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## Open-Access Geographic Sources And Data For The Study And Management Of Natural Resources

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**Abstract:** The objective of this systematic review is to describe and analyze open geographic data provided by governmental sources in order to provide an overview of open geographic sources and data for the study and management of natural resources in Peru. For this purpose, the web was explored and scientific articles were reviewed, finding a huge cartographic archive offered by the Peruvian State. On the one hand, public institutions put their respective geoportals into operation, and on the other hand, the launching into space of the PeruSAT-1 satellite. This increased the supply of official geospatial information in the last five years. In addition, geotechnical data was found in raw and processed form from global initiatives. All of this documentary collection is available to the public in an open, free and free form in cyberspace, which can be used in the study of the use, restoration, conservation and valuation of ecosystems and other elements of the environment.

**Keywords:** Spatial data infrastructure of Peru; PeruSAT-1; space missions; geoportals; cartographic information; open information.

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### INTRODUCTION

Peru, being a megadiverse country, needs to have geographic documentation concerning the current state of its natural resources, and open access data has become the pantry of this type of georeferenced information from a wide variety of sources. One such source is Spatial Data Infrastructures (SDI). [1] These tools allow official institutions and society in general to access official georeferenced information, according to certain guidelines and standards. It is precisely the ability to access timely and reliable information that allows making the right decisions to achieve sustainable development [2].

In this sense, the Peruvian State in the framework of its policy of democratization and data transparency, since the beginning of this millennium has been implementing the Spatial Data Infrastructure of Peru (Idep), which is the central node of official cartographic information where public institutions according to their competences and functions, have made available to citizens their interoperable services of georeferenced information on the National Territory. Similarly, in September 2016, it put into orbit PeruSAT-1, the first high spatial resolution satellite; considered the one with the highest performance in the South American region, which is part of the National Space System [3].

Apart from the data offered by governmental institutions; there is in cyberspace spatial information on natural resources coming from initiatives on a global scale, such as space agencies that have driven specific missions to observe the main processes affecting and impacting the planet, for example global change. These missions have produced and made publicly available raw data, becoming a source of multiple variables referring to the ocean, atmosphere and emerged land, the most prominent being the programs initiated by NASA and the European Space Agency (ESA) [4].

Another source we can mention are virtual globes, the most widely used being Google Maps and Google Earth, which appeared in 2005. The free version of Google Earth makes it possible to visualize cartography of the entire planet, however it uses web services that are neither standard nor interoperable [5]. Overcoming this limitation, starting in 2010 the Google Earth Engine (GEE) portal appears, which offers enhanced opportunities to perform earth observation studies, providing access to satellite and other ancillary data in the cloud, as well as algorithms to process large amounts of data over large areas and over long periods of time [6].

Finally, for more geodata we turn to the stream known as Volunteer Geographic Information (VGI), which in the last decade has revolutionized the spatial domain by shifting the map making process from the hands of experts to those of any volunteer contributor, its best representative being OpenStreetMap. Although in its

beginnings (2004) its main objective was to create maps of the whole world for free, today its uses have demonstrated its potential to generate derivative projects [7]. There are also other initiatives in the network such as Global Forest Watch, designed to monitor forests worldwide.

## 2. OPEN GOVERNMENTAL GEOGRAPHIC DATA

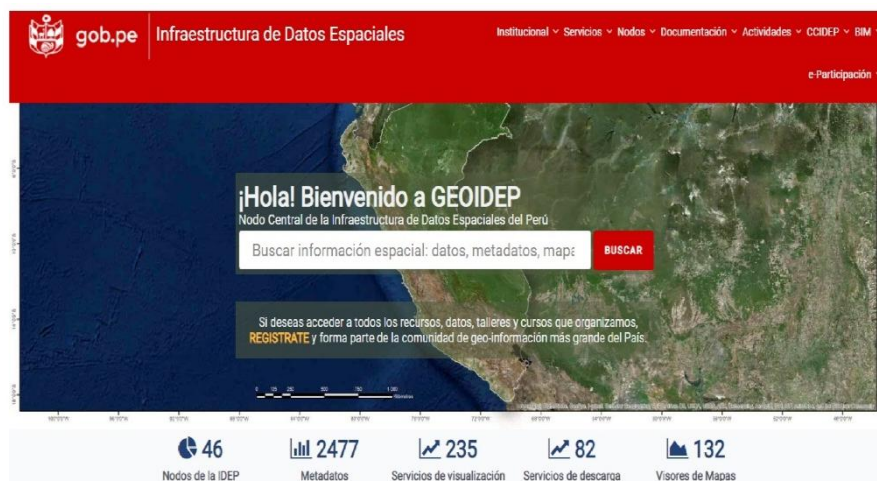
### 2.1. Spatial Data Infrastructure of Peru (IDEP)

Definitely when we talk about official geographic information on the national territory, we must mention IDEP [8]. This is the articulated set of policies, standards, organizations, human and technological resources aimed at facilitating the production, use and access to geographic information of the State in order to support socio-economic development and promote timely decision making.

IDEP had its origins in 2003 when the IDEP Coordinating Committee was formed, but it was in 2007 when the Permanent Coordinating Committee (CCIDEP) was established. In 2011 the portal was created and finally in 2014 the Georeferenced Information Web Services Standards for Data Exchange between Public Administration Entities was established. Currently the CCIDEP is in charge of the Digital Government Secretariat of the Presidency of the Council of Ministers.

Among the services offered by Idep we can mention: Georeferenced System Maps of Peru, National Metadata Catalog, Geoportals, WMS (Web Map Service) visualization services, WFS (Web Feature Service) download services and map viewers of public institutions that share their information which are called Nodes, which mostly implemented geoportals from 2017. In short, Idep works as a central node, gathering geographic information from the public sector.

Ingresando a IDEP es posible acceder a los Nodos que de acuerdo a la cantidad de servicios que brindan se clasifican en: Nodos Básicos; aquellos que permiten solo visualización mediante un visor de mapas o con herramientas externas de la web como IMARPE, Gobierno Regional Cusco, OSINERGMIN, Ministerio de Energía y Minas, y COFOPRI. Nodos Intermedios; cuentan con geoportal para proporcionar servicios de mapas en la web (WMS) como IGP, Gobierno Regional de Callao, OSINFOR, Gobierno Municipal de Cusco, INEI, ANA, CENEPRED, INDECI, Gobierno Regional Madre de Dios, Gobierno Regional Huánuco y Gobierno Regional Amazonas, por último los Nodos Avanzados; además de brindar los servicios que ofrecen los nodos básico e intermedio, comparten su información vía servicios de descarga estandarizados (WFS o WCS) u otros medios y cuentan con un catálogo de metadatos propio. Aquí encontramos a los geoportales de SERNANP, Gobierno Regional Cajamarca, SENAMHI, SERFOR, Gobierno Regional Loreto, INGEMMET, Gobierno Regional Ucayali, IGN, Ministerio del Ambiente y Gobierno Regional San Martín.



**Fig.1: Peru's Spatial Data Infrastructure Geoportal anslated with wwDeepL.com/Translator (free version)**

#### 2.1.1. Base Information Nodes

The spatial representation of natural resources requires a reference cartography, and in Peru to obtain the base cartography it is necessary to resort to the National Geographic Institute of Peru (IGN) [9]. As the governing body of national cartography, its mission is to plan, direct and execute activities related to geomatics, in order to keep the country's official basic cartography updated; in accordance with IDEP; making it available to public and private entities for development and national defense.

By accessing its geoportal [10] you can access the National Geospatial Fundamental Data Infrastructure, the National Geovisor of images that is composed of orthophotos and images taken from satellites and unmanned

vehicles, the Geovisor of the Geodetic Framework, the IGN Metadata, the Technical Norms, Standards and Documentation, the Geovisor of Antarctica and geovisors of other public institutions.

The National Geospatial Data Infrastructure is composed of the large project developed by this institution such as the National Map at a scale of 1:100,000, which are basically topographic maps composed of 500 junctions covering 100% of the national territory that can be downloaded in vector format. In addition, the official basic cartography at scale 1:25,000 of the regions of Ica, Huancavelica, La Libertad, Moquegua, Piura, Tacna and Tumbes as well as the official basic cartography at scale 1:1,000 of the cities of Puno and Huancayo can be viewed.



**Fig.2: Geoportal of the National Geographic Institute's National Infrastructure of Fundamental Geospatial Data of Peru.**

Similarly, we can mention the Organism for the Formalization of Informal Property (COFOPRI) [11] that implements, manages, updates and executes the national urban cadastre that has a multipurpose cadastre platform [12] and the National Institute of Statistics and Informatics (INEI) [13] responsible for producing and disseminating official statistical information of the country, executes census surveys, population statistics, indexes and indicators among others, has one of the oldest portals for the consultation of population centers according to their political location [14].

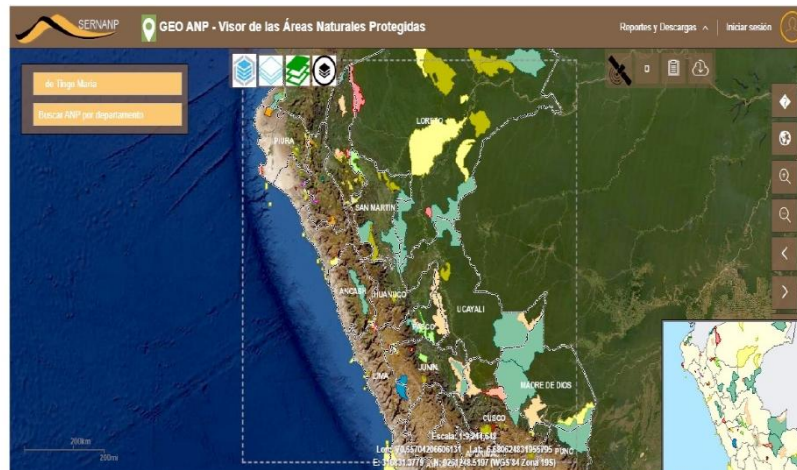
### **2.1.2. Flora, Wildlife and Ecosystem Nodes**

The National Forestry and Wildlife Service (SERFOR) [15], is responsible for managing and promoting sustainable use, conservation, protection of forest and wildlife resources and promoting research. By entering its portal, one can access spatial information on forest management throughout the national territory such as: forest management, forest zoning, forest inventory as well as locating hot spots and forest fire alerts [16].

The Forest and Wildlife Resources Oversight Agency (OSINFOR) [17], in charge of supervising and overseeing the sustainable use and conservation of forest and wildlife resources at the national level, publishes on its website maps of forest and wildlife permits such as: supervised trees, supervision tours, supervised forest management plans and five-year audits [18].

Closing this section, the Ministry of Environment (MINAM) [19] has one of the portals with the most spatial information in three thematic areas: a) Territory; where data on land cover and use, disaster risks, and ecological and economic zoning can be accessed. b) Sea and Coasts; regarding the integrated management of coastal zones, marine erosion and ecosystems by entering GeoCostas [20] and c) Geobosques [21] regarding the monitoring of forest cover changes, and has five sub-modules: Forest and forest loss, Early warnings, Land use and land use change, Degradation, Reference scenarios. In this same sector, but as a decentralized agency, we have the National Service of Natural Protected Areas (SERNANP) [22], in charge of directing and establishing technical and administrative criteria for the conservation of Natural Protected Areas and ensuring the maintenance of biological

diversity, presents one of the most outstanding portals at the national level [23], not only for the large amount of information that can be downloaded directly in shapefile format, but also for having an interface that is always updated and very similar to that of a GIS program, which makes it easy to use. It offers cartography of all the protected natural areas classified according to their category, as well as the corresponding zoning and buffer zones.



**Fig.3: Natural Protected Areas Viewer (SERNANP)**

### **2.1.3. Energy and mining nodes**

We begin this section by mentioning the Instituto Geológico Minero y Metalúrgico (INGEMMET) [24], whose mission is to generate and provide geological information and manage mining rights. Its portal offers georeferenced information on geology and mining cadastre [25]. It makes available the Geological Map of Peru at a scale of 1:1,000,000 in a standardized digital version; based on the 501 quadrangles that make up the National Geological Map, which were surveyed between 1960 and 1999, integrating new information generated between 2000 and 2003 at scales of 1:100,000 and 1:50,000. It also offers georeferenced information on volcanoes and geological hazards.

We can also mention the sector holder, the Ministry of Energy and Mines, which provides the Wind Atlas, Solar Energy Atlas and hydroelectric potential maps [26]. Finally, the Energy and Mining Investment Supervisory Agency (OSINERGMIN) presents information on energy systems by sub-sector Electricity, Natural Gas, Hydrocarbons and Renewable Energy Resources [27].

### **2.1.4. Water and Atmosphere Nodes**

The National Water Authority (ANA) offers access, use and distribution of information on water resources on its portal [28], where one can find the delimitation and coding of hydrographic units (basins), the national inventory of glaciers, high Andean lagoons and dams, classification of marine-coastal water bodies, hydraulic modeling, vulnerable populations due to stream activation, coding of surface watercourses, dynamic barriers, among others.

Next, the National Meteorological and Hydrological Service of Peru (SENAMHI) [29], aims to generate and provide meteorological, hydrological and climatic information and knowledge in a reliable, timely and accessible manner. In its portal one can find climate classification, solar energy, frost frequency, climate change projection, Niño/Niña event, climate forecast, daily monitoring of temperature and precipitation among others [30]. To conclude this section, we cite the Instituto del Mar Peruano (IMARPE) oriented to the study and knowledge of the Peruvian sea and its resources [30].

### **2.1.5. Disaster risk prevention nodes**

The National Center for the Estimation, Prevention and Reduction of Disaster Risk (CENEPRED) [31] provides geospatial information on disaster risk management; by logging in, one can access hazard mapping, risk mapping, exposed elements, as well as download images taken from drones [32].

On the other hand, the Geophysical Institute of Peru (IGP) [33] has the capacity to serve the country's needs in areas such as seismology, volcanology and the study of the El Niño phenomenon. It is possible to access layers of information on earthquakes that occurred from 2005 to 2017 [34]. We can also access information on risks and hazards in the portals of the Ministry of Environment, Ingenmet and ANA.

Finally, for disaster prevention and response, we have the National Institute of Civil Defense (INDECI) [35] where we can access maps of emergencies that occurred in the years 2003 to 2018, as well as evacuation routes and safe areas and maps of emergency operations centers [36].

### **2.1.6. Regional Government Nodes**

Regional governments that implemented their spatial data infrastructure deserve a separate mention. Within the framework of their autonomy, these governments have implemented their portals with open data at regional

level, many of them with the support of national institutions and non-governmental organizations, centralizing information from different sectors. For example, the governments of jungle regions such as Loreto [37], Ucayali [38], Amazonas [33], Madre de Dios [39], San Martín [40] and Huanuco [41] share the Amazon, with the common content among them being forest and wildlife management, protected natural areas, native communities, among others. Continuing with the regional governments, we add to this list the portals of the Cusco [42] and Cajamarca [43] regions, where one can find, among other things, spatial information on tourism and history.

## 2.2. Peruvian satellite system for Earth observation

Under the responsibility of the National Commission for Aerospace Research and Development (CONIDA), which is the governing body for space activities in Peru and the headquarters of the Peruvian Space Agency. Its mission is to promote, research, develop and disseminate space science and technology, generating products and services that contribute to the socioeconomic development and security of the nation [44].

The Peruvian Space Agency, in compliance with its mission, is in charge of the implementation and development of the National Center for Satellite Image Operations (CNOIS), which consists of two segments; the terrestrial segment located in Pucusana from where space operations are programmed and monitored, and the space segment composed of the Peruvian satellite PerúSAT-1. Through its COF application [45] it allows access to images of the national territory captured by PerúSAT-1, and other satellites of the Airbus constellation such as SPOT6/7, Pleiades HR and TerraSAR-X. Although access is not free, you can download the images for free by requesting access as a user to this service if you are part of a public entity, private institution or national or foreign non-profit organization.

Designed for a useful life of 10 years, PerúSAT-1 observes the Earth through its NAOMI camera, which has four bands (Blue, Green, Red and Near Infrared) with a resolution of 2.8 m and a panchromatic band with a resolution of 0.7 m [46]. These features make it possible to use it in applications ranging from homeland security and border monitoring, coastal surveillance and combating illegal trafficking to mining, geology, hydrology, disaster management and environmental protection. It currently allows users to map vegetation, water bodies, and urban areas with high accuracy [47].



**Fig.4: PeruSAT-1 image of the Chaclacayo and Lurigancho area (Lima) 2019. Source: CONIDA**

## 3. OPEN DATA WITH GLOBAL REACH

Due to the huge amount of existing cartographic resources on a global scale, we selected the most recent geotechnologies with the greatest affinity to the study of natural resources in Peru:

### 3.1. Global Ecosystem Dynamics Investigation (GEDI)

Designed and built by NASA and launched to the International Space Station (ISS) in December 2018, has as its instrument the active sensor Lidar to measure tree height and canopy density. During its nominal lifetime of two years, GEDI is anticipated to provide more than 10 billion cloud-free waveforms with footprint resolution (25 m diameter circumference) [48].

The data provided by GEDI are mapped at different processing levels: Level 2, where waveforms are processed to identify ground elevation, canopy top height, and relative height; in the L2A dataset and in L2B, various canopy metrics are calculated, including canopy cover fraction, total leaf area index (LAI), and vertical foliage profile. At Level 3, outputs are gridded by spatially interpolating the footprint estimates coming from Level 2 and their uncertainties and finally Level 4, which represent the output of the models and equations that require the most post-processing [49].

Definitely GEDI data contribute to a more accurate calculation of the carbon stored in the different vertical strata of the Amazon forests, which due to their structure and composition are among the most complex ecosystems in the world. This information is available for free download from NASA's EarthData platform [50] since 2019 in HDF format that can be manipulated in any GIS environment.

### 3.2. Copernicus

An Earth observation and monitoring program managed by the European Space Agency (ESA), it consists of a space component and in situ coordination that allows it to offer operational services in land cover and atmosphere monitoring, marine environment and climate change monitoring, as well as emergency management and civil security. To this end, ESA has developed the Sentinel family of missions; each mission carries with it a range of technologies, such as radar and multispectral imaging instruments according to the purpose for which it was created. Airbus, prime contractor for the development and construction of the Sentinel satellites mentions that the missions are: Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-5P, Sentinel-4, Sentinel-5 and Sentinel-6 [51].

The Sentinel-2 mission consists of two twin satellites (S-2A and S-2B) put into orbit in 2015 and 2017 respectively, both manage to cover the entire Earth in only five days. They have the multispectral optical instrument (MSI) that generates images with 13 bands, four 10-m bands: three visible (red, green, blue) and one near-infrared; six 20-m bands; and three 60-m resolution bands for atmospheric correction and cloud detection. Each tessera is approximately 110 km x 110 km and are delivered to the public in two levels: Level 1C, orthoimages in UTM/WGS84 Projection with reflectance values at the Top of the Atmosphere (TOA) and Level 2A, which are reflectance images at the bottom of the atmosphere (BOA) derived from level 1C [45].

Level 2A products are generated in the ground segment for the entire world since December 2018 which means considerable time savings for users engaged in monitoring forests, land use change and water resources. Sentinel-2 images can be downloaded in jp2 format free of charge and in full along with Sentinel-1 and Sentinel-3 products on the "Copernicus Open Access Hub" portal [52].

In turn, the Sentinel-5P mission has a thematic orientation dedicated to air quality monitoring, with its Tropomi instrument providing daily and global data for Ozone, NO<sub>2</sub>, SO<sub>2</sub>, formaldehyde, aerosol, carbon monoxide, methane and Clouds. S-5p products can be downloaded in NC format with a spatial resolution of 7 x 7 km from the "Sentinel-5P Pre-Operations Data Hub" portal [53]. This spatial temporal capacity to record pollutants has aroused the interest of specialists and institutions, as is the case of the Geophysical Institute of Peru for the evaluation of the behavior of volcanoes in the southern highlands of the country [54], also S-5P data have been used to show the decrease in aerosol pollution in Lima and Amazon regions during the quarantine due to Covid-19 [55].

Finally, the Copernicus Emergency Management Service (EMS) provides information from its satellites for emergency response in relation to different types of natural or provoked disasters. This service consists of two components: the first provides on-demand emergency geospatial information for mapping immediately after the disaster or emergency (Rapid Mapping, RM) or for phases not related to the immediate response (Risk and Recovery Mapping, RRM). While the second component includes: European and Global Flood Awareness System (EFAS and GLOFAS), European Forest Fire Information System (EFFIS) and the Drought Observatory (DO) which provides information on droughts in Europe and the world [56].

Rapid Mapping Service produced flood maps requested by the Peruvian Government within hours of activating the emergency on the northern coast of Peru as a consequence of the El Niño Costero phenomenon in March 2017 [57].

For these reasons, many specialists agree that Copernicus is the revolution of open-access satellite information.

### 3.3. Google Earth Engine (GEE)

Cloud-based platform for planetary-scale geospatial analysis that offers Google's massive computational capabilities to address a variety of high-impact societal problems, including deforestation, drought, disasters, disease, food security, water management, climate monitoring, and environmental protection. In order to access the platform you just need to have a gmail account and register [58].

With GEE you can visualize, download and process online satellite images, geomorphological, climatological and population data. Within its repository we can find the Landsat archive for more than 40 years, complete Sentinel-1 and Sentinel-2 archives, Modis and Aster data and other images such as Proba-V and EO-1, SRTM topographic data, land cover, climatological variables including WorldClim and Worldpop datasets.

In order to analyze the information, GEE offers a series of artificial intelligence algorithms such as Classification and Regression Tree (CART), Random Forest, GMO Max Entropy among others, which allows classifying satellite images for example to quantify deforestation and/or land use change. This is possible by connecting to the Google cloud via the GEE API using JavaScript and Python coding language or for more advanced features REST. In addition, researchers can develop their functions by storing them in their own repositories and share it along with their results.

All of these elements allow users to discover, analyze and visualize Geo Big Data in powerful ways without needing access to supercomputers or specialized coding expertise. Within a decade of its launch, GEE has generated much excitement and engagement in the fields of remote sensing and geospatial data science [59].

### **3.4. OpenStreetMap (OSM)**

Collaborative mapping project created by a community that provides open mapping data on streets, addresses, stores, stations and many more globally. To do so, it uses local knowledge in order to make the data accurate and up-to-date and due to the large number of contributors over time has ensured that OSM data has reached a high degree of quality compared to official data, at least in urban areas where there are more active contributors [60].

In recent years users have used OSM in different applications such as land cover and land use identification which undoubtedly represents a great contribution to land use change and deforestation monitoring. The spatial information provided by OSM is mainly of vector type, and can be downloaded in OSM format directly without registration. [61].

### **3.5. Global Forest Watch**

An online platform that provides data and tools for monitoring forests around the world, using geotechnologies so that anyone can access information in near real time about where and how forests are changing. In the map it presents we find layers of information on land cover, forest change, land use, climate and diversity with their respective legends and analysis from 2001 to 2019 which can be downloaded in spreadsheets [62] This dataset has been developed in collaboration with the University of Maryland, Google, the U.S. Geological Survey and Nasa, using Landsat 5, 7 and 8 images of 30 m spatial resolution. By entering their open data portal, all this information can be downloaded as a document, in raster and vector format or can be connected through the API [63].

In Peru, one of its partners is OSINFOR, as we have already seen it is in charge of supervising forest and wildlife resources, who use and train on the use of forest loss information. Finally, GFW periodically issues the Fire Observatory bulletin, in its June 2020 edition it warns that San Martin is the Peruvian jungle region with the highest number of fires so far this year, which represents an alert to take actions that lead to the excessive reduction of the use of fire.

## **DISCUSSION AND CONCLUSIONS**

The effort made by the Peruvian State to make available to all, updated and cartographic quality official information has been noticed, this has been evidenced in the large amount of open data offered by public institutions [64]. However, there are still many institutions that can provide georeferenced information on natural resources, such as local governments, research institutes and universities, whether public or private.

On the other hand, open data on natural resources are not proportional. One of those with the most spatial information is the Amazon forests, however little or almost no open information has been found on hydrocarbons and other non-renewable resources such as lithium, recently discovered within the national territory.

In addition, little scientific documentation has been found regarding governmental sources and official data itself, [65] so it is of paramount necessity to correctly use the data and generate technical-scientific information, as well as to adequately cite the sources of the data banks, especially those of state entities that allow better localization in academic search engines.

Finally, it is important to highlight the voluntary and global initiatives that offer raw and digitally processed data. [66] We are sure that with the emergence of new geotechnologies, the massification of data and above all the growing concern for preserving the planet, the supply of open spatial information will increase.

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