

Infraestructura de datos espaciales (IDE) para el estudio y análisis ambiental: una experiencia en el sur del Ecuador.

González, Víctor H.^{1 a}; Oñate Valdivieso, Fernando ^a

^(a)Sistemas de Información Geográfica, Universidad Técnica Particular de Loja,
C/. Marcelino Champagnat s/n, 1101608, Loja, Ecuador

RESUMEN

En el presente trabajo se realiza una aplicación del concepto de Infraestructura de Datos Espaciales (IDE) para la elaboración de una herramienta destinada al estudio y análisis de variables mediambientales, que se constituya en un apoyo en la toma de decisiones para un manejo ambiental sostenible y sustentable de la región sur del Ecuador. El sistema planteado ha sido desarrollado con herramientas open source tales como: servidor Apache, MapServer 4.6, y estándares OpenGis para publicación de información georeferenciada a través del Internet. La información temática presentada ha sido recopilada en varios organismos de desarrollo y en su mayor parte ha sido derivada de imágenes satelitales tales como ASTER, LANDSAT y MODIS. El sistema permite la visualización de la información geográfica, la consulta de datos temáticos asociados, con sus correspondientes metadatos y la descarga de las capas temáticas.

Palabras clave: IDE, Mapserver, GIS

ABSTRACT

In this work, we apply the concept of Data Spatial Infrastructure (DSI) in order to create a tool to study and analyze environmental variables. This system will also support decision making for a sustainable environmental management in southern Ecuador. To develop this system, we used Open Source tools such as: Apache Server, MapServer 4.6 and OpenGis standards for publishing georeferenced information on the Internet. The thematic information has been collected from different development organizations. Most of this information is derived from satellite images such as ASTER, LANDSAT; and MODIS. The system also allows for the display of geographical information, associated thematic data query and download of different thematic layers.

Keywords: IDE, Mapserver, GIS.

Introduction to the Geographical Information Infrastructure

In our projects, there is an increasing need for managing maps, spatial data, and geographical characteristics that allows us to describe certain phenomenon, study area or just an object in our environment. These events, apparently isolated, are more and more frequent in our daily life. For this reason, we are aware of the need to increase the availability of spatial data and share them for their use in various projects.

Data Spatial Infrastructure (DSI) is regarded as a set of technologies, policies, and institutional arrangements intended to facilitate the access to spatial information, thus, providing a basis for search, display, analysis and application of spatial data at all levels. The components of DSI are: technologies, institutional framework, data policies, and established standards. (Fig. 1.) (Bosque Sendra, 2007).

In this context, it is important to mention the initiatives of INSPIRE (INfrastructure for SPa-

¹ Contacto autor: Te: 00593 7 2570275 ext 2613 Fax: 00593 7 25

Correo electrónico: vhgonzalez@utpl.edu.ec

Copyright: Universidad Nacional del Centro de la provincia de Buenos Aires, Argentina.

tial Information in Europe) and GMES (Global Monitoring for Environment and Security) (Perez Gómez, 2004). Recently, United Kingdom made laws regarding this field and subsidized the creation of a geographical information infrastructure through the program of the HM Treasury called «Invest to Save Budget». UK government promises to publish 100% of the public information on the Internet by the year 2008. The European Union has also made the first steps towards this initiative (European Standardization Strategies for Geographic Information in the second «Geodata For All in Europe» EUROGI Workshop» in March 1996; work document of the GI2000 «Towards a European Policy Framework for Geographic Information»). The proposal of the United States for the creation of its own National Spatial Information Infrastructure has been put into practice by the FGDC through the National Geospatial Data Clearinghouse. (Bañares J. A., 2001)

A Clearinghouse was established as a distributed online catalogue which offers search services. The Clearinghouse allows an Internet user to visit one of many Gateways or access points to the Internet and to access a query form, in which the user makes a single question to get an answer based on geospatial information contained in a number of data collections.

All of these initiatives attempt to meet the need for spatial data in a wide range of applications such as the environment, agriculture, transportation, sustainable development, security among others.

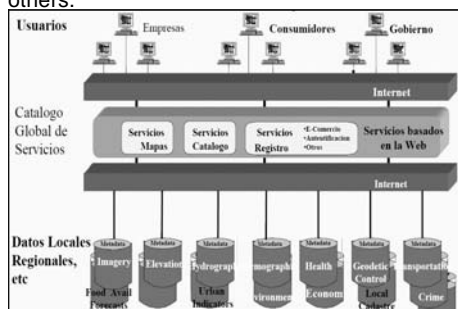


Fig. 1 Structure of a DSI.

Implementing a DSI is important because:

Metadata are essential since global data cannot be provided without them.

There is a great data heterogeneity which makes processes used in spatial information difficult.

Access to information by specialized users and public in general must be allowed.

There are various standards that regulate geographical information published. One example is ISO 19115:2003, which was recently approved as an international standard. ISO, 2003, defines the required scheme for describing geographical and services information. This standard provides information on identification, extension, quality, temporal and spatial scheme, spatial reference, and digital distribution of geographical data.

The OGC (Open GIS Consortium), has defined the following standards: WMS (Web Map Service), WFS (Web Feature Service) and WCS (Web Coverage Service). Today, WCS is being developed.

Web Map Service (WMS) defines both a format for requesting the map and the standard for receiving it. There are some commands to execute such operations. (Web Map Service Documents):

GetCapabilities.- Returns a XML document that describes thematic layers of available information and the projections it supports.

GetMap.- Returns the map image in gif, jpeg, swf or png format.

GetFeatureInfo.- Returns information about the geographical object in XML, GML, HTML or text.

DescribeLayer.- Returns a XML document that describes the available layers and indicates which ones are WFS and WCS.

The practical use of VMS can be applied to:

Restrict physical access to data since VMS only returns an image.

Fast publication service: earthquakes, risks, weather, etc.

Distribution of maps in an URL, since maps are configurable.

Web Feature Service.- A WFS request consists of a description of the query and data transformation operations. The request is generated in the client and is posted to a web feature server using HTTP. There are commands that are similar to those in WMS. (Web Feature Services Documents)

Most of the public and private decisions are based on aspects with some spatial component. Also, cartography on the Internet presents some insuperable features of accessibility, easy upgrading, interactivity, and integration.

A web-based GIS reduces software costs, software upload, and installation time as well as its support and maintenance. It also reduces the users' learning curve and provides a superior environment for DBMS presentation and integration. (Richard W. Greenwood, 2002).

The purpose of this work is to provide information on an experience in implementation of a DSI in southern Ecuador which allows for the display, query, and download of georeferenced information of environmental variables which can be accessed through this link: <http://sig.utpl.edu.ec/ide>

Processed Information

Topographic information 1: 50 000 (IGM, 1980) was digitalized by making thematic maps with information about altitude, populated centers, hydric networks, etc.

As raster information, there are three digital altitude models of the study zone:

A DEM with a resolution of 90m was made by the SRTM project from stereoscopic pairs of radar images obtained by using interferometry. A DEM with a resolution of 50m was made from topographic information of the IGM, then, making a TIN which was subsequently rasterized. A DEM with a resolution of 50m was extracted from ASTER images (Bands 3N and 3B) by re-sampling through the application of collinearity equations which allow us to obtain normalized epipolar images from which the parallax to calculate altitude is determined.

Maps of the slopes at the aforementioned scales were derived from the altitude models. The automatic delimitation of the hydrographical basins as well as the corresponding calculations of the principal morphometric parameters were performed.

Based on the historical rainfall records in 42 pluviometric stations, we made maps of annual isohyets in the study zone through Kriging interpolation. For recording maximum, medium, and minimum air temperatures, we correlated values obtained with the altitude of the stations in which the information to make spatial temperature variation maps was collected.

LANDSAT images from the years 1985, 1986, 1987, 1996, 1999, 2000 and 2001; ASTER images from 2001, 2003 and 2004 as well as MODIS images have been collected as well as radiometrically, geometrically, and topographically corrected.

Using the product MODIS/Aqua Land Surface Temperature/Emissivity daily L3 Global 1 Km, proceeds to calculate the values of evapotranspiration applying the operative equation proposed by Rivas y Caselles (2004), this allow us to adapt the calculus methodology of the evapotranspiration Penman Monteith's Remote Sensing.

$$ET_{o-Ts} = a \cdot T_s + b$$

$$a = \left(\frac{\Delta}{\Delta + \gamma \cdot \left(1 + \frac{r_s}{r_a} \right)} \right) \cdot \left(\frac{-c \cdot \varepsilon_a \cdot \sigma}{\lambda} \right)$$

$$b = \left(\frac{1}{\Delta + \gamma \cdot \left(1 + \frac{r_s}{r_a} \right)} \right) \cdot \left[\frac{1}{\lambda} \left[(\Delta) (1 - \alpha) R_s + \varepsilon_a \sigma (T_s^4 - d) - G \right] + \rho \cdot c_p \left(\frac{e_s - e_a}{r_s} \right) \right]$$

Where T_s is the temperature of the extracted surface of MODIS/Aqua compound. The parameter a represents the average emission of the reference surface for given atmospheric conditions. The parameter b represents aerodynamic effects on the hypothetical surface which receives a certain amount of solar radiation. These parameters correspond to the application area and can be calculated through meteorological data measured at conventional stations (Rivas and Caselles, 2004).

Also, the values of NDVI were derived from the LANDSAT and ASTER images.

Technological elements and implementation of the proposal

To implement a DSI system for environmental analysis, first, there must be an application or system that allows for display and query of spatial information in an application with a shared environment to which all users have access. For this purpose, a geovisualization system with the following components is implemented:

- Web Server
- Map Server
- Spatial Data
- Front-end for data display

The geovisualization system can integrate vector and raster information as well as link alphanumeric information related to vector layers (Spatial Data Repository)

This system permits the sharing of data through the Internet. This facilitates access to information without the need of proprietary or specialized software. It is also important to remark that users of spatial information do not need to be physically present at the place where the repository of such information is located.

For the two first components of this system we used Apache Server 1.3.24 and MapServer 4.6.1.

MapServer is an OpenSource development environment for building spatially enabled Internet applications and does not have all the features of a GIS system. The software was developed based on other popular OpenSource soft-

ware such as Freetype, Proj4, GDAL/ORG (MapServer home page).

The features of MapServer are: advanced output for cartography, support of scripts which are developed using popular environments such as PHP, Python, Java, Ruby and C#. Mapserver is a multiplatform application that runs under operating systems such as Windows, Unix/Linux, MacOS, and Solaris, among others. It also supports various raster and vector formats as well as spatial data projections (MapServer home page).

The application uses the following resources for its proper work:

An HTTP application servers such as Apache or Internet Information Server.

MapServer software

An initialization file for sending initial parameters to the CGI application (Initialization File).

A file that controls the way of working with data (Mapfile). Mapfile defines data that will be used and the operations to be performed with this data. Objects such as maps, legends, scale bar, queries, etc. are defined.

A file that displays the output of spatial data and the controls that the user will have to manage this data (Template File in HTML). The Template File controls how the output of the maps and legends will appear. This is the display mode defined in the Mapfile file.

A Data Repository in which the spatial information is stored. As said, among the characteristics of Mapserver, we have: it supports multiple vector and raster formats, which is essential in order to display the spatial information. In this case our study zone is located in the Province of Loja - Southern Ecuador.

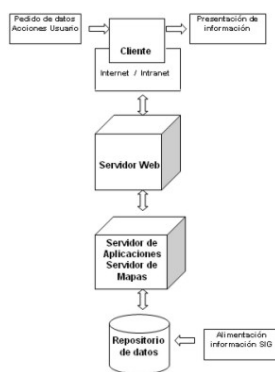


Fig. 2 Structure of the Geovisualization system for implementing a DSI.

In figure 2, the structure of the Geovisualization system for implementing a DSI which works on the internet by using MapServer is shown. This system was implemented and tested under a Windows environment. Additionally, tests under Linux were carried out and in both cases the results were satisfactory. MapServer works as a CGI module with an http application server, the user has access to the applications from a web browser and interacts with the application interface. The actions are sent to the server, executed by the CGI MapServer which accesses the data repository and returns the information to the Web browser (González V, 2005)

The necessary metadata for the distribution of spatial information can be added through a database, XML files, HTML files, or just text files.

In order to add the metadata, we consider the following parameters:

- Identification information
- Extension
- Quality
- Temporal and spatial scheme
- Spatial reference
- Distribution of digital geographic data

Once the system structure has been established we continue with the development of the solution. We start with a script that belongs to the initialization file or page where the call to the CGI application is defined. The MapFile file path that is used for the definition of data which will be used and the browser mode of the MapServer is shown. The link to the CGI is shown in the following script.

```
<html>
<head>
<title>Infraestructura de Datos Espaciales</title>
</head>
<body bgcolor="#ffffff">
<p><a href="/cgi-bin/mapserv.exe? map=c:/Archivos
de programa/Apache Group/Apach/mapa.Map
&mode=browse">Implementación IDE</a><br>
</p>
</body>
</html>
```

This hyperlink can be divided into three parts: the CGI call, a path that indicates the position of the MapFile file to obtain the instructions that are applied to the data to be used and the third parameter that makes reference to the mode in which the CGI is used (Map or Browse mode).

Below, we illustrate the Mapfile file. It is composed mainly of objects, and every one has key words and other objects. The studied file has a hierarchical structure above others. The principal object is MAP and the rest of the objects are found in it. This hierarchy is observed in figure 3.

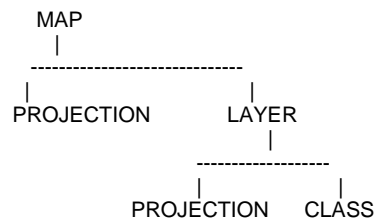


Fig. 3 Objects hierarchy in a Mapfile file

Below, the code corresponding to the Mapfile file is shown, in which we can observe the structure of the objects that this file contains and the key words used. The file starts with the definition of the MAP object which has the highest hierarchy. The rest of the objects are called WEB, PROJECTION, and LAYER. We will start with the key word NAME, which indicates the name of the MAP object. IMAGETIPE corresponds to the output format of the raster file generated by MapServer. EXTENTN where geographical coordinates of the presentation area on the map are placed. SIZE is given in pixels and determines the size of the output image. SHAPEPATH indicates the path where data is going to be taken from.

```

MAP
NAME ides
IMAGETYPE PNG
EXTENT 476041 9438571 1186767 10161286
SIZE 400 300
SHAPEPATH "data"
IMAGECOLOR 255 255 255
TEMPLATEPATTERN "idemap"
UNITS METERS

WEB
TEMPLATE 'idemap.html'
IMAGEPATH 'c:/Archivos de programa/Apac .../'
IMAGEURL 'c:/Archivos de programa/Apach.../'
END

LAYER
NAME Perfil
TYPE POLYGON
STATUS DEFAULT
DATA cuador2
CLASSITEM 'Nom_prov'
CLASS
EXPRESSION 'LOJA'
NAME "PROVINCIA DE LOJA"
STYLE
OUTLINECOLOR 128 128 128
COLOR 225 225 185
END
END
CLASS
EXPRESSION //
NAME "REPÚBLICA DEL ECUADOR"
STYLE
OUTLINECOLOR 128 128 128
COLOR 247 219 176
END
END
END
END
  
```

In the script content we can observe the programming of key words in a detailed way. A layer has been defined in the same script. This layer accesses directly to the defined data source and the content is presented in the output file as a polygon with the definition of color and outline.

Among formats supported by MapServer, we have the vector formats originated from ArcView and raster files corresponding to satellite images or aerial photos or derived information. Processing this information depends on the web system. After making tests by using vector and raster information, it was proven that the response speed was adequate. The result of a source in vector and raster format from a LANDSAT image 2000 is shown in Fig. 4

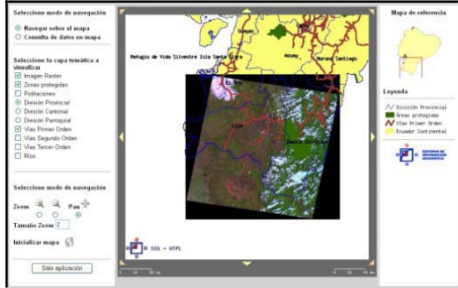


Fig. 4 Representation of vector and raster data.

In the case of using vector sources, the data retrieval can be done by using the CLASS key word through which it is possible to access directly to the data contained in the dBASE file IV with extension .dbf which is an element that is part of the files .shp of ArcView presented as map and queries.

With the work on raster format files, we can access to certain types of files such as: TIFF/geoTIFF, EPPL7 among other types of raster files of lower quality such as BMP and JPEG, see Fig. 4.

Visualization and attributes display in a spatial query

In SIG applications, like in any Information System, it is necessary to perform queries in the data repository.

As you can see in Fig. 5, the graphic environment for data representation is very useful, since we can distinguish; in a quick and clear way the geographical objects as representations of reality and the possible relationships among them.

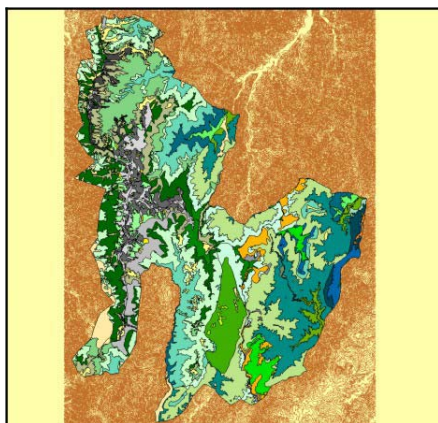


Fig. 5 Display of ecosystems in the study area.

This is an example of maps geovisualization, which is a visual element that helps in decision making, and should be accompanied by the queries of thematic data. For representing results, the formats GIF, PNG, JPEG are recommended. It is proven that the best one is JPEG which is a highly compressed format with adequate color compression for data representation.

For the data query in text and graphic mode, a query to the data chart in the Mapfile file will be established, defining a TEMPLATE file and a QUERY object. Scripts of the definition of the QUERY object and the template file are shown below.

```

QUERYMAP
  SIZE 360 300
  STATUS ON
  STYLE HILITE
  COLOR 255 0 0
  OUTLINECOLOR 255 0 0
  END
  
```

```

<tr align="center">[DE_PROV]</tr>
<tr align="center">[NOMBRE]</tr>
<tr align="center">[AREA]</tr>
  
```

The query result is shown in Fig. 6. This result comprises the stored data in the Protected Areas layer, as well as the geographical area included on the map.



Fig. 6 Query and display of spatial data-DSI for environmental analysis and study.

All the information either in raster format or in vector format is available in order for users to download it. Additionally, each one of these formats has a file that contains their corresponding metadata, so that the expectations of a DSI are fulfilled.

Finally, part of the information that is attached in the metadata file is exposed. This information is part of the reference information.

```

Metadata_Reference_Information:
Metadata_Date: 20070410
Metadata_Contact: fronate@utpl.edu.ec
Contact_Information: vhgonzalez@utpl.edu.ec
Contact_Organization_Primary:
Contact_Organization:
Universidad Técnica Particular de Loja, Equipo de Sistemas de
Información Geográfica
Contact_Person: Fernando Oñate
Contact_Address:
Address_Type: mailing and physical address
Address: Marcelino Champagnat
City: Loja
State_or_Province: Loja
Postal_Code: 1101608
Country: Ecuador
...

```

Conclusions and recommendations

- MapServer CGI is a multiplatform application and it has been tested (versions 4.0 4.1 4.2 4.6) in the operating systems Windows XP Professional and Linux with the Apache http server version 1.3.24. This tool turned out to be stable and reliable.

- When a client is connected to the http server and accesses the application, as a result, the user gets an image in raster format instead of data. The download operation is configurable, keeping the security and confidentiality of the geographical data.

- Mapserver can work with vector and raster data, thus, obtaining good results and adequate response times for Internet publications. The image formats generated by this software are: JPEG, PNG - PNG24, GIF, WBMP, among others. These images are loaded quickly, whereby, the first three formats are recommended, depending on the retrieval of raster or vector data (GIF for vector data; JPG, PNG-PNG24 for raster data).

- When publishing cartography on the Internet, we must use map servers or a computer environment that makes «interoperability» and «scalability» easy, as well as the use of formats and open languages.

- Regarding the visual display of the spatial information, the aesthetic aspects play an outs-

tanding role in the use of maps, because a clear and standardized symbology makes it easy for users to understand.

- The implementation of a SDI system is indispensable for the distribution of spatial data, thus, solving the problem of data integration from different regions, and accessed by different types of users.

Bibliography

Bosque Sendra Joaquin (2006) Universidad de Alcalá .

González Víctor H. (2005) MapServer y su aplicación a SIG, Universidad Técnica Particular de Loja.

Greenwood. Richard W. (2002) «Using MapServer to Integrate Local Government Spatial, Data.» Greenwood Mapping, Inc., http://mapserver.gis.umn.edu/MapServer_home_page.-_Sitio_oficial_de_MapServer.

<http://www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?C S NUMBER = 3 D 2 6 = 0 2 0 & I C S 1 = 3 D 3 5 & I C S 2 = 3 D 2 4 0 & I C S 3 = 3 D 7 0>

International Organization for Standardization.

<http://www.opengeospatial.org/>

OGC.- Desarrollo de estándares para la implementación de aplicaciones geoespaciales.

<http://www.opengeospatial.org/docs/01-68r2.pdf>
WMS.- Documentación Web Map Service

<http://www.opengeospatial.org/docs/02-058.pdf>
WFS.- Documentación Web Feature Service.

J.A.Bañares, M.A. Bernabé, M.Gould, P.R.Muro-Medrano, F.J.Zarazaga. (2001) «Aspectos tecnológicos de la creación de una Infraestructura Nacional Española de Información Geográfica». Universidad de Zaragoza.

Pérez Gómez Rufino, Martínez Marín Rubén (2004). «Análisis Semiológico De Mapas Temáticos Complejos, Su Programación En Entorno De Cartografía Digital Y Su Publicación En Internet. Aplicación A Los Mapas Geomorfológicos.». UPM

Rivas, R., Caselles, V. A simplified equation to estimate spatial reference evaporation from remote sensing –based surface temperature and local meteorological data. Remote Sensing of Environment, v. 93, p. 68-76, 2004.