claims to consider information on risks associated with hazards to obtain vulnerability, which differs from the broadly accepted terminology used either by IPCC or UNISDR making it difficult to interpret the criteria and indicators proposed. Huang et al. (2010) combined three watershed-based environmental indicators: sediment, runoff, and nutrient factors to assess the vulnerability of Chi- Jia-Wan Stream watershed in Taiwan to degradation in the quality of the environment.

Narrowing down to the Amazon region, environmental vulnerability is closely related to vulnerability to deforestation, since this is the mayor cause of environmental degradation. Deforestation facilitates the penetration of wildfires, loggers, hunters, miners, fuelwood gatherers, and livestock into forest remnants causing ecological changes (Laurance 2007). In that sense most of the studies related to environmental vulnerability addresses the vulnerability to deforestation.

Two main drivers of deforestation in the Amazon region are infrastructure construction and agricultural expansion (Ochoa-Quintero et al. 2015; Soares-Filho et al. 2006). UNEP and SOPAC (2005) includes roads as an indicator to calculate EVI, while Etter et al. (2006), Vimal et al. (2012) conclude that environmental vulnerability is affected by the distance to the road. Barber et al. (2014) found out that nearly 95% of all deforestation occurred within 5.5 km of roads in the Amazon as shown in figure 6, and highlight the fact that protected areas have much lower deforestation. The vulnerability indicator “presence of intensive agriculture fields” is also pointed out by UNEP and SOPAC (2005); Etter et al. (2006). Vimal et al. (2012) weighted this vulnerability indicator by its distance to a given cell within an arbitrary zone of 2 km.

Yoshikawa and Sanga-Ngoie (2011) point out that navigable rivers are also an important driver of deforestation, since they allow the transport of people and wood, or goods extracted from the forest. Barber et al. (2014) set the distance of strong influence for rivers at 1.0 km.

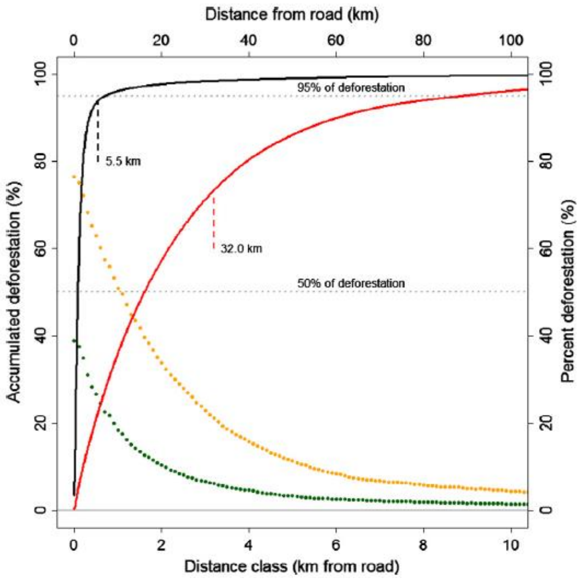


Figure 6. Accumulation of overall deforestation with respect to distance from roads. "Red line is distance to highway network indicating distance at which 95% of deforestation is accounted for and the calculated distance of diminishing influence (Barber et al. 2014 p. 205).

2.9. Spatial Multicriteria Assessment

Spatial Multicriteria decision making refers to the application of multicriteria analysis in the context where the elements of the decision problem such as alternatives, values and criteria have spatial dimensions and allow to enhance spatial multicriteria decision making (Chakhar and Mousseau 2008). It starts with recognition of a decision problem and ends with recommendations to make a decision (Zucca et al. 2008).

Multicriteria methods can be categorized into alternative focused, and value-focused, other authors such as Chakhar and Mousseau (2008) also known as discrete or continuous, respectively. The alternative-focused approach has a discrete number of pre-specified alternatives, then specifies the values and criteria and ends with the evaluation and recommendation of an option. On the other hand the values are the fundamental element for the value-focused approach that determines decision values in a domain of large number of choices (Chakhar and Mousseau 2008; Zucca et al. 2008).

The value-focused approach is based on the definition of criteria, considering the values of the indicators, it develops feasible options to be evaluated according to the predefined value and criteria structure. It is focused on what is desired, rather than on the evaluation of alternatives (Zucca et al. 2008). This approach is based on the building of a criteria tree, whose root is the main goal, and whose leafs are the criteria that together evaluate the performance of this main goal. The branches divide the main goal into partial goals, and subdivide partial goals. Criteria can be either constrains or factors. A constrain represent a feature that is not desirable at all and therefore will have a value of 0 in the final composite index map. A factor is a criterion that contributes to a certain degree to the output. The decision maker's preferences are represented by weights that are assigned to different objective or value functions which translate the variable values into the degree to which a decision objective is achieved (Looijen 2009; Chakhar and Mousseau 2008). Those value functions have values between 0 and 1, where 0 represents the less desirable condition.

Chapter 3. Methods

The methodology followed is focused to produce three (3) main outputs: A technical assessment of the spatial services provided by GeoSUR, an environmental vulnerability assessment and a set of technical elements contained in the INSPIRE directive that can be helpful to improve GeoSUR. The main objective of doing a Spatial Multicriteria Assessment is to have a real case to test the extent to which GeoSUR spatial resources are useful for regional decision making.

Figure 7 shows the workflow describing the activities and the steps followed to produce those three outputs. Based on literature review and the opinion of a professional specialized in environmental studies, a group of target environmental vulnerability indicators is selected. Next, potential useful spatial datasets are found through the catalog service of GeoSUR and the list of available data are evaluated regarding accessibility, applicability and usability. Then, some elements from INSPIRE that can be helpful to improve GeoSUR performance are described. In relation to the case study, after identifying the datasets to be used, criteria are defined and their values are standardized through value functions and then weighted depending on their importance. As a result of the Spatial Multicriteria Assessment, a composite index tree is produced which shows the distribution of environmental vulnerability along the study area.

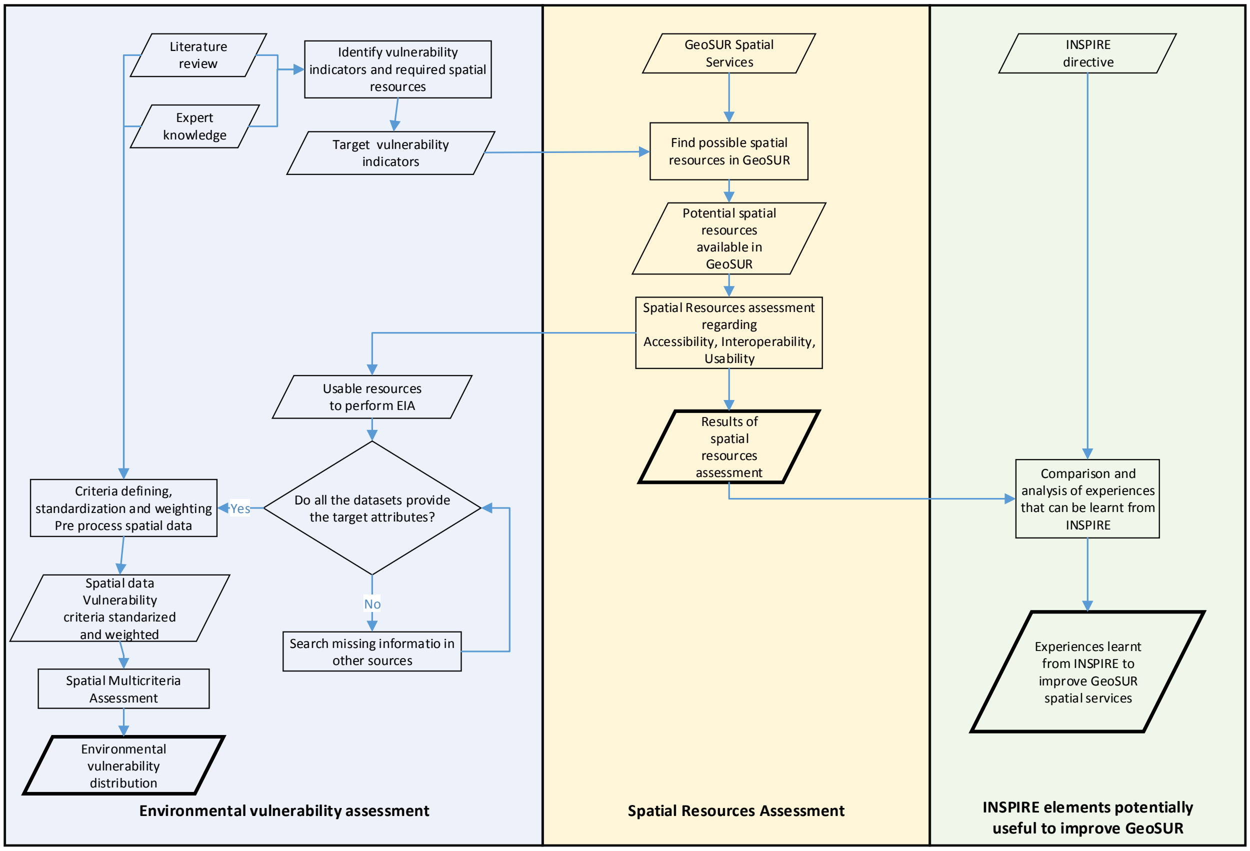


Figure 7. Workflow of activities performed

3.1. Spatial resources Assessment

This study performs a technical assessment of the status of user requirements for spatial data to perform analyses at regional level. From the frame proposed by Georgiadou et al. (2006), it is a 'control' assessment, it considers technical issues using quantifiable measures and non-quantitative instruments, such as users' surveys to assess ultimate outcomes. Since the objective of this evaluation is to provide elements to support GeoSUR improvement as a key entity in the consolidation of the Spatial data of the Americas, it is considered a 'during' evaluation approach (Georgiadou et al. 2006). It considers the general characteristics of GeoSUR as a Spatial Data clearinghouse and also assesses some of the available individual resources. Since it is not possible to assess all the resources offered, an environmental vulnerability assessment is performed as case study, to retrieve part of them.

The state of user requirements for spatial data will be assessed considering indicators for accessibility, applicability and usability.

3.1.1. Accessibility Assessment

Three approaches are developed to assess the level of accessibility to datasets offered by GeoSUR: An evaluation of the architecture of GeoSUR to identify the extent to which it can be considered a spatial clearinghouse; an inquiry performed to potential users of

GeoSUR in order to get a general perception on how user friendly is GeoSUR interface for discovering and retrieving spatial data; and an evaluation to identify the extent to which the services provided by GeoSUR are interoperable in order to access spatial datasets.

The first stage is to identify to which extent GeoSUR follows the general structure of a spatial clearinghouse as defined by Mansourian et al. (2011), based on a geoportal, catalogue services, and spatial services (Figure 8). This step provides a first glance of the extent to which GeoSUR has the technical capability to allow users to access spatial datasets and services. The flowchart in figure 8 describes the criteria considered to identify whether GeoSUR is a spatial data clearinghouse.

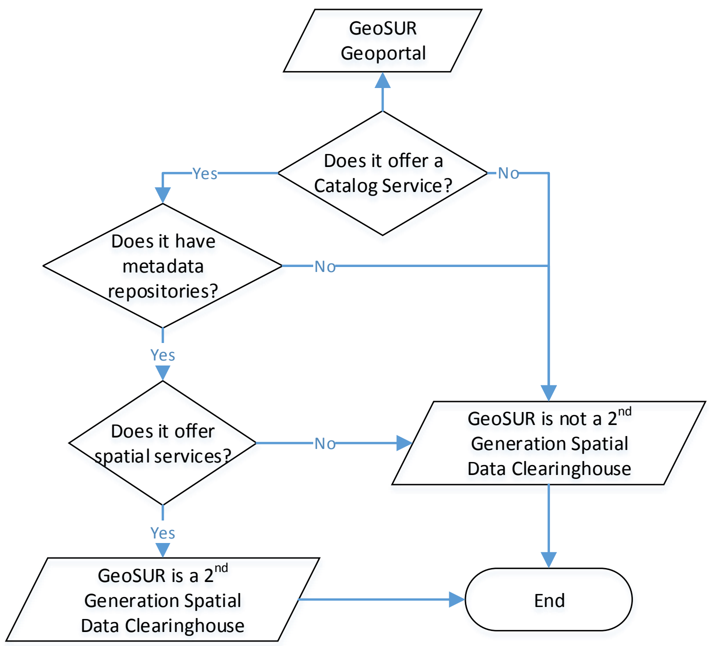


Figure 8. Flowchart to assess whether GeoSUR can be considered as a Spatial Data Clearinghouse

Accessibility refers to limitations to access available spatial resources (Toomanian 2012). Considering that services that enable users to discover, view, download and transform spatial data should be available and easy to use (European Commission 2015; Crompvoets et al. 2004), an inquiry was performed to characterize the overall perception of end users regarding the accessibility provided by the interface of GeoSUR. GeoSUR performed a similar perception survey with participant institutions in 2011 to see what data users and producers thought about the initiative and to identify what motivated them to join GeoSUR rather than assessing the interface to discover and access spatial data.

In the online survey performed during 2 weeks, participated 9 South American professionals from areas such as hydrometeorology, agricultural engineering, geology, land survey, geodesy and environmental engineering considered potential users of the spatial data offered by GeoSUR. The invitation to participate in the survey was sent to 20 acquaintances with background in engineering, geology, hydrology and related areas that work in different countries in South America. A copy of the online survey applied using

Google forms through the link http://goo.gl/forms/PT8g8YoCOv is shown in Annex I. It addresses the indicators shown in table 1, which are selected with the support and knowledge of Dr. Ali Mansourian. The first two indicators aim to identify how easy is to find and handle the search service offered by GeoSUR. Indicators 1.1.3 up to 1.1.5 are related to metadata, how complete and useful it is for users. The last indicator refers to the capability to download the required resource by the user.

Table 1. Indicators to assess the perception about GeoSUR regarding accessibility

ID	Indicator	Description	Domain
1.1	**Perception of potential GeoSUR users about accessing spatial data**		
1.1.1	Easiness to find the catalog	How easy is for the respondent to find the catalog service	•Could not find it •Extremely difficult •Difficult •Easy •Very easy
1.1.2	Easiness to use the searching tools	How easy is for the respondent to use the searching tools	•Could not use them •Extremely difficult •Difficult •Easy •Very easy
1.1.3.	Easiness to find associated metadata	How easy is to find associated metadata for the respondent	•Could not find any metadata file •Very difficult •Difficult •Easy •Very easy
1.1.4.	Completeness of metadata	How complete the metadata is for the respondent	•Could not understand the content of metadata •Incomplete •Complete (Only for basic information) •Very complete
1.1.5	Usefulness of metadata	How useful the metadata is for the respondent	•Could not understand the content of metadata •Useless •Useful •Very useful
1.1.6	Easiness to obtain the resources of interest	How easy is for the respondent to obtain the resource of interest	•Do not know how to download it •Very difficult •Difficult •Easy •Very easy

The spatial datasets found in GeoSUR through the catalog service and the list of available data are evaluated considering the indicators shown in table 2.

The indicators grouped in the numeral 1.2 (table 2) describe the accessibility to metadata through discovery services. Those indicators associated to metadata such as availability, compliance to standards and metadata delivery format are common for accessibility and applicability. From the point of view of accessibility, the availability of standardized discovery metadata with general information about the data, such as geographical coverage, nature, content and scope, facilitates the discovery of resources. In addition, metadata delivered in a friendly interface, facilitates the end user to understand the content of the dataset. The compliance of datasets metadata to ISO 19115 and of services metadata to ISO 19119 was checked by using the software CatMDEdit 5.0. CatMDEdit is an open source metadata editor tool, with special focus on the description of geographic information resources. It was developed by the University of Zaragoza and the GeoSpatiumLab (GSL) in the frame of an Initiative from the National Geographic Institute of Spain (IGN).

Indicators grouped under numeral 1.3 are related to the easiness of obtaining the datasets. They describe the required procedures to get access to the dataset as well as the time that it takes. The numeral 1.4 allows to establish relationships between the type of spatial data producer and the accessibility to datasets.

Table 2. Indicators for the Accessibility assessment

ID	Indicator	Description	Domain
1.2	**Accessibility to metadata through discovery services**		
1.2.1	Discovery of dataset through the catalog service	Indicates whether the resource was found by using the GeoSUR catalog service	Yes/No
1.2.2	Availability of metadata associated to the dataset	Indicates if there is available metadata to describe the dataset	Yes/No
1.2.3	Dataset metadata compliance to ISO 19115	Indicates if the metadata associated to the dataset is compliant to ISO 19115	Yes/No
1.2.4	Format presentation of dataset metadata	Indicates in which formats the dataset metadata is served to user, since xml is not user friendly to interpret it.	• xml • html • xml and html
1.2.5.	View services associated to the dataset	Indicates if there is any view service to preview the dataset	Yes/No
1.2.6	Availability of metadata associated to the view services	Indicates if there is available metadata to describe the view service	Yes/No
1.2.7	View service metadata compliance to ISO 1911	Indicates if the metadata associated to the view service is compliant to ISO 19119	Yes/No
1.2.8	Accessibility to view service from Geoportal	Indicates if the metadata associated to the view service is compliant to ISO 19115	Yes/No
1.2.9	Format presentation of service metadata	Indicates in which formats the service metadata is served to user, since xml is not user friendly to interpret it.	• xml • html • xml and html
1.3.	**Easiness to obtain the dataset**		
1.3.1	Procedure to download the resource	Indicates how the dataset can be obtained	• Direct link in GeoSUR • Order online • Link in resource owner's website
1.3.2	Time elapsed since ordering the resource until it is obtained	When a dataset has to be ordered online, it indicates the elapsed time since it is required, until when it is obtained.	Days
1.4	**Spatial dataset producer level**		
1.4.1	Type of spatial producer level	Indicates the nature of the entity that creates the dataset	•National • Regional •Global

3.1.2. Applicability Assessment

Applicability assessment considers three indicator groups: Availability of metadata for evaluation and use, dataset inner technical characteristics, and data quality. The first group indicators assess the availability of metadata that allow to identify the dataset conformance with the interoperability target specifications (Mohammadi et al. 2010). The interoperability target specifications are defined by the user and are described by metadata required for interoperability, also called metadata for evaluation and use. Metadata for evaluation and use (also called for exploration and exploitation) provide fundamental information for interoperability among datasets as well as to identify whether they fit for a given purpose. It shall include information regarding coordinate reference systems, temporal reference system, encoding and topological consistence (European Commission 2010).

The second group of indicators describe technical frame characteristics that are useful to human and machine in the proper use of the geospatial data (GSDI 2012). They include distribution format, semantics, data quality, projection and geometric structure (Toomanian 2012). In the frame of the current study, only dataset formats, coordinate system, data quality and geometrical structure are considered. Differences among formats, coordinate systems and geometric characteristics increases the number of processes required to prepare data. In addition performing projection operations over the datasets may produce displacements in relation to the original ones. Those factors plus incompleteness of attributes limit interoperability among datasets and therefore their level of applicability. Due to the lack of time, this research does not assess semantic interoperability as influencing factor for accessibility. Although this fact does not affect the current research, because the spatial datasets chosen for each indicator of environmental vulnerability cover the entire the study area and no junctions must be done among datasets, semantic interoperability should be considered in further studies.

All the resources assessed for accessibility were considered for the applicability assessment. Table 3 describes the assessed indicators.

Table 3. Indicators for the applicability assessment

ID	Indicator	Description	Domain
2.1	**Availability of metadata for evaluation and use**		
2.1.1	Metadata containing distribution format	Indicates if the metadata contains information regarding distribution format	Yes/No
2.1.2	Metadata containing geographic reference system	Indicates if the metadata contains information regarding the geographic reference system or/and projection	Yes/No
2.1.3	Metadata containing spatial scale	Indicates if the metadata contains information regarding the spatial extent of the dataset	Yes/No
2.1.4	Metadata containing temporal resolution	Indicates if the metadata contains information regarding the temporal resolution of the dataset	Yes/No
2.2	**Dataset technical characteristics**		

ID	Indicator	Description	Domain
2.2.1	Distribution format	Indicates the format in which the dataset is distributed	•SHP •GML •TIFF •FGDBR •GDB
2.2.2	Reference system	Indicates the coordinate reference system and/or projection in which the dataset is delivered	World coordinate reference systems and projections
2.2.3	Quality regarding to completeness of data	Describes the completeness of the dataset in terms of its attributes.	Free description
2.2.4	Geometric structure	Describes the compatibility of geometries among datasets	Free description

3.1.3. Usability Assessment

The usability assessment evaluates to which extent the resource characteristics and content fit the user requirements so the user make the decision to use it or not. It first describes the characteristics considered to use or reject each one of the datasets to perform the environmental vulnerability assessment. These characteristics such temporal dimension, spatial dimension, resource description and restrictions of use plus the results obtained for the applicability and accessibility assessment were the criteria consider to use or reject each dataset.

This sutdy will only assess the extent to which the resources provided by GeoSUR are useful to perform an environmental vulnerability assessment for the IIRSA Amazon region. There are considered four groups of indicators: temporal dimension, spatial dimension, resource content and restrictions of use. Temporal and spatial dimension allow to identify if the dates range, spatial coverage and resolution are adequate to the target user requirements. The resource description basically describes the extent to which the description of the dataset provided in the metadata is enough to understand its full meaning, or if it is required to find other resources to get additional documentation, and restrictions of use refer to the establishment of limitations associated to commercial use, copyright or security issues.

Table 4. Indicators considered to perform the usability assessment

ID	Indicator	Description	Domain
3.1	**Temporal dimension**		
3.1.1	Date	Indicates the date associated to the dataset	Date • No date associated
3.1.1	Type of date	Indicates the type of date associated to the dataset (Domain based on CI_DateTypeCode (Standardization 2014)	• Creation • Publication • Revision • No type of date associated
3.1.1	Temporal resolution	Indicates the temporal resolution of the dataset	• Date • No temporal resolution associated

ID	Indicator	Description	Domain
3.2	**Spatial dimension**		
3.2.1	Spatial coverage	Indicates the percentage of the study area completely covered	% Values
3.2.2	Scale/Equivalent scale	Indicates the scale (or equivalent scale for raster) of the dataset	Scales
3.3	**Resource description**		
3.3.1	Metadata description is clear enough to understand the dataset contents	It indicates if the description of the dataset provided in the metadata is enough to use it or reject it	Free description
3.4	**Restrictions**		
3.4.1	Restrictions of use	Indicates the restrictions of use described in the metadata	Free description

3.2. Spatial Multicriteria Assessment

This study applies a value-focused approach, since environmental vulnerability assessment has to deal with several decision values (Zucca et al. 2008). It comprises the definition of a set of constraints and objective functions which are weighted depending on the decision maker's preferences. The first step is to identify the main goal as well as the hierarchy of sub goals. Then a criteria tree is built based on the criteria and indicators that measure the performance of the sub goals. In order to make criteria comparable with each other, the values must be standardized through a value function. The criteria within each sub-goal as well as groups of criteria (sub-goals) are weighted based on stakeholder preferences (Looijen 2009) and/or expert opinions. Figure 10 describes the Spatial Multicriteria assessment performed within this research in order to produce environmental suitability maps.

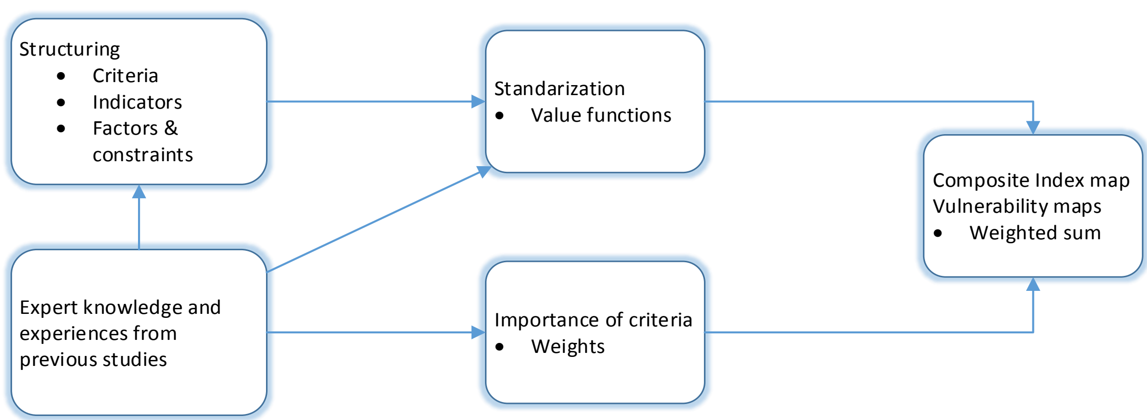


Figure 9. Steps of spatial Multicriteria Evaluation to produce environmental vulnerably maps, based on Looijen (2009)

The environmental vulnerability assessment is performed using the SMCE module of the software ILWIS 3.8.4. It allows to identify to which extent the spatial datasets provided by GeoSUR are suitable to be analyzed in the context of free software which use has been rising in recent years.

3.2.1. Structuring step: Criteria tree building

When defining the Criteria tree, the main goal of the assessment is to identify the current natural environmental vulnerability distribution in the IIRSA Amazon region. Table 2 shows the criteria tree designed to perform the assessment of the natural environment. The main objective of the SMCA is to identify the current environmental vulnerability distribution in the IIRSA Amazon region. There are three main sub-goals. The first one refers to the vulnerability due to the closeness of areas with presence of people and traffic. Since roads and navigable rivers allow transportation of people and goods, areas closer to them and those closer to urban areas are more accessible for hunting, cutting down of trees, animal's extraction for traffic and road killing of animals (Laurance et al. 2009).

The second sub goal which in turn is a factor, refers to the reduction of environmental vulnerability inside protected areas, due to the regulations that restrict human access and intervention (Barber et al. 2014).

The third sub goal refers to the vulnerability due to past and present anthropic intervention on the natural environment, and contains three criteria. The first considers that the percentage of crop coverage increases vulnerability in the surrounding areas since agriculture implies the use of chemical fertilizers and pesticides which destroy the natural environment (UNEP and SOPAC 2005). The second criterion of this sub goal indicates that the conservation status of an ecoregion affects vulnerability, since the more degraded it is, the resilience capacity of the natural environment is lower. The third one is related to the vulnerability of areas near to deforested zones, since previous deforestation increases vulnerability of surrounding areas at facilitating the penetration of wildfires, loggers, hunters, miners, fuelwood gatherers, and livestock into forest remnants (Laurance 2007).

Table 5. Group of objectives considered for the SMCA

Main Goal	Sub-goal	Factors
1. Identify the current natural environmental vulnerability distribution in the IIRSA Amazon region.	1.1. The closer an area is to areas with people presence or traffic, the more vulnerable it is	1.1.1. The closer a road, the more vulnerable to environment degradation the area is, because roads facilitate access of loggers or hunters to the natural areas (Barber et al. 2014)
		1.1.2. The closer to a navigable river, the more vulnerable to environment degradation the area is, because the loggers can access the area easily through the river *(Barber et al. 2014)
		1.1.3. The closer to an urban area, the more vulnerable to environmental degradation the area is, because hunters or loggers can access easily to natural areas (Vimal et al. 2012)
	1.2. Areas located outside protected areas are more vulnerable to environmental degradation because there is no law that regulate human intervention there (Barber et al. 2014)	

Main Goal	Sub-goal	Factors
	1.3. The more direct human impacts an area has, the more vulnerable it is to be degraded	1.3.1. The more the area is covered by crops the more vulnerable to environmental degradation it is, because fertilizers and pesticides used can affect natural environment (UNEP and SOPAC 2005)
		1.3.2. The less conserved an ecoregion is, the more vulnerable it is to environmental degradation because the resilience capacity of the natural environment is lower (UNEP and SOPAC 2005)
		1.3.3. The closer an area to a deforested area the more vulnerable it is to degradation because it facilitates access of hunters or loggers, it reduces wetness of vegetation in the forest edges facilitating penetration of wildfires (Laurance 2007)

*Since GeoSUR does not offer a dataset with information about navigable rivers, so in it is assumed that those rivers under the class “continental water body border” are navigable.

3.2.2. Standardization

Since an SMCA considers several indicators with different values and units of measurement, they need to be standardized to the same unit of measurement (value scores) through a value function. The value score is dimensionless and ranges between 0 and 1. A value of 1 indicates the high objective achievement, while a value of 0 indicates the worst performance.

Different standardization functions are available on ILWIS depending on the domain of the map or attribute column. When the variable is represented by a value domain ILWIS offers six kind of standardization functions: Maximum, interval, goal, convex, concave and combination. When the input domain represents classes, they have to be reclassified in performance scores between 0 and 1 as well.

Table 6 shows a summary of the standardized values for each input map. The definition of the function values should also consider the knowledge of experts in vulnerability assessment for the study area. However due to limitations in time, the difficulty to find the collaboration of professionals with such background, and the fact that the case study is a tool to assess GeoSUR spatial resource, the function values were defined based on previous studies and personal knowledge.

The function values for the criteria 1.1.1 and 1.1.2 were chosen based on the results obtained by Barber et al. (2014) for deforestation. Considering the cell size at which the SMCE was performed (300 m), the vulnerability at the road distance of 0 has the worst vulnerability value of 0. Since there was not criteria found to define a function value for vulnerability due to distance from urban areas, the results for road distances were adapted including a value of 1 for the urban area as itself. The function values for the criteria 1.2, 1.3.1 and 1.3.2 were defined based on personal knowledge, since no literature is found to this respect. Figures 11 up to 13 show the function values provided by the interface of the SMCE module of ILWIS for the criteria associated to distances.

Table 6. Standardized values for all the inputs

sub goals	**Factor / criteria**	**Standardized values** **Input value = Standardized value**
1.1. The closer an area is to areas with people presence or traffic, the more vulnerable it is	1.1.1. The closer a road, the more vulnerable to environment degradation the area is, because roads facilitate access of loggers or hunters to the natural areas	Distance 0 = 0 Distance 32 km = 0.22 Distance 100 km = 1 Based on Barber et al. (2014)
	1.1.2. The closer to a navigable river, the more vulnerable to environment degradation the area is, because the loggers can access the area easily through the river	Distance 0 = 0 Distance >1 km = 1 (Barber et al. 2014)
	1.1.3. The closer to an urban area, the more vulnerable to environmental degradation the area is, because hunters or loggers can access easily to natural areas	Preliminary Distance 0 =1 Distance 0-32 km = 0.22 Distance 100 km =1 Adapted from distances provided by Barber et al. (2014)for roads
1.2. Areas located outside protected areas are more vulnerable to environmental degradation		Protected area = 1 Non Protected area = 0
1.3. The more direct human impacts an area has, the more vulnerable it is to be degraded	1.3.1. The more the area is covered by crops the more vulnerable to environmental degradation it is, because fertilizers and pesticides used can affect natural environment	Rainfed croplands = 0
		Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%) = 0.2
		Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%) = 0.3
		Other type of land cover = 1
	1.3.2. The less conserved an ecoregion is, the more vulnerable it is to environmental degradation because the resilience capacity of the natural environment is lower	Critical/Endangered conservation status = 0
		Vulnerable conservation status = 0.5
		Relatively Stable/Intact conservation status = 1
	1.3.3. The closer an area to a deforested area the more vulnerable it is to degradation because it facilitates access of hunters or loggers, it reduces wetness of vegetation in the forest edges facilitating penetration of wildfires	0 meters = 0 420 meters = 1 Based on Laurance (2007)

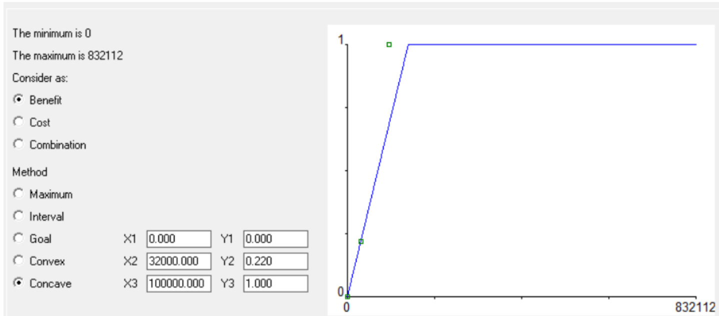


Figure 10. Function value for criteria related to distances from roads (1.1.1)[2]

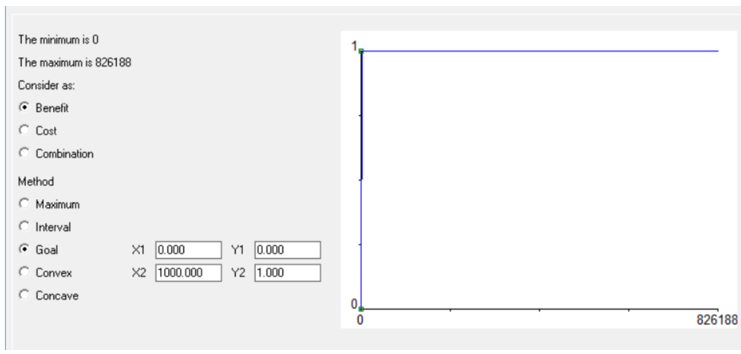


Figure 11. Function value for criteria related to distance from rivers (1.1.2)

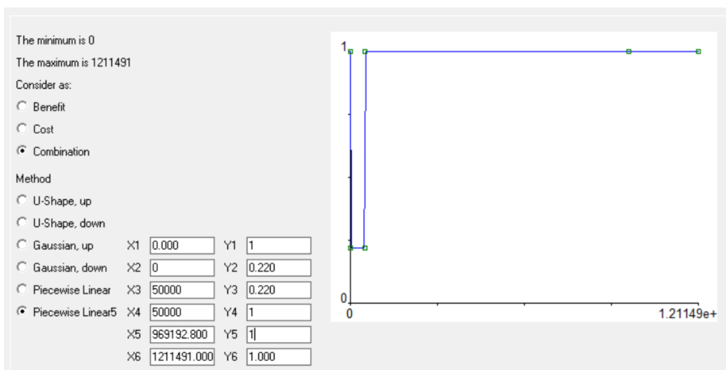


Figure 12. Function value for criteria related to distance from urban areas (1.1.3)

3.2.3. Weighting

The weights assigned to each one of the criteria and sub goals considered are defined mostly on personal experience and knowledge gathered from literature, since it became difficult to find an expert with background in environmental vulnerability and the fact that the SMCA is a tool to achieve the main goal of assessing GeoSUR.

Figure 14 shows the criteria tree with its associated weights as displayed by ILWIS interface.

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[2] **This is a concave function, but due to the scale of the charts displayed by ILWIS it looks linear.**

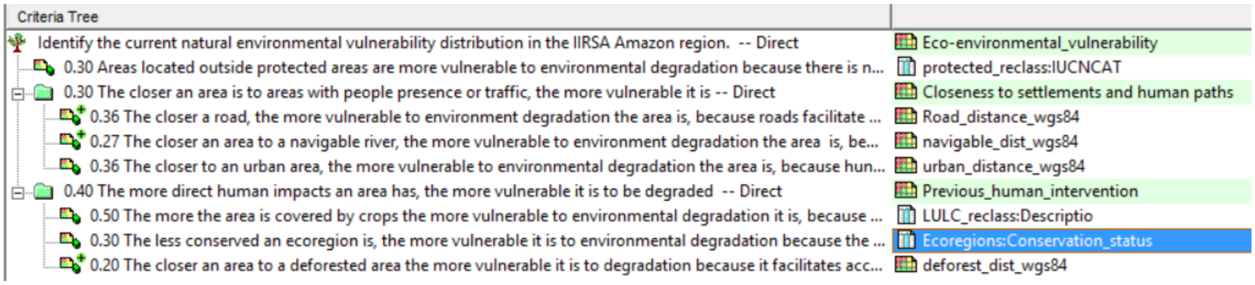


Figure 13. Temporal image of criteria tree as shown by INSPIRE interface

3.2.4. Composite index maps calculation

The SMCE module of ILWIS allows to calculate a composite index maps for each sub goal and one for the main goal, which contains the environmental vulnerability for all criteria. Their values range from 0 to 1 and are based on the score values and weights assigned to the criteria tree. Cells with values of 0 represent more vulnerable areas and those with value 1 represent those areas no vulnerable under the criteria considered. The calculation is based on the Weighted Sum method, represented by the equation1:

Equation 1

$$S_j = \sum_{i}^{n} W_i \times S_{ij}$$

Where S_j is the weighted score for cell j in the overall suitability map, W_i is the weight for the i-th input map, and Sij is the score for the j-th pixel in the i-th map. The higher the weighted score S_j, the higher the suitability(Looijen 2014).

3.3. Spatial Data processing

All spatial data is pre-processed to make them suitable to perform the Spatial Multicriteria Assessment (SMCA) in the software ILWIS 3.8. These pre-processing steps are performed initially in ArcGIS, since some of the resources obtained are in ESRI formats such as GDB or FGDBR.

Those resources distributed in format shape file are directly imported to ILWIS through the import tool and are rasterized. The raster files distributed as TIFF format, are imported through the tool Import –GDAL-Raster. All the raster datasets are resampled (Bilinear method) based on the cell size, spatial extension and coordinate system of the Land cover raster (300 m). Since ILWIS requires that those source maps to perform Euclidean distance calculation must be projected, the datasets associated to roads, navigable rivers, urban areas and deforested areas are projected to WGS_1984_Web_Mercator_Auxiliary_Sphere. Since the smallest resolution among the datasets was 300 m, all the resources were up-scaled to this resolution in order to perform the SMCE.

Those raster distributed in the ESRI file geodatabase raster format FGDBR, have to be converted into TIFF format through ArcGIS, and then imported into ILWIS.

Chapter 4. Results

Obtained results for the assessment of the status of user requirements for spatial data are described in terms of accessibility, applicability and usability. For the environmental vulnerability assessment, the result is a composite index map, and a summary of the vulnerability of the natural environment per country.

4.1. Accessibility assessment

The results for the accessibility assessment are given in terms of the three approaches described in section 3.1.1: An evaluation of the architecture of GeoSUR to identify the extent to which it can be considered a spatial clearinghouse; an interview performed to potential users of GeoSUR in order to get a general perception on how user friendly is GeoSUR interface for discovering and retrieving spatial data; and an evaluation to identify the extent to which the services provided by GeoSUR are interoperable in order to access spatial datasets.

The results of the steps described in the figure 8, indicate that GeoSUR can be considered a second generation Spatial Data Clearinghouse. It has a Catalog Service compliant to OGC Catalog interface standards that harvests metadata from member organizations and store them in a central database where it can be consulted by users later on (Anthony and Van Praag 2008). GeoSUR offers access to spatial services produced by Latin American and Caribbean agencies that follow OGC standards such as WMS, WFS and CSW. In 2013 GeoSUR developed a Topographic processing service which allows users to derive 1 arc-second resolution derivative products from the SRTM level-2 DEM (GeoSUR program and USGS 2015). So far it does not use OGC protocols.

4.1.1. Perception survey

The inquiry performed to potential users of spatial information available in GeoSUR provides an overview of the extent to which its interface facilitates accessibility to spatial resources. The level of expertise on Geoinformation technologies was evenly distributed among basic and expert knowledge (5 and 4 respondents respectively). In general for experts it was easy to find the discovery service, and 6 out of 9 respondents considered easy and very easy to use the searching tools available. Since 2 users with basic knowledge in Geoinformation Science were not able to find the searching data link, they did not answer to the following questions.

Table 7. Results for easiness to find the catalog, classified based on the level of knowledge on Geoinfromation technologies

Easiness to find the "search for data" link	Count of answers
Expert	**5**
Could not find it	0
Extremely difficult	0
Difficult	1

Easiness to find the "search for data" link	Count of answers
Easy	1
Very easy	3
Basic knowledge	**4**
You could not find it	2
Extremely difficult	0
Difficult	0
Easy	0
Very easy	2

Table 8. Results for easiness to find associated metadata based on the level of knowledge on Geoinfromation technologies

Easiness to find associated metadata	Count of answers
Expert	**5**
Could not use them	0
Extremely difficult	0
Difficult	1
Easy	4
Basic knowledge	**2**
Could not use them	1
Extremely difficult	0
Difficult	0
Easy	1

The majority of respondents that are able to find a metadata file consider that it is complete only for basic information, table 9 indicates the distribution of answers among experts and those with basic knowledge. Table 10 summarizes how useful users find the available metadata.

Table 9. Results for completeness of metadata, classified based on the level of knowledge on Geoinfromation technologies

Completeness of metadata	Count of answers out of 9
Expert	**5**
Could not understand the content of metadata	0
Did not understand the content of metadata	1
Complete (Only for basic information)	4
Very complete	0
No answer	0
Basic knowledge	**4**
Could not understand the content of metadata	0
Did not understand the content of metadata	0
Complete (Only for basic information)	1
Very complete	0

No answer	3

Table 10. Results for usefulness of metadata, classified based on the level of knowledge on Geoinfromation technologies

Usefulness of metadata	Count of answers
Expert	**5**
Useful	2
Very useful	1
You did not understand the content of metadata	2
Could not understand the content of metadata	0
Basic knowledge	**4**
Useful	1
Very useful	0
You did not understand the content of metadata	0
Could not understand the content of metadata	0
No answer	3

At trying to obtain the resource of interest 3 out of the 6 respondents that provide an answer indicate not to know how to do so, and 2 of them find the task difficult or very difficult, (Figure 14)

Table 11. Results for easiness to get the resource, classified based on the level of knowledge on Geoinfromation technologies

Easiness to get the resource of interest	Count of answers
Expert	**5**
You do not know how to download it	2
Very difficult	0
Difficult	1
Easy	2
Very easy	0
No answer	0
Basic knowledge	**4**
You do not know how to download it	1
Very difficult	1
Difficult	0
Easy	0
Very easy	0
No answer	2

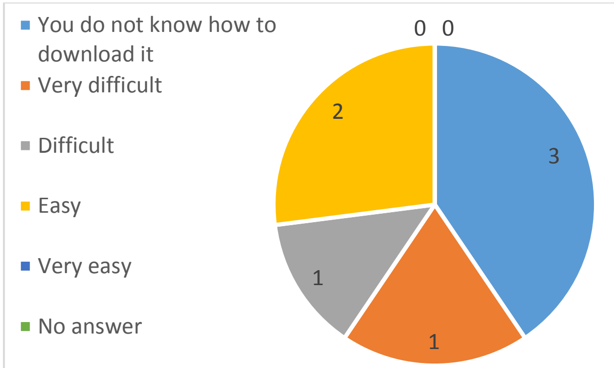


Figure 14. Users' perception regarding easiness to get the resource

Additionally participants indicated comments regarding the following issues:

- The metadata format is not user friendly to read.
- The platform sped is relatively slow.
- The option for buying the information is not easy to find, and the option to add resources to a shopping cart, is not available.
- Search filters do not result useful to search data
- The website does not seem user friendly to people with limited knowledge on handling spatial information. It is recommended to implement tutorial to use the website.
- The website is easy to use and contains adequate information on spatial resources

4.1.2. Spatial Resources assessment

The search service of GeoSUR is used to find possible dataset to associate to each criteria considered in the environmental vulnerability assessment. As discussed in section 3.1.1, these 39 spatial resources were assessed for accessibility. The results of the assessment regarding accessibility to metadata through discovery services are shown in table 12 and figure 16. Most of the resources were found through the catalog service, but one with information about deforested areas was found in the list of available dataset available in GeoSUR website.

In general the results obtained after performing a search operation are shown as two main categories: web map services and datasets. It means that the obtained results are not provided in terms of datasets associated to web services, but rather as two different kind of retrieved records. Thus, those resources which have metadata associated to the datasets do not have metadata associated to the view service, and vice versa. Although 72% of the resources provide a link to access the view service, only 56% actually allow to preview the spatial resource.

Regarding the format in which metadata is served, 100% of the resources provide metadata in an html user friendly format, while 97% provide it in XML format.

Table 12.Results for accessibility to metadata through discovery services

Accessibility to metadata through discovery services		
Indicator value	**Count**	**Percentage of total resources**
Resources found through the catalog service	39	100%
Resources with dataset metadata	27	69%
Resources whose dataset metadata is compliant to ISO 19115	25	64%
Resources whose dataset metadata is served in xml format	26	67%
Resources whose dataset metadata is served in html format	27	69%
Resources with a view service	22	56%
Resources with a WMS	22	56%
Resources with view service metadata	12	31%
Resources whose view service metadata is compliant to ISO 19119	12	31%
Resources which have a link to access the view service from GeoSUR	28	72%
Resources for which view service metadata is served in xml format	17	44%
Resources for which view service metadata is served in html format	17	44%

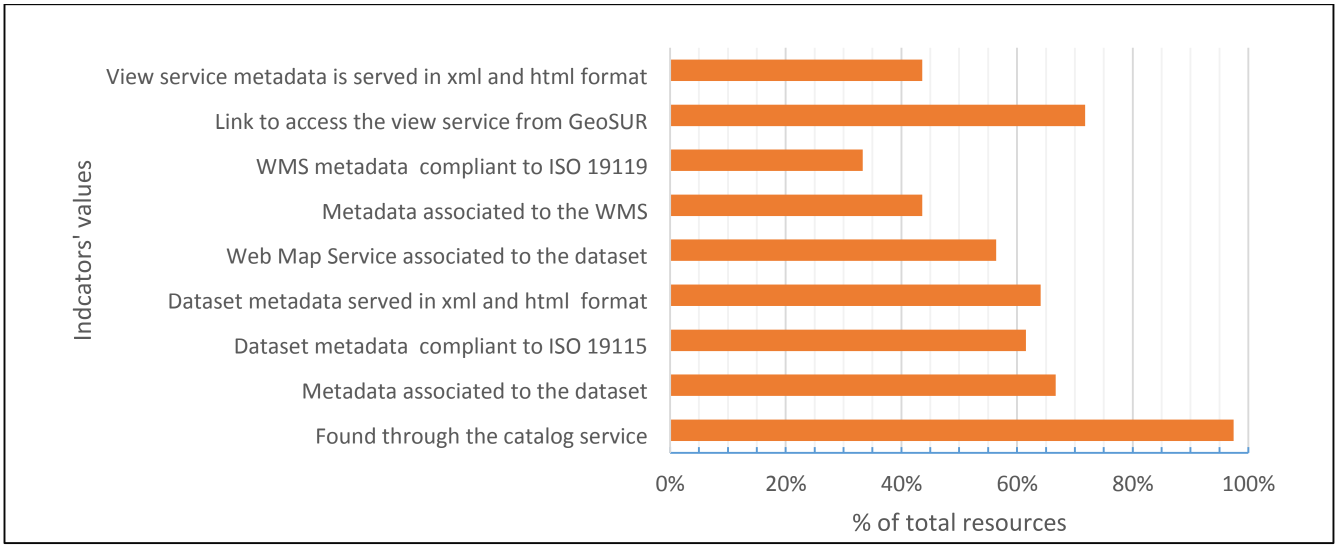


Figure 15. Results for accessibility to metadata through discovery services

The indicator values related to the easiness to obtain the dataset are summarized in table 13 and figure 17. Those resources that were obtained either from GeoSUR directly, the owner's website or via email correspond to 69% of the total considered for accessibility. Half of the resources ordered online were delivered via email with no cost, 90% of them were delivered within 10 days since the requirement was performed. In general those resources owned by regional organizations were easier to get than those belonging to national entities.

Although the reply from the Ecuadorian Spatial Institute was within one day of ordering the resources, they could not be obtained, because the Entity that created them disappeared some years ago. The requirement was sent to the Ministry of the Environment, however there has not been any reply to date. For 33% of the resources ordered online there was not reply from the Organizations responsible of them as indicated in the metadata file. Annex 2 shows the values of each one of the indicators assessed for all the resources assessed.

Table 13. Results for easiness to obtain metadata through discovery services

Easiness to obtain the dataset		
Indicator value	**Count**	**Percentage of total resources**
There is a direct link in GeoSUR to download the metadata	14	36%
The resource has to be ordered online	24	62%
There is a link in the resource owner's website to download it	1	3%
Resources delivered within 10 days since being ordered	11	28%
Resources delivered within 10 and 20 days since being ordered	1	3%
Resources that could not be obtained	12	31%
Resources for which no reply was obtained after ordering them	8	21%

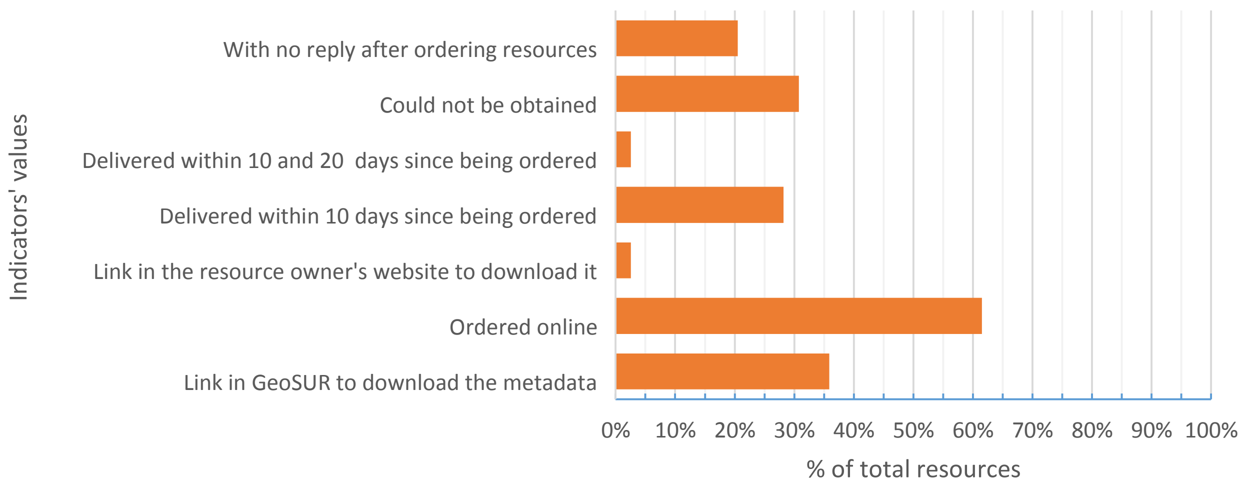


Figure 16. Results for Accessibility related to easiness to obtain a dataset

Figure 18 shows the results for the indicator 1.4.1, which relates the datasets that could be obtained and the nature of their owner institution. The fact that GoeSUR provides access to download most of regional datasets implies that they are easily to get that those owned by national entities.

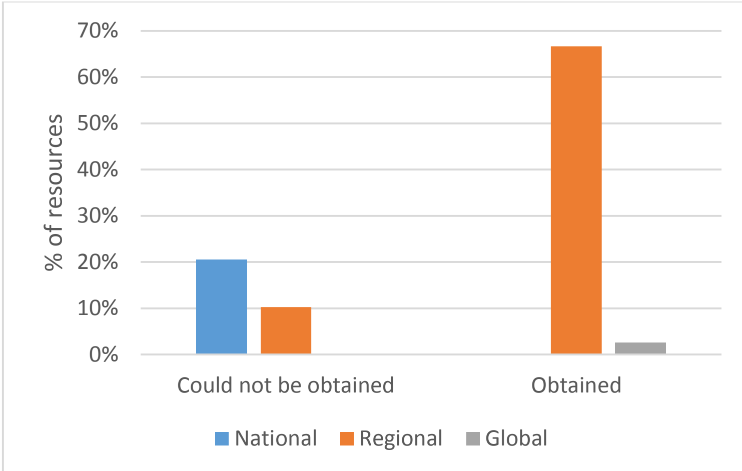


Figure 17. Relationship between the type of resource and the accessibility to the dataset

Accessibility is strongly affected by the limitations to download services specially regarding to data produced by national entities. This happens mainly because data producers do not update contact information in the metadata, and usually it is associated to a person e-mail instead than an institutional one. On the other hand, an important strength of GeoSUR is the accessibility to downloadable regional spatial datasets that assure the coverage of a big percentage of the whole region. Since there is no legal framework in LAC to guarantee the accessibility to datasets produced by all countries, linking information from global and regional open data organizations such as the Global Biodiversity Information Facility (GBIF) can strengthen the access and use of information about themes useful for regional decision making.

4.2. Applicability assessment

All the 39 resources assessed for accessibility were considered in the applicability assessment. The first two indicators related to availability of discovery metadata and compliance to standards was already assessed in the accessibility assessment.

The results regarding the availability of evaluation and use metadata which allow to identify if the resource fits the interoperability targets are described in table 14 and figure 19. Regarding the additional metadata considered key to interoperability, information of coordinate systems, distribution format and spatial extent was the most popular among the studied resources. Although some metadata files do not have values under the tags “spatialResolution” and “temporalResolution” the description of the dataset includes this information.

Table 14. Results for the availability of metadata for evaluation and use

Availability of metadata for evaluation and use		
Indicator value	**Count**	**Percentage of total resources**
Metadata containing distribution format	27	69%

Availability of metadata for evaluation and use		
Indicator value	**Count**	**Percentage of total resources**
Metadata containing coordinate reference system	25	64%
Metadata containing spatial scale under the tag "spatialResolution"	5	13%
Metadata containing spatial scale outside the tag "spatialResolution"	5	13%
Metadata containing temporal resolution under the tag temporalResolution	14	36%
Metadata containing temporal resolution outside the tag "temporalResolution"	8	21%

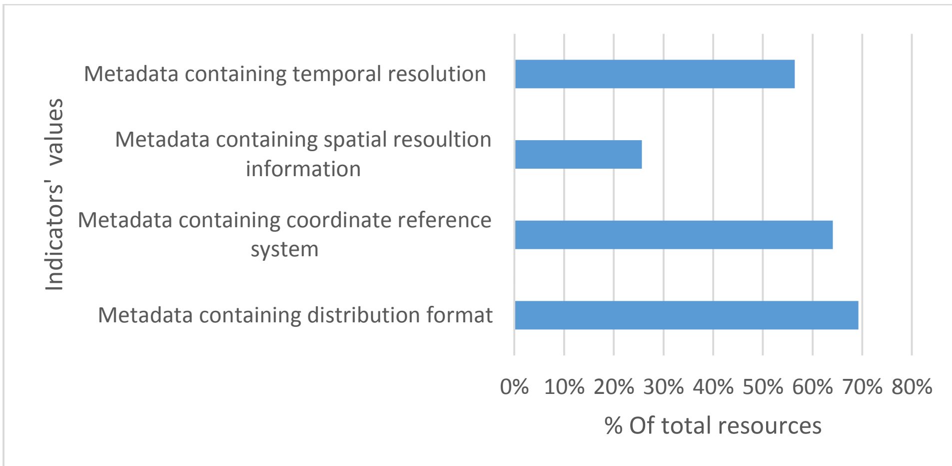


Figure 18. Results for availability of metadata for evaluation and use

Regarding the dataset technical characteristics, figure 19 shows that almost 70% of the resources are distributed in ESRI shapefile format, while 8% of them are distributed in a non-spatial format as indicated by the metadata file[3]. In relation to coordinate systems, figure 20 shows that 77% of the resources are based on WGS 84[4]. Only the resource Ecosistemas terrestres de Suramérica, owned by The Nature Conservancy, is based on a different Geocentric reference system. In relation to data quality, 38% of the datasets report 100% of attributes completeness.

Table 15. Results for applicability in terms of dataset technical characteristics

Dataset technical characteristics		
Distribution format	(See figure 19)	•SHP •GML •TIFF •FGDBR •GDB
Reference system	(See figure 20)	World coordinate reference systems and projections
Attributes completeness 100%	15	38%
Geometrical structure	See description in paragraph below	

[3] Those resources could not be acquired, the information about delivery format comes from metadata
[4] Not including those resources that could not be obtained and did not have information of coordinate system in their metadata.

The different spatial scales used by organizations to create datasets and the lack of definition of common boundaries for fundamental datasets such as country boundaries led to have problems at integrated the spatial resources, especially those areas close to their borders. Thus, it is required to stretch the study area in 0.1 % (around 597.146 ha) in order to guarantee that all the datasets cover it completely.

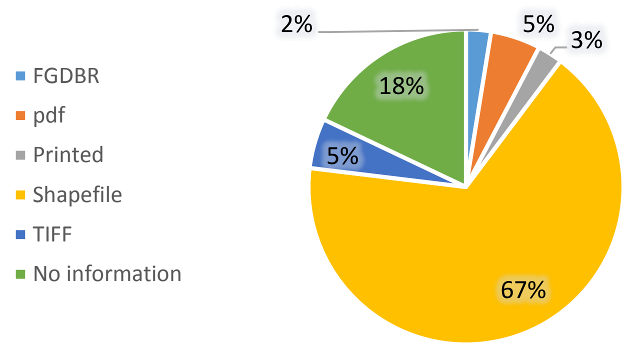


Figure 19. Distribution formats for the resources

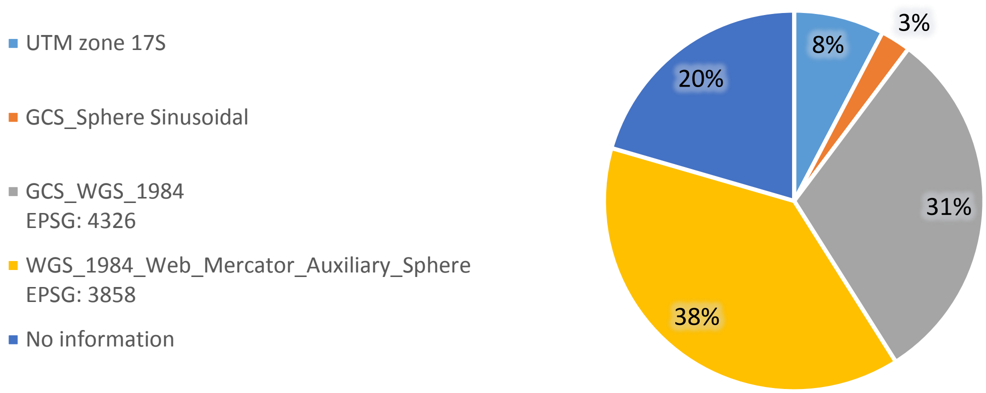


Figure 20. Coordinate reference systems of the resources

4.3. Usability assessment

The assessment of usability is divided in 2 main parts: The assessment of individual resources based on the indicators shown in table 4 and an analysis which explains which resources were selected and why.

The results consider the temporal dimension, spatial dimension, resource content and restrictions of use, the results are summarized in table 16. The temporal dimension allows to identify if the datasets range within the dates required by the user. Most of the metadata elements associated to temporal dimension such as date, and type of date, agree with the INSPIRE directive of metadata with indicates that regarding temporal dimension, metadata should contain elements associated to date of publication, creation, revision or temporal extent. The spatial dimension gives information related to the percentage of coverage of the study area and allows to identify the number of resources required to cover it completely and an appropriate description of the dataset is a key factor to identify to which extent it satisfies the user spatial data requirements.

In terms of restrictions of use, 25 resources have metadata which address this issue, most of them have restrictions when data is used for commercial purposes, and require to be cited for academic and non-profit use.

Table 16. Results of interoperability indicators associated with data usability

Indicator value	Count of resources	Percentage of total resources
Temporal dimension		
Dates from 2004-2008(creation, publication and revision)	14	36%
Dates from 2009-2014 (creation, publication and revision)	25	64%
Creation date	7	18%
Publication date	32	82%
Revision date	1	3%
Temporal resolution	22	56%
Spatial dimension		
Fully coverage of the study area	22	56%
Spatial Coverage of the study area 90%-97%	3	8%
Spatial Coverage of the study area-0.4%-24%	2	5%
No information about spatial coverage	12	31%
Resource content		
Metadata description is clear enough to understand the dataset contents	36	92%
Restriction of use		
Commercial use restricted	22	56%
Copyright	22	56%
No restriction	3	8%
No information about restrictions	2	5%
No dataset metadata available	12	31%

Table 17. Summary of the motives to reject spatial datasets

Motive for resource rejection	Count of resources	% of total resources
It could not be obtained	12	32%
Not considered in the environmental vulnerability assessment	9	24%
There are more recent resources	1	3%
The dataset description was not clear enough to understand its meaning	3	8%
The resource do not cover the entire study area and there are not enough similar resources to cover the rest of it.	6	16%

The criteria considered to design the Spatial Multicriteria Assessment, was the result of adapting the findings in related literature to the data available in GeoSUR. Thus, there is a group of desirable spatial datasets in terms of content, and those available in GeoSUR that fit the best those desirable features. Reddish cells in table 19, show those dataset characteristics that do not fill completely the exact user requirements to perform the case study. Table 18, shows the comparison between the target spatial resources characteristics and the datasets selected to perform the environmental vulnerability assessment. It shows that almost 80% of the target environmental criteria can be covered with the available criteria in GeoSUR. However only three of them can match exactly based on the associated attributes: protected areas, land under agriculture and deforested areas. Regarding the temporal resolution, only 4 target resources match with the implemented ones. When datasets do not have the exact kind of attribute, the environmental vulnerability criteria was simplified in order to avoid that level of detail, as the case of type of roads, rivers and population associated to urban areas. Table 18 also shows that two target environmental criteria could not be considered due to the lack of suitable spatial resources accessible from GeoSUR.

Table 19 provides a summary of the matches between the target datasets characteristics and the found datasets in GeoSUR. It shows that most of the target criteria are found in GeoSUR, however only 3 out of 7 datasets used had a 100% coincidence with the target ones in terms of content, spatial and temporal resolution.

Table 18. Description of datasets and attributes expected, versus the characteristics of the datasets found in GeoSUR

Criteria	Target Datasets characteristics			Selected datasets characteristics			
	Spatial dataset	Associated attributes	Temporal resolution	Dataset name	Attribute chosen	Temporal dimension	% Coverage
The closer a road, the more vulnerable to environment degradation the area is.	Road network	Paved and non-paved roads	2004-2014	Road network	All registered roads	N.I.	100%
The closer to a navigable river, the more vulnerable to environment degradation the area is	Drainage network	Navigability	2004-2014	Drainage network	Type of river: Continental water body border	N.I.	100%
The closer to an urban area, the more vulnerable to environmental degradation the area is	Urban areas	Population	2009-2014	Global land cover map	Urban areas presence	2010 (Revision)	100%
Areas located outside protected areas are more vulnerable to environmental degradation	Protected areas	All protected areas	2009-2014	Boundaries of national protected areas UICNP	All protected areas	2004 (Creation)	100%

Criteria	Target Datasets characteristics			Selected datasets characteristics			
	Spatial dataset	Associated attributes	Temporal resolution	Dataset name	Attribute chosen	Temporal dimension	% Coverage
The more the area is covered by crops the more vulnerable to environmental degradation it is	Land under agriculture	Intensity of agriculture	2009-2014	Global land cover map	% of agriculture per cell	2009	100%
The less conserved an ecoregion is, the more vulnerable it is	Ecoregions	Ecoregion conservation status	2004-2014	South American Ecoregions	Ecoregion conservation status (Not available in the dataset, external information is required)	2004 (Creation)	100%
The closer an area to a deforested area the more vulnerable it is	Deforestation	All deforested areas	2009-2014	Terra-i vegetation change	Areas with loose of vegetation	2009-2014	100%
The more endemic species an area has, the more vulnerable it is	Endemic species	Amount of endemic species per area	2009-2014	Not found			
The more endangered species an area has, the more vulnerable it is	Endangered species	Amount of endangered species per area	2009-2014	Not found			

Table 19. Summary of target resources characteristics, vs implemented resources characteristics

Description	Count
Target environmental criteria	9
Implemented criteria	7
Exact coincidence between desired and implemented attributes	3
Exact coincidence between desired and implemented attributes temporal resolution	4
Implemented resources with no temporal resolution information	2
Implemented resources with no spatial resolution information	3

4.4. Environmental Vulnerability assessment

The Spatial Multicriteria Assessment produced a Composite Index map showing the distribution of vulnerability considering all the criteria indicated in table 6 and two intermediate maps for the two main big groups of criteria. Figure 21 shows the Criteria tree as displayed by the SMCE tool of ILWIS, and figures 22 and map 2 show the Composite index maps obtained after performing the Spatial Multicriteria Evaluation.

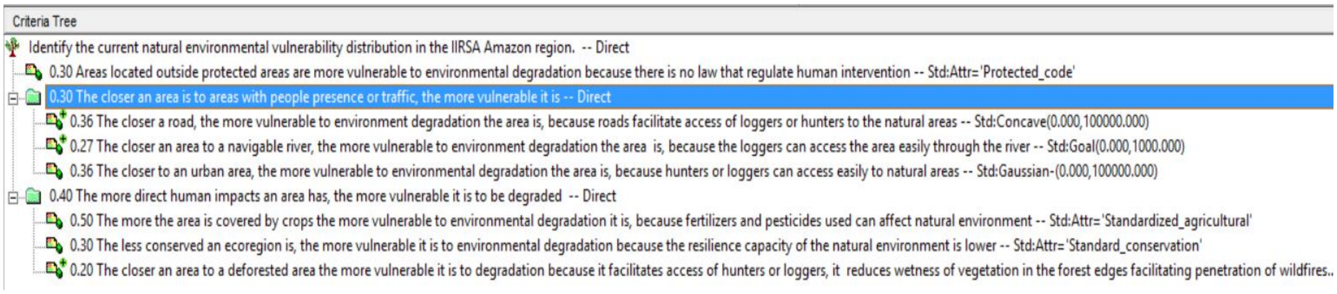


Figure 21. Criteria and weights considered as displayed by the SMCE tool in ILWIS

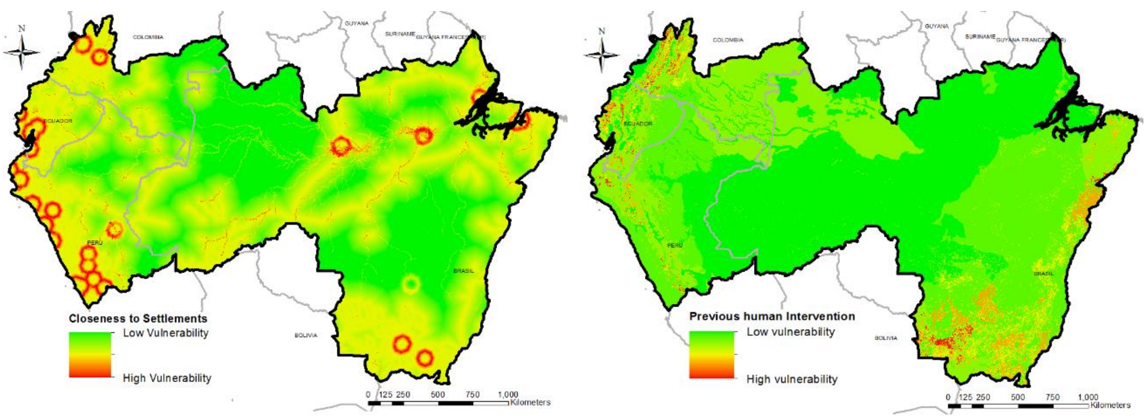
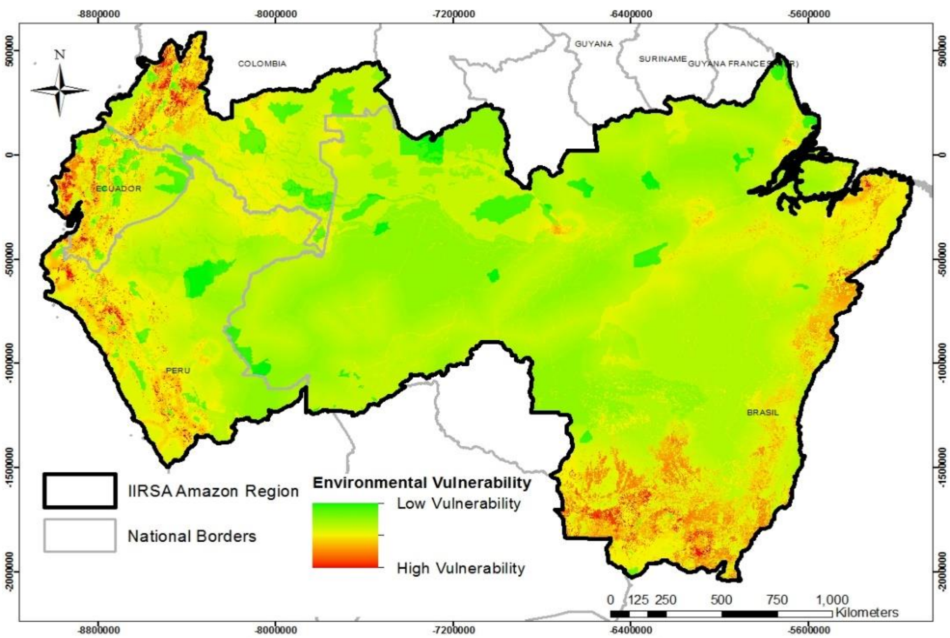
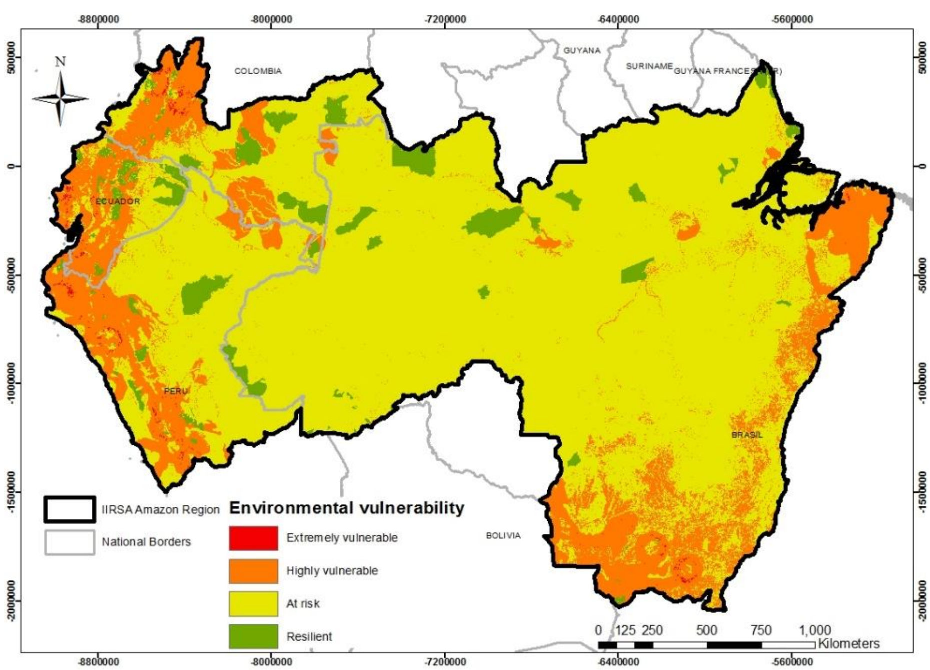


Figure 22. Intermediate Composite Index Maps. The left one corresponds to the criteria group related to the vulnerability due to the closeness to areas with people presence or traffic. The right map corresponds to the group of criteria associated to previous human impacts



Map 2. Final Composite Index Map for environmental vulnerability as displayed by ILWIS

The values for vulnerability were reclassified into 4 classes based on the classiffication defined by (UNEP and SOPAC 2005): Extremely vulnerable, Highly vulnerable, At risk, and Resilient



Map 3. Environmental vulnerability distribution (Classified into 4 classes)

The results show that the status of environmental vulnerability for most of the area is "at risk". The region located within Brazil boundaries is considerable larger than for the other countries which explains the fact that more than 1 million hectares of the area at risk are located in this country as can be seen in figure 26.

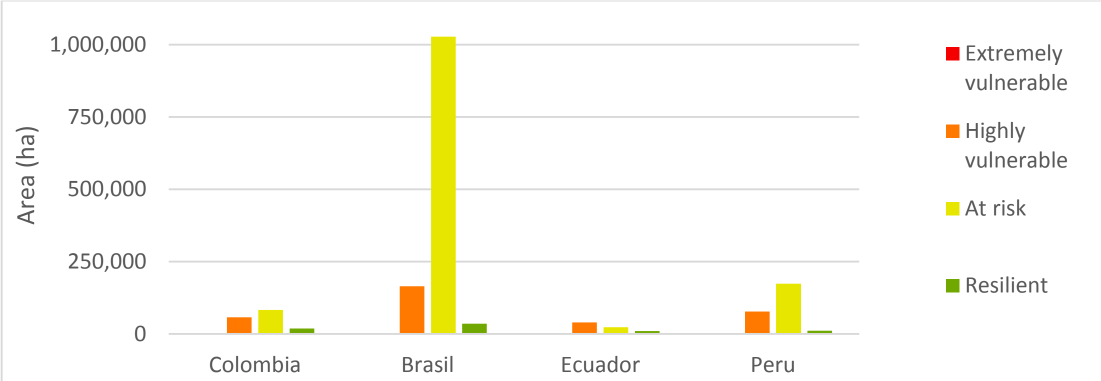


Figure 23. Vulnerability distribution per country

Figure 27 shows Ecuador as the country with the higher percentage of area highly vulnerable with respect to the total area of the country that falls within the study area (In this case the whole country). It is explained mainly by the high density of roads located along the Andes and the presence of ecosystems classified as endangered.

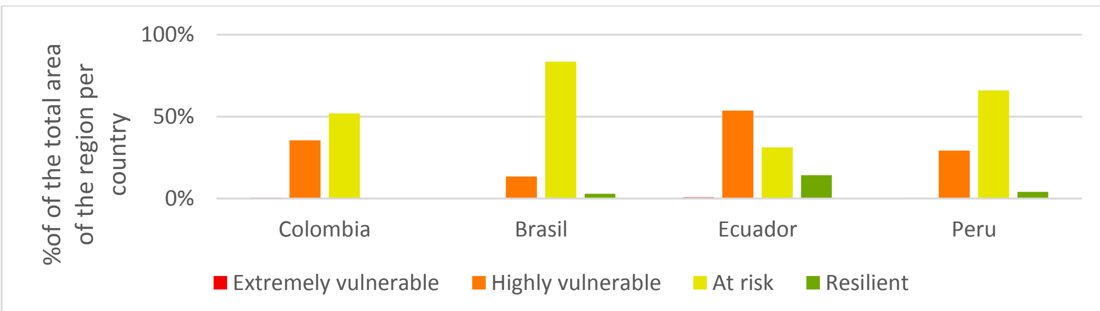


Figure 24. Percentage of vulnerability with respect to the total amount of area that falls within each country boundary.

Chapter 5. Analysis and Discussion

This research performs a technical assessment of the extent to which services and resources provided by GeoSUR are interoperable to facilitate accessibility, applicability and usage of spatial data.

Due to the limited amount of time to perform this study, availability was not considered within its scope, and therefore, the fact that some of the required target spatial datasets could not be included in the case study does not mean that those resources do not exist.

This study only addresses interoperability from the syntactic perspective leaving aside semantic interoperability. The case study analysis was performed using unique regional and global datasets per theme that covered the entire study area. These large datasets were used instead of those provided by national institutions because they were not available for all the countries. In this sense, further studies need to consider semantic interoperability among spatial datasets from different sources, including equivalence between data models and concepts.

5.1. Accessibility

Three approaches are developed to assess the level of accessibility to datasets offered by GeoSUR. An evaluation of the architecture of GeoSUR to identify the extent to which it can be considered a spatial clearinghouse; an interview performed to potential users of GeoSUR in order to get a general perception on how user friendly is GeoSUR interface for discovering and retrieving spatial data; and an evaluation to identify the extent to which the services provided by GeoSUR are interoperable in order to access spatial datasets.

Most of the people inquired regarding the general perception about GeoSUR interface, considered easy to find and use the tools to discovery spatial resources, and categorized found metadata as complete only for basic information. It is relevant the fact that users with basic knowledge of GIS considered useful the metadata provided.

On the other hand, download of datasets seems to be a limitation to accessibility, since less than 30% of participants consider easy to obtain the resources, and 43% do not know how to download them. 40% of “experts” indicate not having idea of how to get the datasets, and 20% consider it a difficult task. It plays an important role the fact that there is an option to add items to a “shopping cart”, but there is no way to check its content or any payment option. Although some resources are categorized as downloadable data, there is not any link to get it. In order to obtain the datasets discovered through the catalog service, it is required to go to the list of available data and find the resource that fits with the description provided by metadata.

The assessment to individual resources, which results are shown in tables 12 and 13, indicates that more than 30% of the resources can be downloaded from the list of available datasets in GeoSUR, however still 62% of them have to be ordered online following the contact information available in the metadata file. This tasks in some cases is difficult to achieve because metadata is not updated, some institutions disappeared, or the point of contact has changed. Getting the data was also challenging. Only 50% of the ordered resources could be obtained in a time period of 2 months, and more than 70% percent of them were obtained from the USGS with GeoSUR help. Thus, the limited upgrading of metadata by the owner organizations, plus the lack of defined mechanisms within organizations to establish sharing procedures, affect negatively the accessibility to datasets.

The relatively easiness to discover spatial resources compared to the difficulty to access the datasets is consistent with the results of a survey performed by GeoSUR over 35 participating agencies. It indicates that around 80% of respondents use GeoSUR for searching data, while 30% use it to download data and information. The results related to the use that participant institutions give to GeoSUR are shown in figure 25. These results are part of a survey performed in 2011 by CAF, UNEP and the PAIGH in order to get users impressions about the services currently provided by the GeoSUR Program and ideas about its potential development (Van Praag et al. 2012b). Similar findings are described for INSPIRE in the Mid-Term evaluation report. European Commission (2014) reports a larger positive result for the use and accessibility of discovery and view services than for the download services. This is expected, since the legal obligation for Member Countries to make download services operational come at a later stage in the roadmap (European Commission 2014).

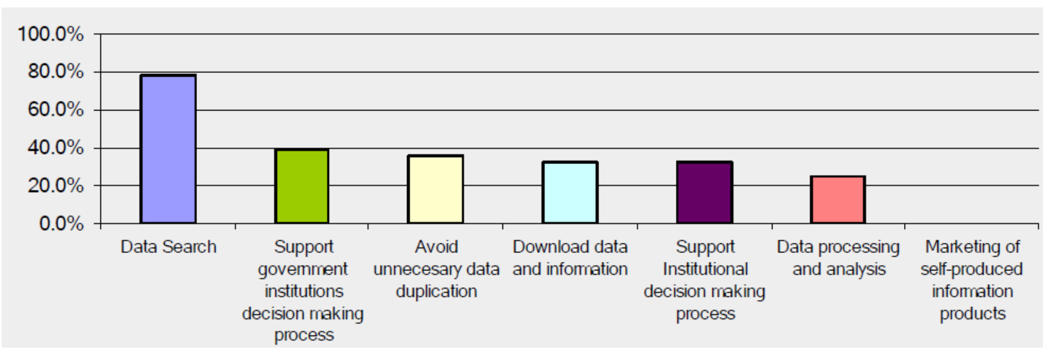


Figure 25. Use given by institutions to services provided through the GeoSUR Portal (Van Praag et al. 2012b)

A public consultation was performed during 2013 and 2014 by the European Commission (EC) to get the opinion of respondents about their experiences as producers or users of spatial data related to INSPIRE. This survey indicated that 63% of participants were able to discover the needed spatial data as well as the conditions for use and other relevant documentation (metadata), in contrast with 26% who were able to download the needed spatial data.

The public consultations performed in the frame of INSPIRE and the current study, show the extent to which users can discover and download resources from the INSPIRE Geoportal, while GeoSUR's survey is focused on identify what institutions use the Geoportal for. Bearing this in mind, and also the fact that the questions and answer options were different, figure 26 shows the result of an attempt to homogenize the findings in these 3 studies. In order to do that, the following assumptions are made:

- In the current study, respondents that answer “Easy”, “difficult”, and “very difficult” to the question: “How easy was to get the resource of interest”, are able to download the resource.
- In the survey performed in the frame of INSPIRE, respondents that answer “agree” and “strongly agree” to the question “I have used the INSPIRE geo-portal and was able to download the spatial data that I need” are able to download the resource.
- In the survey performed by GeoSUR, respondents that answer they use the Geoportal for downloading data are the number of users that are able to do so.
- In the current study, respondents that answer “very easy”, “easy”, “difficult”, and “very difficult” to the question: “How easy was to find the associated metadata, are able to discover resources and associated metadata.
- In the survey performed in the frame of INSPIRE, respondents that answer “agree” and “strongly agree” to the question “I have used the INSPIRE geo-portal and was able to discover the spatial data that I need as well as the conditions for use and other relevant documentation (metadata)” are able to discover resources and associated metadata.
- In the survey performed by GeoSUR, respondents that answer they use the Geoportal for down to find data are the number of users that are able to do so.

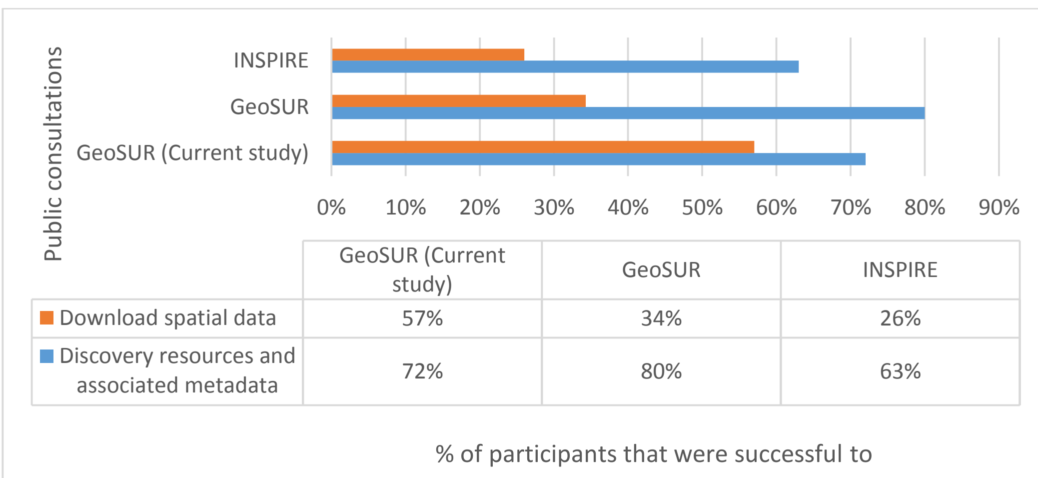


Figure 26. Comparison among the results obtained by the EC, GeoSUR and the current survey regarding capability of both INSPIRE and GeoSUR geoportals to discover and download spatial datasets.

Results shown in figure 29, indicate that for GeoSUR and INSPIRE geoportals, the capability to discover resources is better than the capability to download datasets. GeoSUR however, shows better results in terms of discovery and download of data. An explanation for this behavior may be the fact that GeoSUR serves several regional and global datasets that cannot be accessed from national SDIs, and also participates in the creation of some of them. Considering this, the Spatial Data Infrastructure of the Americas, rather than GeoSUR, has to work on establishing institutional agreements to facilitate data and service sharing. INSPIRE addresses this issue through the implementation of the data and service sharing (DSS) implementing rules, which "define the conditions under which Member States shall provide the institutions and bodies of the Union with access to spatial data sets and services in accordance with harmonized conditions"(European Commission 2014 p. 12).

GeoSUR and the INSPIRE Geoportal are gateways to access catalogs and map services from participant organizations and have similar interfaces to search and filter search operations. GeoSUR provides the capability of viewing the extent of the displayed records in kml format. However the way they show the obtained records and they characteristics is different. While INSPIRE displays the results in terms of datasets, GeoSUR shows one record per dataset, or service available. It turns difficult to understand and quantify the real amount of different spatial datasets, since it is possible to obtain two records for one single dataset: one the dataset as itself and also its associated WMS (See figure 30). This explains the fact that those records that have associated metadata to the dataset, do not have metadata associated to the WMS and vice versa, as shown in figure 15. Those records displayed as WMS, have metadata associated to the service but not to the dataset as itself. Thus, 97% of the metadata assessed are compliant to ISO/TC 211 standards either ISO 19115 for datasets or ISO 19119 for services. In order to facilitate the discovery of spatial resources, the interface to discover services should display the results of a search operation in terms of the datasets available, and make available links to access the associated web services with their correspondent metadata.

All the records offer to the user the option to visualize metadata in XML format and in a user friendly html interface. When a WMS service is available an additional link allows the user to preview the dataset, although sometimes it is broken.

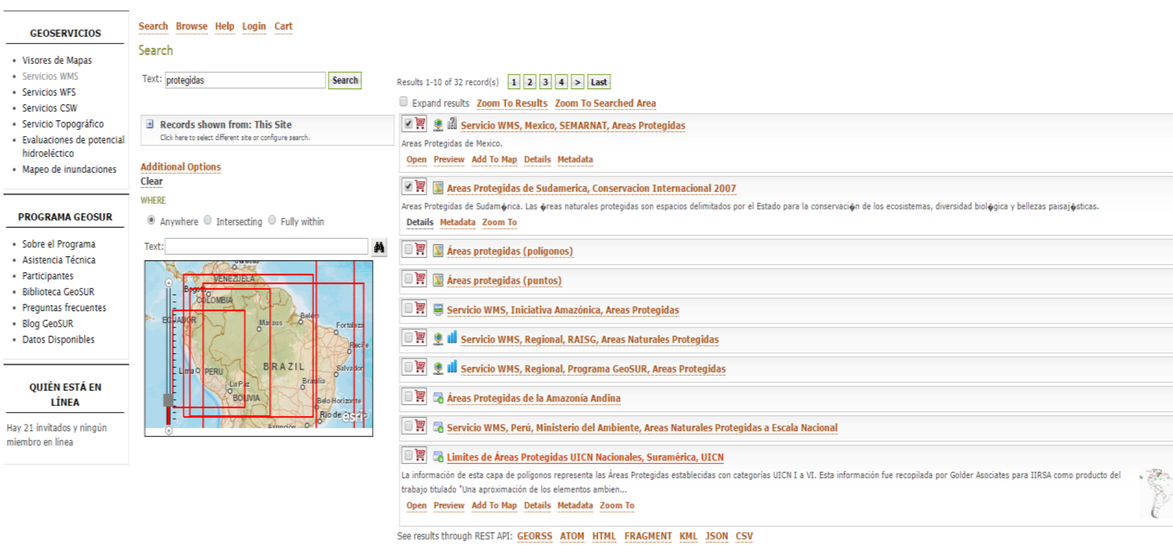


Figure 27. Typical list of records after performing a search operation in GeoSUR catalog.

INSPIRE addresses the issue of accessibility in the network services (NSs) implementing rules, which specify common interfaces for web services for discovering, viewing, downloading and transforming spatial data sets (European Commission 2014)

5.2. Applicability

Although most of resources have associated discovery metadata compliant to either ISO 19115 or ISO 19119, metadata for evaluation and use is not always available, especially regarding spatial and temporal resolution. In order to get this dataset information, it is required to wait until the resource is delivered, which sometimes can take even more than two months as shown in the section 5.1. In order to guarantee that users have enough information of datasets to identify whether it is useful or not, it is required to establish common rules to register not only discovery but also metadata for evaluation and use. So far, the PAIGH and the Geographic Institute of Colombia have created a Latin-American geographic metadata profile, which defines a common structure to document information associated to spatial resources based on ISO 19115 (IPGH and IGAC 2011). It establishes mandatory metadata to guarantee discovery services, but not a minimum of metadata information for evaluation and use. INSPIRE establishes the interoperability of spatial data sets and services (ISDSSs) implementing rules to provide semantic interoperability among datasets and ensure that users of data can interpret the data they are accessing even before they get the dataset. Those common rules include minimum requirements of metadata for evaluation and use of datasets, such as coordinate reference system, temporal reference system, encoding standards and topological consistency (European Commission 2010), which may be helpful to improve the applicability of spatial resources discoverable through GeoSUR

Some of the resources include information regarding temporal or/and spatial resolution as part of the description of the dataset but not under the correspondent tags. It slows down the process of identifying the datasets characteristics.

Shapefile is the most common delivery format. Although it does not follow standards established by the OGC, is a widely used format by GIS practitioners around the world. Most of GIS software, such as ILWIS are able to transform shapefile and TIFF files into their own formats. Few national spatial resources are delivered in no geographic software supported format such as paper or pdf. In terms of coordinate systems, surprisingly no dataset used the Geocentric Reference Frame for the Americas – SIRGAS. However more than 75% of them use WGS 84, and associated projections.

To avoid these problems of differences among datasets formats or coordinate systems INSPIRE developed a group of network services (NSs) implementing rules to specify common interfaces for web services to download and transform spatial data sets (European Commission 2014). Having such common interfaces facilitates users to switch among formats easily and saves time for data producers that can avoid the process of extraction of information based on users' requirements.

5.3. Usability

The main cause to not consider spatial resources is the absence of the dataset. The usability assessment shows that 30% of rejections of spatial resources are not related to interoperability issues but rather to their low suitability in terms of contents to perform the environmental vulnerability assessment. The percentage of coverage of the whole study played an important role in the final selection of datasets. In this sense, global and those regional datasets whose creation was linked to GeoSUR CAF or IIRSA showed to be more prone to spatially cover the whole area. No one of the indicators considered in the SMCE were fully covered by the national resources.

In order to guarantee the accessibility to data required for policy formulation, INSPIRE Directive set a list of themes for which spatial data must be produced and shared. In order to foster semantic interoperability regarding data models, and attributes contents, a set of data specifications regarding the themes indicated in Annex I, II and III are defined. These specifications include the scope and important attributes for each theme, considering the feasibility and relevance for community policy (Drafting Team "Data Specifications" 2008). Implementation of such specifications regarding common themes for all participant entities in GeoSUR can improve interoperability among datasets and allow to integrate national datasets which usually have a larger scales and more attributes associated.

One weakness of the assessment approach considered in this research is that it does not evaluate all the usability indicators such as datasets completeness, temporal and spatial resolution for those datasets that could not be obtained and that do not provide such information in their metadata.

5.4. Environmental Vulnerability Assessment

Apart from the use of SMCE to serve as a test for usability of GeoSUR, the implementation of this method produces a composite index map with the distribution of environmental vulnerability along the IIRSA Amazon region.

The results for the Spatial Multicriteria Evaluation only take into account one vision which consider the closeness to areas with human presence as the most important factor that affects the vulnerability of the environment. Under this consideration, areas extemely vulnerables and with high vulnerability are located in the Andean zone, where more roads and human settlements are located, and in those areas with presence of intensive agriculture.

The construction of the projects planned in IIRSA portfolio, which aim to articulate five waterways in the region, may change this vision, since the road and waterways traffic would increase and therefore the pressure over the natural resources may be higher leading to an increase of the weight assigned to this group of criteria. In this sense, it is recommended for further studies to include a sensitivity analysis in order to assess the stability of results with respect to the variation of weights.

The vulnerability of the environment to degradation depends on biotic and non-biotic factors, however due to the limitations in terms of time to develop this study, only those related to the biota are considered. Thus, in order identify the suitability of the spatial resources offered by GeoSUR to perform a complete vulnerability assessment of the environment other technical factors such as geology, geomorphology, soils, as well as social and economic criteria should be included.

Chapter 6. Conclusions

GeoSUR and INSPIRE have evident differences based on the objectives and the conditions under they were created. The Infrastructure for Spatial Information in Europe is created in the frame of a Directive of the European Commission with a fixed objective in mind: to support Community environmental policies, and policies or activities which may have an impact on the environment. On the other hand, GeoSUR is a voluntary, dynamic and collaborative program, which continuously adjust its vision and objectives to fit the evolving needs of the participants. Thus, while INSPIRE is an infrastructure linked to policies that involve all the EU Member States, GeoSUR is a network where membership has not a mandatory nature as in the case of INSPIRE.

Based on the results of the research, the weaknesses in terms of accessibility, applicability and usability of the datasets provided by the organizations participating in GeoSUR are related to problems associated with the lack of definition of common technical rules to describe, exchange and serve datasets. Accessibility was limited by the lack of preview services and metadata associated to the datasets, but mainly by difficulties at trying to get the resources from some institutions. Applicability and usability of spatial data are highly affected by the lack of metadata for evaluation and use, since the user cannot know how useful the datasets are to fulfil its target requirements. Differences in presentation formats, reference coordinate systems and geometric structure increase the amount of datasets processing activities required to integrate and use them affecting their interoperability. Considering this, GeoSUR can define common technical requirements for Geospatial Services (discovery, downloading, transformation) that include details about implementation and relations with existing standards, technologies, and practices as INSPIRE. It will improve the compatibility and usability of spatial resources produced by participant organizations in terms of accessibility and semantic interoperability. Most of the resources were found

The role of GeoSUR within the ongoing consolidation of the Spatial Data Infrastructure for the Americas is to develop geoservices and applications based on institutional and regional spatial databases. In order to make spatial data suitable to accomplish this task, common implementation rules and organizational agreements should be defined for all the participant institutions. In this respect, the Spatial Data Infrastructure for the Americas should consider the definition of common implementation rules that address metadata, network services, interoperability of spatial datasets and services and mechanisms to exchange spatial data services as INSPIRE does. This will facilitate the compatibility of spatial datasets and services produced by participant institutions as well as the accessibility, applicability and usability of spatial information in decision making processes. So far, the first step on this way was the definition of the Latin American profile of Geographic Metadata – LAMP, based on ISO 19115 which provides a common structure to describe geographic and non- geographic datasets and is based on ISO 19115.

The case study performed in the frame of this research, shows that the datasets accessible through GeoSUR can be integrated to methods such as Spatial Multicriteria Evaluation to support decision making processes at regional level. This goes in the same line with the role of GeoSUR within the consolidation of the Spatial Data Infrastructure of the Americas as a developer of applications based on participant institutions datasets and with the previous development of services such as the CONDOR program and the topographic Processing Service.

Considering the limitations of this study, further studies should:

- Increase the sample size of the perception survey. This survey should be performed mainly on user from the participant organizations
- Include additional criteria to perform the Environmental vulnerability assessment (Social, economic, geology, soils)
- Consider more scenarios for the SMCE, to assess the stability of results with respect to the variation of weights
- Compare the results of the Environmental Vulnerability assessment with similar studies performed at regional or national level to assess accuracy of the SMCE and the spatial resources offered by GeoSUR.

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Chapter 7. Appendix

ANNEX I

Copy of the inquiry about the perception on user friendliness of GeoSUR interface for discovering and retrieving spatial resources

Assessing the GeoSUR Catalog Service

Data Clearinghouse in Latin America (GeoSUR) in order to perform spatial analysis at regional level.
The Geospatial Network for South American Integration – GeoSur Program is a regional spatial data network established in Latin America and the Caribbean (LAC) which aims to generate, disseminate, and exploit geospatial data useful for decision-making in Latin America and the Caribbean (Praag et al. 2012a)
The aim of this questioner is to assess the user friendliness of the GeoSUR portal. It will consider how user friendly it is to find datasets, examine metadata and download them.
Please, visit the GeoSUR portal: http://www.geosur.info, locate the search tag, use the searching tools to find spatial resources of interest for you and assess the following indicators.

* Required

1. **Please indicate your professional background** *

   ____

2. **Please indicate your level of expertise regarding geographic information technologies** *

   Mark only one oval.

   - ( ) Null
   - ( ) Basic
   - ( ) Medium
   - ( ) Expert
   - ( ) Developer

Finding the catalog

3. **How easy did you find the "search for data" link to search spatial resources?** *

   Mark only one oval.

   - ( ) You could not find it   *Skip to question 10.*
   - ( ) Extremely difficult
   - ( ) Difficult
   - ( ) Easy
   - ( ) Very easy

Searching tools

4. **How easy did you find to use the searching tools to narrow down the search?** *
Mark only one oval.

- ◯ You could not use them
- ◯ Extremely difficult
- ◯ Dificult
- ◯ Easy
- ◯ Very easy

Accessing metadata

5. **How easy was to find associated metadata? (Information and/or details about the resource)** *
Mark only one oval.

- ◯ You could not find any metadata file *Skip to question 9.*
- ◯ Very difficult *Skip to question 6.*
- ◯ Difficult *Skip to question 6.*
- ◯ Easy *Skip to question 6.*
- ◯ Very easy *Skip to question 6.*

Metadata completeness

6. **How complete is the metadata?**
Mark only one oval.

- ◯ You did not understand the content of metadata
- ◯ Incomplete
- ◯ Complete (Only for basic information)
- ◯ Very complete
- ◯ Option 5

7. **Why did you not understand the metadata?**

____
____
____
____
____

Metadata usefulness

8. **How useful did you find the metadata? (Information about the resource)**
Mark only one oval.

- ⬭ You did not understand the content of metadata
- ⬭ Useless
- ⬭ Useful
- ⬭ Very useful

Retrieving the resource

9. **How easy was to get the resource of interest?**
Try to download the spatial resource
Mark only one oval.

- ⬭ You do not know how to download it
- ⬭ Very difficult
- ⬭ Difficult
- ⬭ Easy
- ⬭ Very easy

Additional comments

10. **Please indicate additional comments regarding GeoSUR portal and its catalog to search spatial resources**

____

____

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____

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ANNEX II
Results for assessment to spatial resources regarding Accessibility

		Accessibility of metadata through discovery services									Easiness to obtain the dataset	
Resource Name	**Type of data**	**Accessible through the catalog service?**	**Has metadata?**	**Metadata compliant to ISO 19115?**	**Dataset metadata format**	**Web service associated?**	**Web service metadata**	**View service metadata compliant to ISO 19119?**	**View service metadata format**	**Link to access the view service from GeoSUR?**	**How can be downloaded?**	**Time elapsed (Days)**
Límites Internacionales de países, Suramérica, ESRI	Regional	Yes	Yes	Yes	html/xml	No				No	Direct link from GeoSUR	N.A
Servicio WMS, Regional, Programa GeoSUR, Mapa Pantropical de Biomasa	Regional	Yes	No			WMS	Yes	Yes	html/xml	Yes	Direct link from GeoSUR	N.A
Servicio WMS, Regional, RAISG, Deforestacion	Regional	Yes	No			WMS	Yes	Yes	html/xml	No	Order online	Not obtained
Terra-i Vegetation Change	Regional	No	Yes	No	html	No				No	Direct link from GeoSUR	N.A
MAPA de deforestación del Ecuador Continental (V)	National	Yes	Yes	Yes	html/xml	No				No	Order online	Not obtained
Sistemas Ecologicos Andes Amazonas, NatureServe	Regional	Yes	Yes	Yes	html/xml	No				No	Direct link from GeoSUR	N.A
Ecosistemas terrestres de Suramérica,	Regional	Yes	Yes	Yes	html/xml	WMS			html/xml	Yes	Direct link from GeoSUR	N.A
Ecoregiones, Suramérica, WWF	Regional	Yes	Yes	Yes	html/xml	No				No	Direct link from GeoSUR	N.A
Servicio WMS, Colombia, Instituto Von Humboldt, Ecosistemas	National	Yes	No			WMS	Yes	Yes	html/xml	No	Order online	Not obtained

		Accessibility of metadata through discovery services									Easiness to obtain the dataset	
Resource Name	**Type of data**	**Accessible through the catalog service?**	**Has metadata?**	**Metadata compliant to ISO 19115?**	**Dataset metadata format**	**Web service associated?**	**Web service metadata**	**View service metadata compliant to ISO 19119?**	**View service metadata format**	**Link to access the view service from GeoSUR?**	**How can be downloaded?**	**Time elapsed (Days)**
Servicio WMS, Ecosistemas Fragiles a Escala Nacional	National	Yes	No			WMS	Yes	Yes	html/xml	No	Order online	Not obtained
Servicio WMS, Instituto von Humbolt, Colombia, Ecosistemas de los Andes	National	Yes	No			WMS	Yes	Yes	html/xml	No	Order online	Not obtained
Servicio WMS, Ministerio del Ambiente de Brasil, Ecoregiones	Regional	Yes	No			WMS	Yes	Yes	html/xml	Yes	Link in resource owner's website	N.A
Servicio WMS, Colombia, IDEAM, Ecosistemas	National	Yes	No			WMS	Yes	Yes	html/xml	No	Order online	Not obtained
Rareza de especies en ecosistemas terrestres Andes Amazonas	Regional	Yes	Yes	Yes	html/xml	No				No	Direct link from GeoSUR	N.A
Procesos de Ordenación forestal en la Amazonía Andina	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	Not obtained
Mapa Global de Cobertura de la Tierra 2009 (Global Land Cover Service)	Global	Yes	Yes	Yes	html/xml	WMS	No	No	html/xml	Yes	Direct link from GeoSUR	N.A
Servicio WMS, Iniciativa Amazónica, Cobertura del Suelo	Regional	Yes	No			WMS	Yes	Yes	html/xml	Yes	Order online	1
Mapa de uso del suelo	National	Yes	Yes	Yes	html/xml	No				No	Order online	Not obtained
Areas Protegidas de Sudamerica,	Regional	Yes	Yes	No	html/xml	No				No	Order online	Not obtained

		Accessibility of metadata through discovery services									Easiness to obtain the dataset	
Resource Name	**Type of data**	**Accessible through the catalog service?**	**Has metadata?**	**Metadata compliant to ISO 19115?**	**Dataset metadata format**	**Web service associated?**	**Web service metadata**	**View service metadata compliant to ISO 19119?**	**View service metadata format**	**Link to access the view service from GeoSUR?**	**How can be downloaded?**	**Time elapsed (Days)**
Servicio WMS, Regional, RAISG, Areas Naturales Protegidas	Regional	Yes	No			WMS	Yes	Yes	html/xml	No	Order online	Not obtained
Servicio WMSRegional, Programa GeoSUR, Areas Protegidas	Regional	Yes	No			WMS	Yes	Yes	html/xml	Yes	Direct link from GeoSUR	N.A
Límites de Áreas Protegidas UICN Nacionales, Suramérica, UICN	Regional	Yes	Yes	Yes	html/xml	No				No	Direct link from GeoSUR	N.A
Servicio WMS, Iniciativa Amazónica, Areas Protegidas	Regional	Yes	No			WMS	Yes	Yes	html/xml	Yes	Order online	1
Áreas Protegidas de la Amazonía Andina	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	20
Servicio WMS, Perú, Ministerio del Ambiente, Areas Naturales Protegidas a Escala Nacional	National	Yes	No			WMS	Yes	Yes	html/xml	Yes	Order online	Not obtained
Areas Protegidas y Cobertura Natural sin estatus legal de la cuenca alta y media del rio Pastaza (V)	National	Yes	Yes	Yes	html/xml	No				No	Order online	Not obtained
Red vial, Suramérica, CAF	Regional	Yes	Yes	Yes	html/xml	WMS			html/xml	Yes	Direct link from GeoSUR	N.A
Áreas de agrupamientos de proyectos del Eje del Amazonas, Suramérica, CAF	Regional	Yes	Yes	Yes	html/xml	WMS			html/xml	Yes	Direct link from GeoSUR	N.A

		Accessibility of metadata through discovery services									Easiness to obtain the dataset	
Resource Name	**Type of data**	**Accessible through the catalog service?**	**Has metadata?**	**Metadata compliant to ISO 19115?**	**Dataset metadata format**	**Web service associated?**	**Web service metadata**	**View service metadata compliant to ISO 19119?**	**View service metadata format**	**Link to access the view service from GeoSUR?**	**How can be downloaded?**	**Time elapsed (Days)**
Riqueza de Aves de Suramerica, Conservacion Internacional 2007	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	8
Riqueza de Mamiferos de Suramerica (Andes), Conservacion Internacional 2007	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	8
Riqueza de Anfibios de Suramerica, Conservacion Internacional 2007	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	8
Riqueza Maxima de Anfibios Endemicos por Ecoregion, Conservacion Internacional 2007	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	8
Riqueza Maxima de Mamiferos Endemicos por Ecoregion, Conservacion Internacional 2007	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	8
Riqueza Maxima de Aves Endemicos por Ecoregion, Conservacion Internacional 2007	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	8
Riqueza Maxima de Mamiferos por Ecoregion, Conservacion Internacional 2007	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	8
Riqueza Maxima de Anfibios por Ecoregion,	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	8

		Accessibility of metadata through discovery services									Easiness to obtain the dataset	
Resource Name	**Type of data**	**Accessible through the catalog service?**	**Has metadata?**	**Metadata compliant to ISO 19115?**	**Dataset metadata format**	**Web service associated?**	**Web service metadata**	**View service metadata compliant to ISO 19119?**	**View service metadata format**	**Link to access the view service from GeoSUR?**	**How can be downloaded?**	**Time elapsed (Days)**
Conservacion Internacional 2007												
Riqueza Maxima de Aves por Ecoregion, Conservacion Internacional 2007	Regional	Yes	Yes	Yes	html/xml	No				No	Order online	8
Red de drenaje, Suramérica, ESRI	Regional	Yes	Yes			WMS				Yes	Direct link from GeoSUR	N.A
Cuerpos de agua, grandes lagos y reservorios, Suramérica, GLWD	Regional	Yes	Yes	Yes	html/xml	No				No	Direct link from GeoSUR	N.A

ANNEX III

Results for assessment to spatial resources regarding Usability

	Availability of metadata for evaluation and use				Dataset technical characteristics		
Resource Name	Distribution format	Coordinate system	Spatial scale	Temporal resolution	Distribution format	Reference system	Completeness of metadata
Límites Internacionales de países, Suramérica, ESRI	Yes	Yes	No	No	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Servicio WMS, Regional, Programa GeoSUR, Mapa Pantropical de Biomasa	No	No	No	No	TIFF	GCS_WGS_1984 EPSG: 4326	Completeness = 100%
Servicio WMS, Regional, RAISG, Deforestacion	No	No	No	No			Resource not available
Terra-i Vegetation Change	Yes	Yes	Yes, but not in scale	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Values=0 due to clouds presence
MAPA de deforestación del Ecuador Continental (V)	Yes	Yes	yes	Yes but not under the tag TemporalExtent	Shapefile	EPSG: 24877	Resource not available
Sistemas Ecologicos Andes Amazonas, NatureServe	Yes	Yes	Yes, but not in scale	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Ecosistemas terrestres de Suramérica,	Yes	Yes	Yes, but not in scale	Yes but not under the tag TemporalExtent	Shapefile	GCS_Sphere Sinusoidal	0.12% of elements don't have the attribute "System_nam"
Ecoregiones, Suramérica, WWF	Yes	Yes	No	No	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completenes=100%
Servicio WMS, Colombia, Instituto Von Humboldt, Ecosistemas	No	No	No	No			Resource not available
Servicio WMS, Ecosistemas Fragiles a Escala Nacional	Yes	No	No	No	pdf		Resource not available
Servicio WMS, Instituto von Humbolt, Colombia, Ecosistemas de los Andes	No	No	No	No			Resource not available

	Availability of metadata for evaluation and use				Dataset technical characteristics		
Resource Name	Distribution format	Coordinate system	Spatial scale	Temporal resolution	Distribution format	Reference system	Completeness of metadata
Servicio WMS, Ministerio del Ambiente de Brasil, Ecoregiones	No	No	Yes	Yes	Shapefile	GCS_WGS_1984 EPSG: 4326	20% of elements don't have information for the field "Ecorregi3" and "Bioma"
Servicio WMS, Colombia, IDEAM, Ecosistemas	No	No	No	No			Resource not available
Rareza de especies en ecosistemas terrestres Andes Amazonas	Yes	Yes	Yes, but not in scale	Yes but not under the tag TemporalExtent	Shapefile	GCS_WGS_1984 EPSG: 4326	Completeness = 100%
Procesos de Ordenación forestal en la Amazonía Andina	Yes	Yes	No	Yes but not under the tag TemporalExtent		GCS_WGS_1984 EPSG: 4326	Resource not available
Mapa Global de Cobertura de la Tierra 2009 (Global Land Cover Service)	No	No	Yes, but not in scale	Yes but not under the tag TemporalExtent	TIFF	GCS_WGS_1984 EPSG: 4326	Completeness = 100%
Servicio WMS, Iniciativa Amazónica, Cobertura del Suelo	No	No	No	Yes but not under the tag TemporalExtent	FGDBR	GCS_WGS_1984 EPSG: 4326	Completeness = 100%
Mapa de uso del suelo	Yes	Yes	Yes	No	Printed	EPSG: 24877	Resource not available
Areas Protegidas de Sudamerica,	Yes	Yes	No	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Servicio WMS, Regional, RAISG, Areas Naturales Protegidas	No	No	No	No			Resource not available
Servicio WMSRegional, Programa GeoSUR, Areas Protegidas	No	No	No	No			Resource not available
Limites de Áreas Protegidas UICN Nacionales, Suramérica, UICN	Yes	Yes	No	Yes but not under the tag TemporalExtent	Shapefile	GCS_WGS_1984 EPSG: 4326	47% of elements don't have the attribute"legal_base"
Servicio WMS, Iniciativa Amazónica, Areas Protegidas	No	No	No	No	GDB	GCS_WGS_1984 EPSG: 4326	Completeness = 100%

	Availability of metadata for evaluation and use				Dataset technical characteristics		
Resource Name	**Distribution format**	**Coordinate system**	**Spatial scale**	**Temporal resolution**	**Distribution format**	**Reference system**	**Completeness of metadata**
Áreas Protegidas de la Amazonía Andina	Yes	Yes	No	Yes but not under the tag TemporalExtent	Shapefile	GCS_WGS_1984 EPSG: 4326	Completeness = 100%
Servicio WMS, Perú, Ministerio del Ambiente, Areas Naturales Protegidas a Escala Nacional	Yes	No	No	No	pdf		Resource not available
Areas Protegidas y Cobertura Natural sin estatus legal de la cuenca alta y media del rio Pastaza (V)	Yes	Yes	Yes	Yes but its content is not clear	Shapefile	EPSG: 24877	Resource not available
Red vial, Suramérica, CAF	Yes	Yes	No	No	Shapefile	GCS_WGS_1984 EPSG: 4326	0.7% of elements don't have the attribute " type of road" 0.7% don't indicate the source
Áreas de agrupamientos de proyectos del Eje del Amazonas, Suramérica, CAF	Yes	Yes	No	Yes	Shapefile	GCS_WGS_1984 EPSG: 4326	Completeness = 100%
Riqueza de Aves de Suramerica, Conservacion Internacional 2007	Yes	Yes	No	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Riqueza de Mamiferos de Suramerica (Andes), Conservacion Internacional 2007	Yes	Yes	No	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Riqueza de Anfibios de Suramerica, Conservacion Internacional 2007	Yes	Yes	No	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Riqueza Maxima de Anfibios Endemicos por Ecoregion, Conservacion Internacional 2007	Yes	Yes	No	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%

	Availability of metadata for evaluation and use				Dataset technical characteristics		
Resource Name	**Distribution format**	**Coordinate system**	**Spatial scale**	**Temporal resolution**	**Distribution format**	**Reference system**	**Completeness of metadata**
Riqueza Maxima de Mamiferos Endemicos por Ecoregion, Conservacion Internacional 2007	Yes	Yes	No	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Riqueza Maxima de Aves Endemicos por Ecoregion, Conservacion Internacional 2007	Yes	Yes	No	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Riqueza Maxima de Mamiferos por Ecoregion, Conservacion Internacional 2007	Yes	Yes	No	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Riqueza Maxima de Anfibios por Ecoregion, Conservacion Internacional 2007	Yes	Yes	No	Yes	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Riqueza Maxima de Aves por Ecoregion, Conservacion Internacional 2007	Yes	Yes	No	No	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Completeness = 100%
Red de drenaje, Suramérica, ESRI	No	No	No	No	Shapefile	GCS_WGS_1984 EPSG: 4326	0.03% of elements does not have the attribute "Tupe of drainege"
Cuerpos de agua, grandes lagos y reservorios, Suramérica, GLWD	Yes	Yes	Yes	No	Shapefile	WGS_1984_Web_Mercator_Auxiliary_Sphere EPSG: 3858	Half of the elements don't have lake name

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