# COMPARATIVE ANALYSIS OF FOUR QGIS PLUGINS FOR WEB MAPS CREATION

## ANÁLISIS COMPARATIVO DE CUATRO PLUGINS DE QGIS PARA LA CREACIÓN DE MAPAS WEB

Lia Duarte*, Catarina Queirós and Ana Cláudia Teodoro

*Department of Geosciences, Environment and Spatial Planning, Faculty of Sciences, University of Porto, Portugal; Institute of Earth Sciences, FCUP pole, Rua do Campo Alegre, Porto, Portugal*

*Corresponding author: liaduarte@fc.up.pt

**Abstract**

QGIS is a free and open-source software that allows viewing, editing, and analyzing georeferenced data. It is a Geographic Information System (GIS) software composed by tools that allow to manipulate geographic information and consequently to create maps which help to get a better understanding and organization of geospatial data. Unfortunately, maps created directly in the GIS desktop software are not automatically transferred to a website. This research aimed to compare publishing capabilities in different QGIS plugins to create Web Maps. This study analyzes four QGIS plugins (QGIS2Web, QGIS Cloud, GIS Cloud Publisher and Mappia Publisher), performing a comparison between them, considering their advantages and disadvantages, the free and subscription plans, the tools offered by each plugin and other generic aspects. The four plugins were tested in a specific case study to automatically obtain different Web Maps. This study could help users to choose the most adequate tools to publish Web Maps under QGIS software.

*Keywords*: QGIS Cloud, QGIS 2 Web, GIS Cloud Publisher; Mappia Publisher, WebGIS, WebMap.

**Resumen**

QGIS es un software gratuito y de código abierto que permite visualizar, editar y analizar datos georreferenciados. Es un software de Sistema de Información Geográfica (SIG) compuesto por herramientas que permiten manipular la información geográfica y crear mapas que ayuden a obtener una mejor comprensión y organización de los datos geoespaciales. Desafortunadamente, los mapas que se crean directamente en el software de escritorio GIS no se pueden transferir automáticamente a un sitio web. Por lo tanto, esta investigación tuvo como objetivo comparar las capacidades de publicación en complementos de QGIS, y crear mapas web. El estudio analiza cuatro plugins de QGIS (QGIS2Web, QGIS Cloud, GIS Cloud Publisher y Mappia Publisher), realizando una comparativa entre ellos, considerando sus ventajas y desventajas, los planes gratuitos y de suscripción, las herramientas que ofrece cada plugin y otros

aspectos genéricos. Los cuatro complementos se probaron en un caso de estudio específico para obtener automática-
mente los diferentes mapas web. Este estudio podría ayudar a los usuarios a elegir las herramientas más adecuadas
para publicar mapas web en el software QGIS.

***Palabras clave***: QGIS Cloud, QGIS 2 Web, GIS Cloud Publisher; Mappia Publisher, WebSIG, WebMapas.

Orcid IDs:

Lia Duarte: http://orcid.org/0000-0002-7537-6606
Catarina Queirós: http://orcid.org/0000-0002-0893-628X
Ana Cláudia Teodoro: http://orcid.org/0000-0002-8043-6431

2

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# 1 Introduction

A Geographic Information Systems (GIS) is a framework for obtaining, managing and analyzing geospatial data, and could be defined as an aggregation of several components as hardware, software, data, methodologies and people (operators and users), that can make possible an analysis of geographical data, associating attribute information to the objects.

GIS maps could be easily shared and embedded in applications, and accessible virtually. A Web Map is not only cartography available via web, but a service by which the users can choose the characteristics of the map that will be shown (Parker et al., 2013). Therefore, a Web Map is not only a map but is also the related content (database) presented via web with an appropriate interface and optional functionality (for instance, for queries and reports). A Web Map application refers not only to the code that is created to define the web interface, but also to the elements and functions provided through the interface.

Web Maps are user interfaces for geospatial information and constitute the tools by which the users interact with and explore that information (Cartwright et al., 2001). In order to make the geographical information accessible to any user, there is a need to more simplistic interfaces environments. In order to satisfy this need and to support the cognitive usability principles of a user, the Web Maps should be composed by elements such as: navigation tools, zoom options, pan, move, changing the scale, among others (Cartwright et al., 2001). In the past few years, the number of users has increased due to the functionalities developed by the creators considering: easy access, diversity and more intelligent applications integrated, providing more collaborative environment (Veenendaal et al., 2017). Most of the GIS Web Maps are created using open-source software (QGIS or other) and proprietary (for instance, ArcGIS). One example is the most recently created ArcGIS Online (ArcGIS, 2021). Other platforms can also be used such as: CartoDB, MapBox, SimpleMappr, MangoMap, Click2Map, among others (https://digital-geography.com/create-maps-online-a-comparison-webmap-providers/). However, the referred platforms are not free to use, except for the SingleMappr, which only allows to upload information in a web map.

The workflow for developing a Web Map comprises four primary main steps: (i) collecting the data to be putted on the map; (ii) conceptualizing the map; (iii) planning the user experience and; (iv) producing the final web map.

Generally, there are two types of Web Maps: (i) the static map, where the map content is fixed and unchanged, however, these maps can be dynamically generated where the server runs software that generates a map image based on changing conditions or specific user request, and; (ii) interactive Web Maps, where users interact with the map. For representation of highly dynamic data, real-time maps can be created. However, these require complex, and custom programming. Hossain and Meyer (2018) investigated appropriate and stable solutions for representing the statistical data into map with some special features. This research also includes the comparison between different solutions for specific features. They found three solutions using three different technologies, one of them including QGIS.

Web Maps also present some challenges compared to desktop GIS software, such as: i) a static GIS Web Map is not flexible, an edition must be performed every time the information changed, so it is time-consuming; ii) higher hardware and software costs, requiring more powerful web servers and programs and; iii) internet connection. However, the powerful advantages exceed the disadvantages; hence, web maps are increasingly used worldwide.

QGIS is an open-source GIS that respects the Stallman four freedoms (Stallman, 2007), and is licensed under a GNU GPL license. One of the main advantages of QGIS relies on the easiness and quickness of developing new plugins, using python language (Teodoro and Duarte, 2013; Duarte et al., 2016, 2018a,b, 2019). There are several plugins available in QGIS for the Web Maps creation, for instance, QGIS Cloud (https://qgiscloud.com/); QGIS2Web (https://plugins.qgis.org/plugins/qgis2web/ ); Lizmap (https://www.lizmap.com/en/); GIS Cloud Publisher (https://www.giscloud.com/apps/gis-cloud-publisher-for-qgis/); GIS-QUICK (http://gisquick.org/); Mappia Publisher (https://plugins.qgis.org/plugins/mappia_

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3

publisher/) and NextGIS (https://nextgis.com/). Sukic and Rančić (2011) have already discussed in 2011 the open-source plugins that have contributed to the GIS improvement and the way it is used. However, since then, several updates and improvements were done.

The integration of Web Map services has gained great notoriety in different areas of application. Chen and Nguyen (2017) develop a framework for the integration of Building Information Modeling (BIM) and Web Map service technologies for location and transportation analysis in green building certifications. With the aim of improving the traditional method of collecting road data and knowledge and management of the road network in Gharbi and Haddadi (2020) developed a GIS Mobile application using several solutions (PostgreSQL, PostGIS, QGIS, IntraMaps Roam, QGIS Cloud). Garnero and Vigna (2018) used QGIS2Web to support the activities of a forestry consortium (Canavese Forestry Consortium), which needs to plan its work in relation to the territory it manages. Bhatia et al. (2018) created a web GIS application using open-source tools, where Leaflet, Geoserver and PostgreSQL were used.

Four of these plugins were selected, specifically QGIS2Web, QGIS Cloud, GIS Cloud Publisher and Mappia Publisher, to perform a comparative analysis between them. The main objective of this study was to compare the referred plugins, which allows to create Web Maps through QGIS software, QGIS2Web, QGIS Cloud, GIS Cloud Publisher and Mappia Publisher, considering their advantages/disadvantages, main functionalities, subscription plans and their general functionalities. These plugins were considered since the QGIS2Web and QGIS Cloud plugins are the most downloaded plugins in QGIS official repository and the GIS Cloud Publisher and Mappia Publisher are more recent plugins, both created in February 2020. The results obtained provide a comparative analysis that can help the users understand the best plugin to use in a specific condition.

## 2 Materials and Methods

As already referred, this study analyzes four QGIS plugins (QGIS2Web, QGIS Cloud, GIS Cloud Publisher and Mappia Publisher), performing a comparison between them, considering their advantages and disadvantages, the free and subscription plans, the tools offered by each plugin and other generic aspects.

In the end of 2020, the QGIS repository was composed by 1302 plugins (https://plugins.qgis.org/plugins/).In this list, QGIS2Web have 649 717 downloads since the first version launched in June 2015. The QGIS Cloud Plugin have 290 423 downloads since the first version launched in August 2012. The GIS Cloud Publisher was recently created and have 4 462 downloads. Finally, the Mappia Publisher, also a recent created plugin has 10 692 downloads. These numbers are referred to 20 October 2020.

For all the 4 plugins referred, a base map was required in the Web Map composition. All the plugins have that functionality incorporated, except for QGIS2Web in which the plugin *QuickMapServices* (from QGIS software) was required to be installed before. The Open Street Map (OSM) and the satellite imagery from Google Earth were used as base maps. The data used in these four plugins to test the Web Maps include: i) two-point shapefiles; ii) two-line shapefiles; iii) two-polygon shapefiles and; iv) two-raster files. The processing time of each Web Map was also recorded.

### 2.1 Case Study

To compare the four plugins, a case study was considered in Alentejo, Portugal, in the Herdade da Contenda (HC) property (Figure 1). HC study area was chosen due to the set of geographical information available, vectorial and raster data, which can be used as input in the Web Maps. HC is a protected zone located in the municipality of Moura, Beja district, Portugal (Duarte et al., 2016).

Table 1 presents the information regarding the dataset used in the Web Maps created. This information includes the data type, the description of the data, the resolution/scale and the source.

All the information used was in European Terrestrial Reference System 1989 – Portugal Transverse Mercator 2006 (ETRS89 PTTM06; EPSG: 3763) coordinate system.
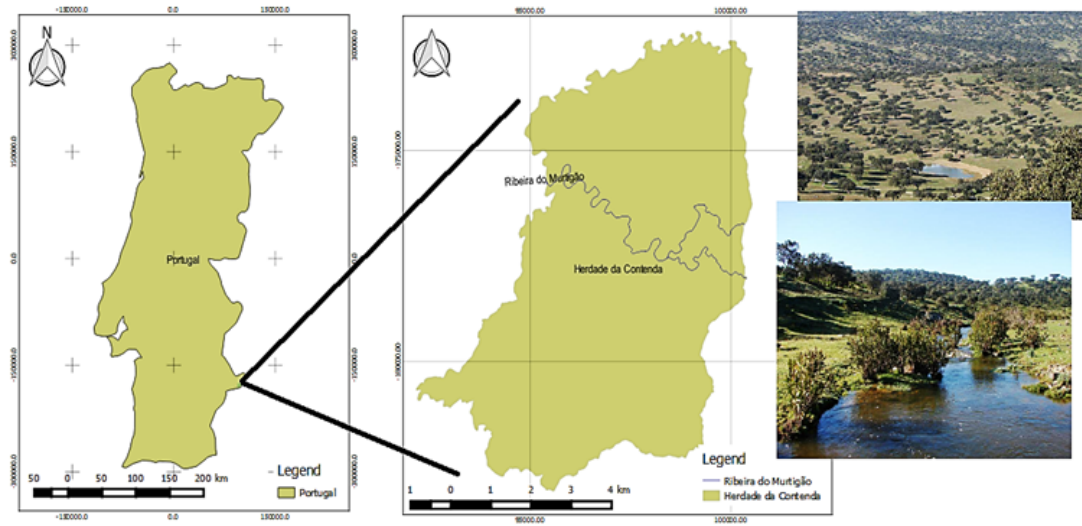
4

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**Figure 1.** Study area (adapted from Duarte et al. (2016)).

**Table 1.** Dataset description of the study case.

| Data type | Description | Resolution/Scale | Source |
|---|---|---|---|
| Vector – point | Carnivore in winter | - | Obtained in the field |
| Vector – point | Carnivore in summer | - | Obtained in the field |
| Vector – line | Contour lines | 10 m equidistance | Generated from DEM |
| Vector – line | Rivers | 1/100 000 | DGT*(DGT - dgTerritório, 2015) |
| Vector – polygon | Land Cover map 2007 | 1/100 000 | DGT*(DGT - dgTerritório, 2015) |
| Vector – polygon | Soil map | 1/ 35 000 | ICNF**(ICNF, 2015) |
| Raster | DEM | 10 m | Obtained from flight |
| Raster | Slope | 10 m | Generated from DEM |

\* DGT *(Direção Geral do Território)*.

\*\* ICNF *(Instituto da Conservação da Natureza e da Floresta)*

In order to introduce the data into the Web Maps, all the themes were projected to WGS84 (World Geodetic System 1984) in QGIS software. For each plugin were evaluated: i) the advantages (regarding for instance documentation, open source library, security, connectivity, among others); ii) disadvantages (regarding for instance the requirement of external programs, existence of subscription plans, among others); iii) a detailed comparison between the plugins considering if there have free plans or subscription plans considering also the limit for the data (when applicable); iv) the visualization and edition tools presented in each plugin (for instance, zoom in, zoom out, measure tools, pan, coordinates, creation of heat maps, data manage-

ment tools, among others) and; v) a detailed comparison regarding the general functionalities such the existence of tutorials, the accessibility, the storage, the security, the cloud and the mobile application, among other functionalities.

## 2.2 QGIS2Web

QGIS2Web is the most popular plugin in QGIS to create Web Maps. QGIS2Web uses the open-source libraries *Leaflet*, *MapBox* and *OpenLayers* to store the created Web Maps.

The *Leaflet library* is a free and open-source *Javascript* library to build Web Maps. It was first laun-

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5

ched in 2011, and supports mobile and desktop platforms with HTML5 and CSS3 support. *Leaflet* is the most popular library for interactive maps, and it is used along with *OpenLayers* and the *Google Maps Application Programming Interface* (API) in the known websites such as *FourSquare, Pinterest, Flickr*, among others (Leaflet, 2020). The *Leaflet* library allows users to display Web Maps in mosaics, hosted by a public server. It contains well-structured documentation with several tutorials. It supports the *GeoJSON* format. However, it has support for other formats such as CSV (Well-known Text), WKT (Well-known Text), TopoJSON, GPX (GPS eXchange Format; Geoapify (2020)).

The *OpenLayers* is a free and open source *Javascript* library for displaying map data in internet browsers such as mosaic and dynamic maps. It was first launched in 2006 and provides an API to build geographic maps on the internet similar to *Google Maps* and *Bing Maps* (Google Maps, 2020; Bing Maps, 2021). The *OpenLayers* library provides more features than *Leaflet* library such as the tools for map control. However, it requires complex knowledge to use projections and to define the coordinates (*LonLat* format; Leaflet (2020)). The documentation of *OpenLayers* contains *QuickStarts*, tutorials and many examples. It supports GeoRSS, Keyhole Markup Language (KML), Geography Markup Language (GML), *GeoJSON* and data from any source using Open Geospatial Consortium (OGC) standards such as Web Map Services (WMS) or Web Feature Service (WFS). The control and flexibility over the library are the main advantages of *OpenLayers*.

The *MapBox library* was created in 2010 by the same creators of *Leaflet*, and it allows to create personalized online maps for websites and applications such as *Foursquare, Lonely Planet, Facebook*, among others (MapBox, 2020). It significantly contributes to several open-source web mapping libraries and applications, including the *MapBox GL-JS Javascript* library, the *MBTiles* specification, the *TileMill mapping IDE*, among others. Data is obtained through open-source sources such as *OpenStreetMap* and *National Aeronautics and Space Administration* (NASA) and from private companies, such as *DigitalGlobe*.

This technology is based on *Node.js, Mapnik, Geospatial Data Abstraction Library* (GDAL) and *Leaflet* (MapBox, 2020). It contains a Software Development Kit (SDK), which is composed by a set of tools, allowing developers to create new applications. It is possible to find some similarities between *Mapbox* and *Leaflet* libraries. However, *MapBox* provides more features, data visualization options and higher quality in the vector maps creation.
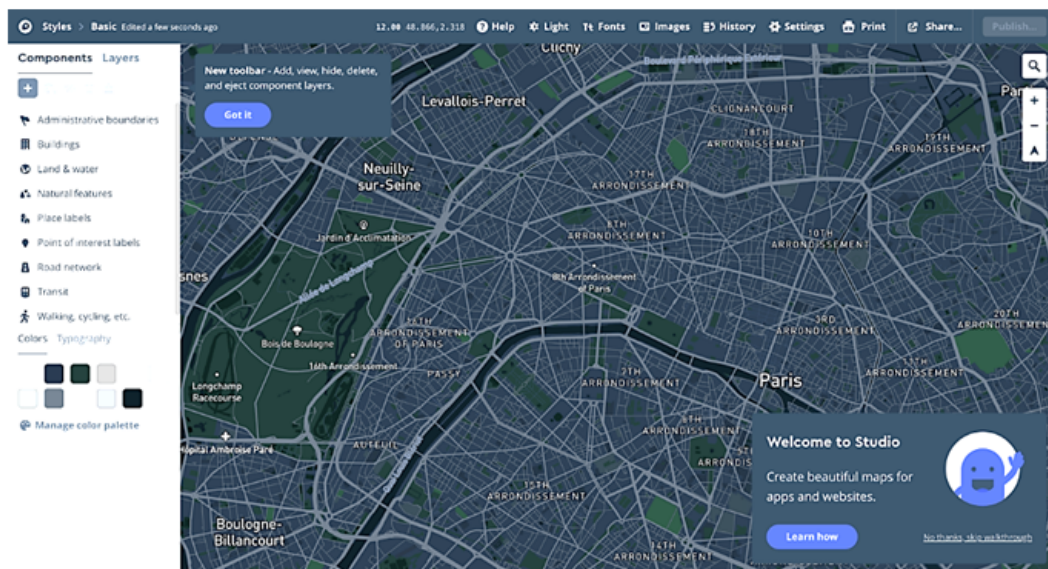


**Figure 2.** Web Map at official Mapbox website (source: https://www.mapbox.com/).

6

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Universidad Politécnica Salesiana, Ecuador.

In this work, the QGIS2Web functionalities were defined in a Graphical User Interface (GUI) under QGIS software. Then the Web Map was exported in *GeoJSON* file. It can also be exported to a File Transfer Protocol (FTP) site, where it is possible to publish the Web Maps directly on the World Wide Web (WWW).

QGIS2Web exports the *HTML, CSS* and *Javascript* files required for the website creation to a local folder, allowing to open the Web Map in a personal browser. However, a server would be required to publish the map. The Web Map is only editable under QGIS software. QGIS2Web does not have extra features on the web page, such as the possibility of editing the map.

These functionalities are similar in the 3 libraries (*Leaflet, OpenLayers* and *MapBox*). However, the *MapBox* library contains a JS library that provides a web page to help the user to obtain extra tools for the Web Maps creation. This site allows the user to create Web Maps directly on it and transfer the file to the QGIS. Figure 2 presents an example of Web Map at official *Mapbox* website.

## 2.3 QGIS cloud

The QGIS Cloud is a powerful web GIS platform for publishing maps, data, and services on the internet. This plugin does not require a server or an infrastructure (QGIS Cloud, 2020). It provides a PostgreSQL 9 database extended with PostGIS 2. The user can modify the data storage by considering any compatible tool, such as *pgAdmin3*, the *QGIS browser* or the *QGIS DB-Manager*. It is also possible to share maps and data on the OGC compatible web page and display maps as WMS or download data as WFS. The users are free to edit the data directly on the web page or use the QGIS Cloud web GIS and the *Mobile Client* integrated into the QGIS Cloud with the Well-Formed Substring Table (WFS-T). There is also a functionality to provide high quality maps for printing as WMS. The data can also be stored in the PostgreSQL cloud. The access to the data is protected through a password and it is possible to access through Secure Shell (SSH). The QGIS Cloud provides two subscription plans: *QGIS Cloud Free*, where all the maps published on the internet can be freely accessed until 50 MB; and

the *QGIS Cloud Pro*, where map access is limited.

The QGIS Cloud website requires the account creation and the free plan subscription. In the QGIS Cloud plugin (under QGIS environment) a database is created, and the data is uploaded to it. Finally, the map is published using the *Publish Map* button. A base map, *OSM, OpenTopoMap, OSM/ThunderForest, Wikipedia Maps or Bing Maps* can be also chosen from this GUI. The plugin provides 3 web publishing links and a customer support email: a link to the Web Map page, a Public WMS link to serve HTTP images, and finally a link to the map administrator, *Map Admin*. Therefore, the user can obtain a Web Map with public access through the QGIS Cloud website.

## 2.4 GIS Cloud Publisher

GIS Cloud Publisher is a QGIS plugin which allows to upload QGIS maps in Web Map form through the GIS Cloud website. It creates a data cloud for each user to save their Web Maps. This makes it much easier to transfer and publish GIS data from the personal computer to the cloud. This plugin has made a promising contribution to the GIS community by helping users who require a fast and accessible system to share larger maps or data sets with customers and make public that data. The map presented in QGIS is instantly replicated on a web page in the GIS Cloud account and easily shared via a link through a website (GIS Cloud, 2020).

The GIS Cloud editor allows the user to publish their maps and QGIS data to the GIS Cloud in just a few seconds, preserving the symbology and integrating the GIS data with the cloud. It is also possible to update all changes in the user's QGIS project and synchronize it with the maps published in the GIS cloud, as the project evolves.

It offers a wide variety of subscription plans for different types of functionality: free plans offering up to 100MB per account as well as viewing maps up to 1 smartphone and; extra QGIS plans if the user wants to create maps through the website (GIS Cloud, 2020). It is free for QGIS and ArcGIS.

It also requires a website account. Under QGIS software, the GUI is very intuitive since it provides step by step options. After publishing the map, GIS

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Universidad Politécnica Salesiana, Ecuador.

7

Cloud Publisher provides two publishing options: (i) open the map in GIS Cloud; (ii) provide a link to another user.

This plugin provides several editing tools, such as for instance create, edit, add, share, export, duplicate, archive or update new maps by importing excel tables and adding bookmarks; edit, add, clone, and join shapefiles, apply a spatial filter; a buffer can be created, a point proximity relationship can be performed, or a heat map can be created.

## 2.5 Mappia Publisher

Mappia Publisher is an open-source web mapping platform that requires a free *GitHub* account to start creating the Web Maps. *GitHub* is a for-profit company that provides a hosting service for *Git* repositories (used for software development) based on a cloud (GitHub, 2020).

The plugin automatically configures the user's map for Web Map through *GitHub*. It is possible to customize the online interactions for Web Maps created through a friendly GUI. It also allows to use several Web Maps at the same time and does not require any server. It is possible to share Web Maps or combine maps from different sources, creating an interactive online platform. Through QGIS, Mappia Publisher creates tiles for display on the web page with a variety of zoom levels. *GitHub* helps to store files from QGIS, metadata, legends, and other information. The data stored on *GitHub* is completely under the control of the account's owner. It is possible to publish, delete and edit data without interference from Mappia Publisher (MappiaEarth, 2020).

The Mappia Publisher website provides a free online display map service (such as WMS or WTS) along with customization benefits. To display the maps, the Mappia Publisher platform loads the tiles and places them in the correct geographical position directly on *GitHub*, allowing it to work even without a private server. The user can share their source maps (*GitHub* has a 2GB map size limit), where it is controlled by the *Upload maps* parameter, and other users can download it directly from the Mappia Publisher platform.

Under QGIS software, the Web Map is created and exported to a public file linked to GitHub. After exporting, Mappia Publisher automatically opens a web page with the publication of the Web Map.

## 2.6 Recording times

The processing times (in seconds) of the creation of each Web Map were recorded. The procedures were performed in the computer CPU (Intel® Core™ i5-4278U CPU 2.60 GHz, with memory (8.00 GB RAM), and the operating system (Windows 10 Home v.1903). The times were processed under a connection to internet with the following configurations: 19 ms (Ping), 24.21 Mbps (Download) and 20.69 Mbps (Upload).

## 3 Results

The Web Maps were created based on each plugin investigated. The next sub-sections present the Web Maps obtained.

## 3.1 QGIS2Web

Under the QGIS2Web plugin, 3 Web Maps were created based on *Leaflet, OpenLayers* and *MapBox* libraries (Figure 3).
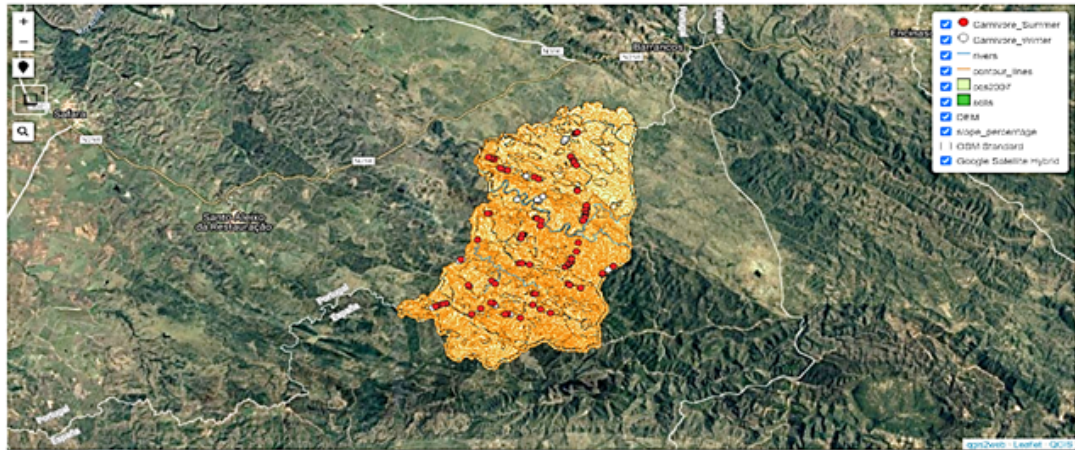
From Figure 3 was possible to verify that the 3 Web Map GUIs are very similar, composed by the same tools but with different interface widgets. The *Popups* in each Web Map have also different interfaces (Figure 4).
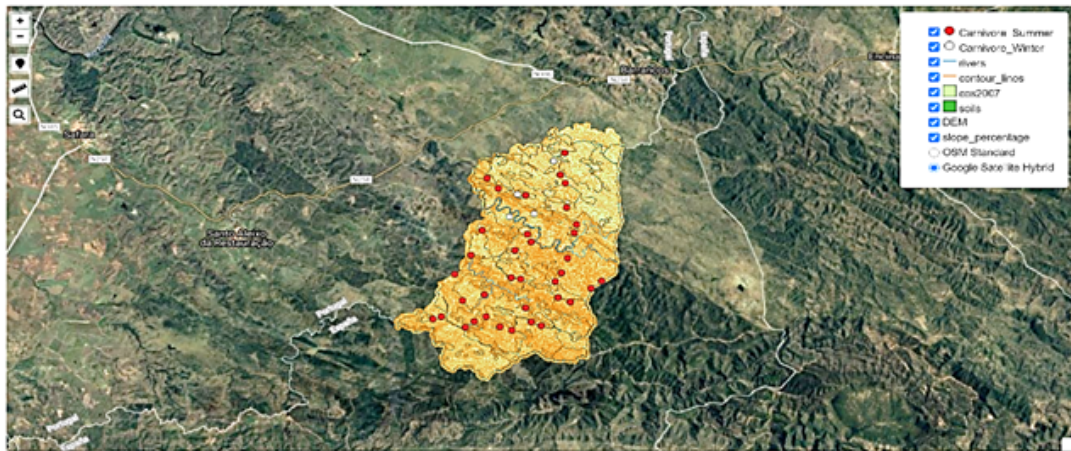
## 3.2 QGIS Cloud

The QGIS Cloud Web Map is presented in Figure 5. It contains the same functionalities as QGIS2Web but also offers the possibility to view and modify the map scale, the reference system and displayed map coordinates.
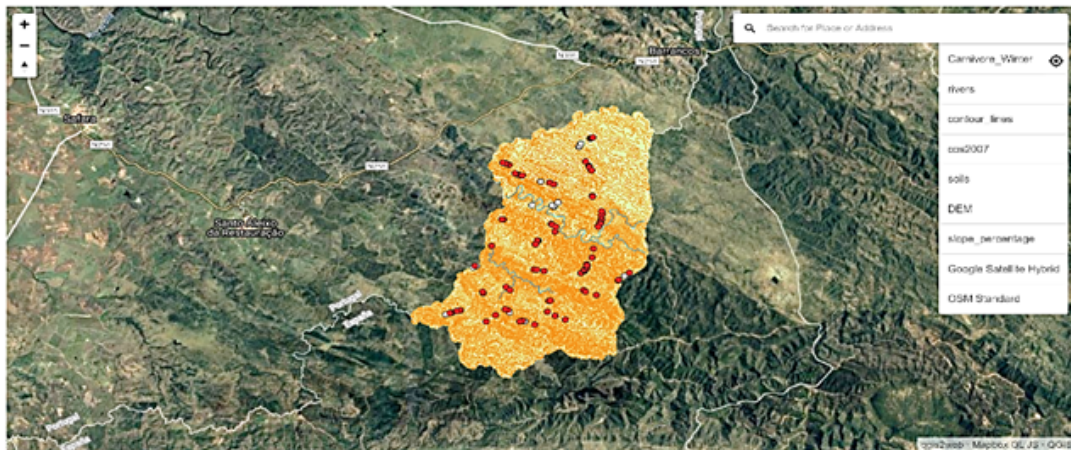
## 3.3 GIS Cloud Publisher

The GIS Cloud Publisher Web Map provides the functionalities similar to the other Web Maps, however, it provides menus and several editing tools (Figure 6).

8

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Universidad Politécnica Salesiana, Ecuador.

(a) **Leaflet**



(b) **Open Layers**



(c) **Map Box**

**Figure 3.** QGIS2Web web maps: a) *Leaflet*; b) *OpenLayers*; c) *MapBox*.

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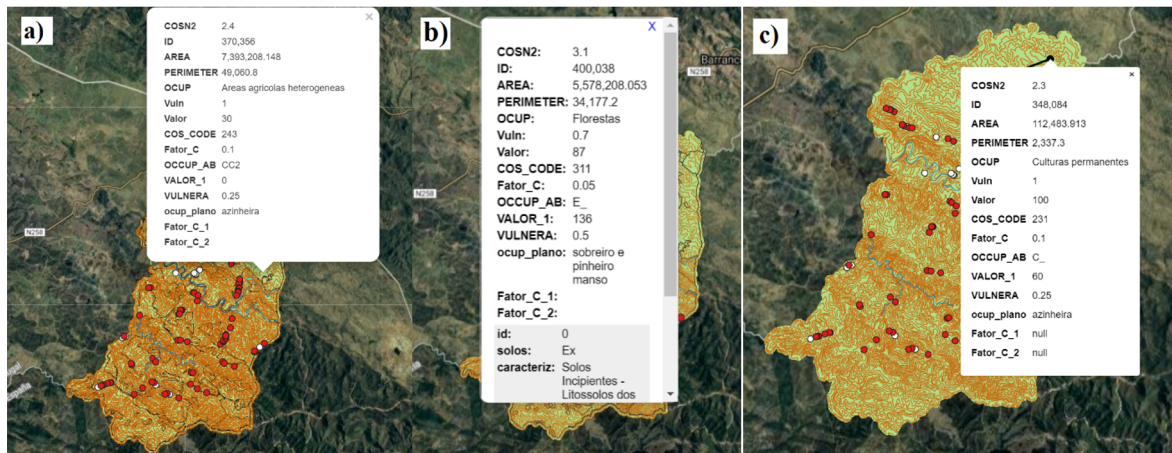Universidad Politécnica Salesiana, Ecuador.

9

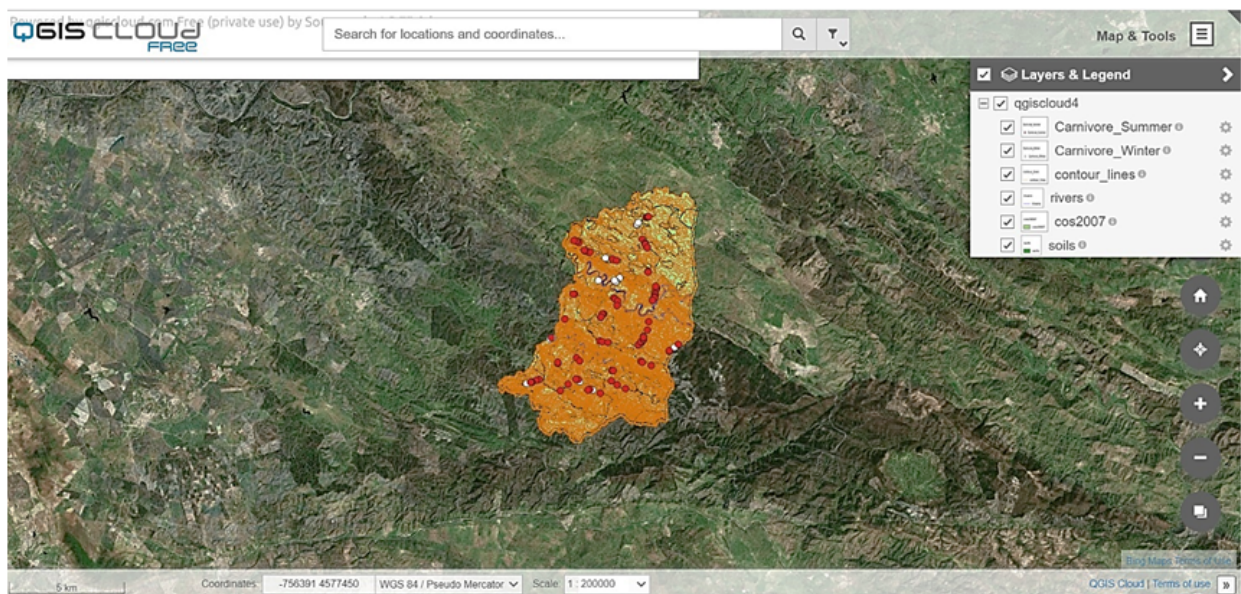**Figure 4.** Popups: a) *Leaflet*, b) *OpenLayers* and c) *MapBox*.



**Figure 5.** QGIS Cloud web map.

From Figure 6 it is possible to verify that beyond the visualization tools, it provides more editing tools (presented in Map, Layer, Analysis and Tools menus, Figure 7). In the map area, more tools are available such as: (i) *Info* button; (ii) *Select* tool; (iii) *Area Selection*; (iv) *Freehand Selection*; (v) *Show Google Street View*; (vi) *View Entire Map*; (vii) *Print*; (viii) *Scale*; and (ix) *Jump to Coordinates* (Figure 6).

### 3.4 Mappia Publisher

The Mappia Publisher Web Map offers similar visualization tools to the other Web Maps (Figure 8). However, it additionally provides: (i) user help tools; (ii) a tool for checking the information of an entity; (iii) a tool for visualizing metadata; (iv) enable and disable warning messages; (v) hide shapefile windows; and (vi) update new layers generated in QGIS.

10

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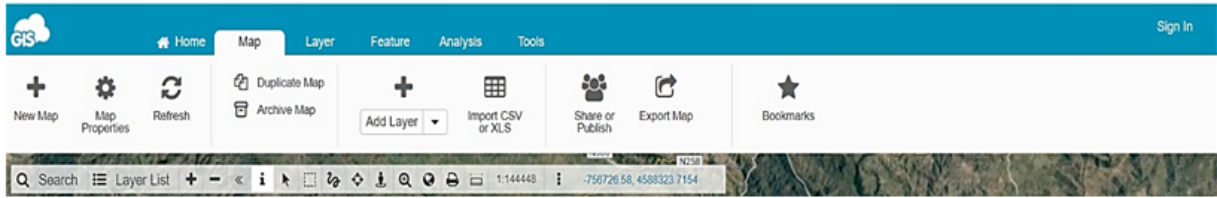Universidad Politécnica Salesiana, Ecuador.

**Figure 6.** GIS Cloud Publisher web map functionalities.
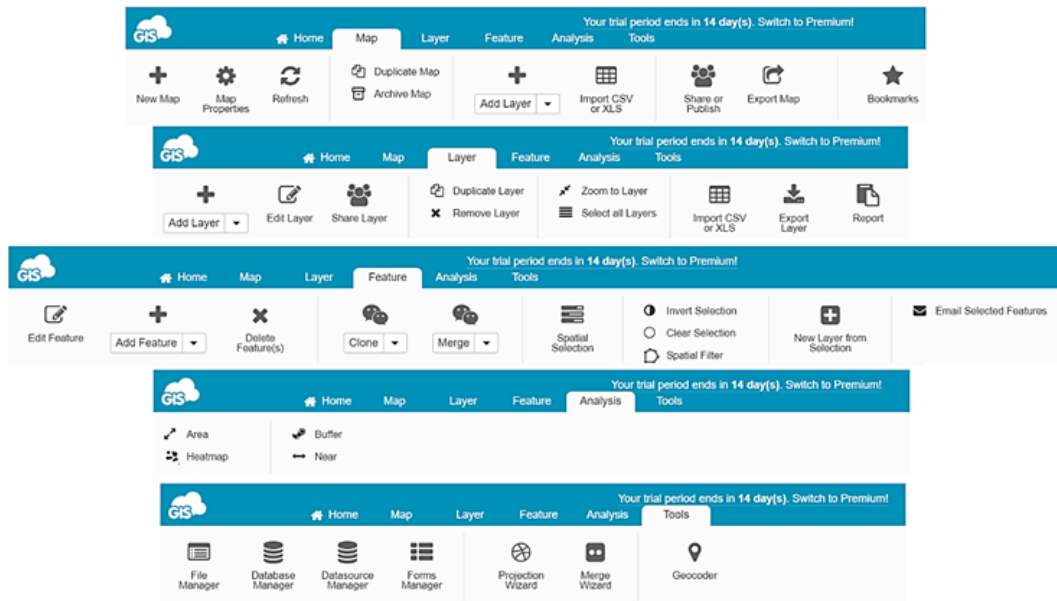


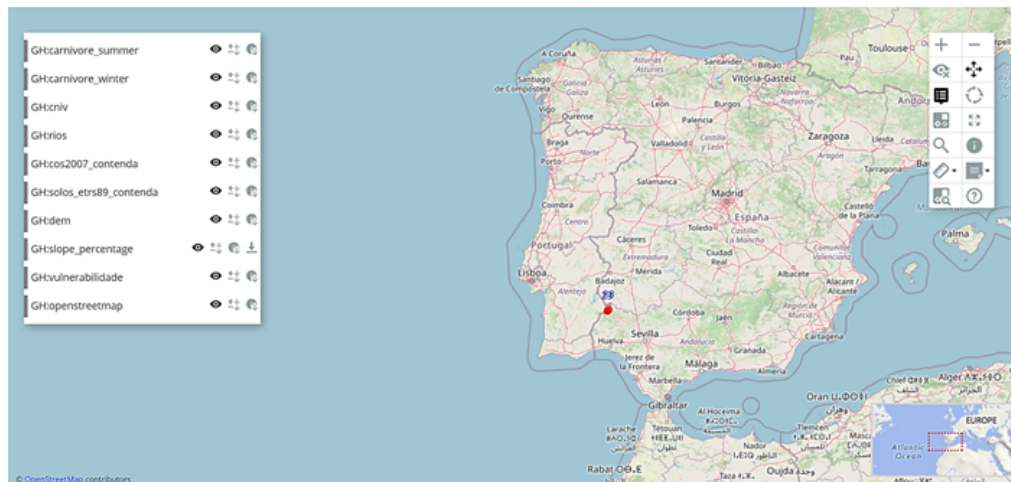**Figure 7.** Detailed functionalities from GIS Cloud Publisher Web Map.



**Figure 8.** Mappia Publisher Web Map.

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11

However, when zoomed in the case study zone, the Web Map does not correctly load the data (Figure 9), which can be a serious limitation to this plugin. Also, it was the Web Map with more time consumed in the creation.
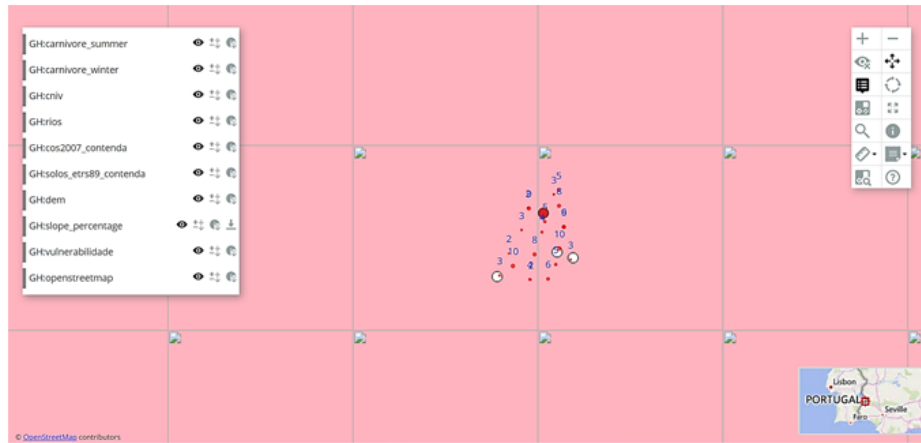


**Figure 9.** Zoom in to Mappia Publisher Web Map.

Table 2 presents the advantages and disadvantages regarding the most important features of each plugin. Table 3 provides a comparative analysis of the plans from each plugin, and Table 4 presents a comparative analysis of the visualization and editing tools associated to each plugin. Table 2 presented the advantages and disadvantages of each plugin, allowing to evaluate the compatibility with the user's needs. It was checked the type of programming language that each plugin uses, as well as the type of file it can export to. It is possible to visualize the tools embedded in the web pages for a better understanding of the Web Map. It also allows to evaluate the comparison of the storage for each plugin, as well as if it is protected by some type of security system on the website. It can also be checked if the plugin provides a web page that can be publicly accessed or if it requires external programs to perform this function.

From Table 3 it was concluded that the programs that offer full functionality over the plugin without requiring user subscription plans (open-source and free) are QGIS2Web and Mappia Publisher, where Mappia Publisher provides a Web Map preview page directly from the plugin and QGIS2Web provides the HTML code for the user to be able to publish on the internet. The plugins that offer an open-source

plan, but with limit features, are defined in this work as partially free, as they can be used free of charge but with limitations in the use of some functionalities that are usually based on the storage, as such QGIS Cloud and GIS Cloud Publisher.

From Table 4 it was concluded that the GIS Cloud Publisher is the only plugin that provides edition tools. A summary of this comparative analysis is presented in Table 5.

From Table 5 it is possible to verify that GIS Cloud Publisher plugin contains almost all the evaluated elements, being the only plugin that allows to insert/use edition tools. However, it is not an open-free source, so it has costs to use. Table 5 allows to compare general characteristics between the four plugins evaluated.

## 3.5 Processing times

Table 6 presents the processing time regarding the four plugins analyzed. In terms of processing time, all plugins exported the Web Map almost instantly; however, the Mappia Publisher plugin took almost 2 hours to export it. The rest of the changes made after that export were almost instantaneous.

12

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**Table 2.** Comparison of the four plugins regarding the advantages and disadvantages.

| Plugins | Advantages | Disadvantages |
|---|---|---|
| **QGIS2Web** | - Open source library.<br><br>- Supports HTML, CSS 3, GeoJSON, GeoRSS, KML, Node.js, Mapnik, GDAL.<br><br>- Mobile application (MapBox library).<br><br>- API documentation.<br>- Simple for users with no experience in QGIS.<br>- The most used plugin by the open source community. | - Requires external programs for the web map to be published.<br><br>- Requires a base map.<br><br>- Few web map editing tools on the web page. |
| **QGIS Cloud** | - No online infrastructure required.<br><br>- PostgreSQ9 database extended with PostGIS2.<br>- Possibility to share maps with OGC or via WMS and download via WFS.<br><br>- Print high quality maps (WMS).<br><br>- Security SSL.<br>- Password protection.<br>- No need for external programs for the web map to be public.<br>- Simple for users with no experience in QGIS.<br>- Mobile application. | - Momentary failures on the website server.<br>- Only offers full functionality with subscription plan.<br>- Does not work with the MacOS system.<br>- Storage of free plan only 50MB. |
| **GIS Cloud Publisher** | - Cloud creation.<br><br>- Possibility to transfer QGIS data (vectors, rasters, WMS, WFS) and their symbology.<br>- Points, lines, polygons, categories and labels are supported.<br>- Possibility to update changes on the map.<br>- Share public maps (URL link).<br>- Share private maps within the GIS cloud.<br>- Connection with secure SSL.<br>- No need for external programs for the web map to be public.<br>- Simple for users with no experience in QGIS.<br>- Compatibility with QGIS 3 and QGIS 2. | - Only offers full functionality with a subscription plan.<br><br>- Storage of only 100MB for free plan. |
| **Mappia Publisher** | - Opensource.<br><br>- GitHub account storage.<br>- 2GB limit for data.<br>- Do not require external programs to be public.<br>- Offers a web page for the map display service (with WMS or WTS).<br>- Simple for users with no experience in QGIS. | - The web map takes too long to create.<br>- Some bugs. |

LA GRANJA: *Revista de Ciencias de la Vida*
Universidad Politécnica Salesiana, Ecuador.

13

**Table 3.** Comparison of the four plugins regarding the subscription plans.

| Plugins | Free Plans | Subscription Plans |
|---|---|---|
| **QGIS2Web** | - Only free plans. | - Not applicable. |
| **QGIS Cloud** | - Free plan with 50MB cloud storage and a PostGIS 2.0 database. | - Offers web maps with restricted access, SSL support, PostGIS 2.0 databases with 500 MB/total, daily backups, web map editing tool on QGIS Cloud, domain names, logos and Custom CSS. -Additional plan to increase cloud storage and 10 additional databases. |
| **GIS Cloud Publisher** | - Offers a free plan with 100MB cloud storage and 10,000 vectors integrated within the vector files. | - The GIS Cloud Publisher Premium/Map Editor plan: private web maps, storage up to 1GB, 200,000 vectors integrated into vector files and premium support. - The Map Viewer plan: private web maps, personalized branding and access via the smartphone application. - The Map Portal plan: a domain and personalized branding and public access to 50,000 Map Views. - The Mobile Data Collection : the possibility to publish web maps in a smartphone application. - There is a plan to increase cloud storage for an addition of 500,000, 1,000,000, 2,500,000, 5,000,000, 7,500,000, 10,000,000, for vectors within the vector files. - A plan to increase storage for the addition of 10GB, 100GB and 1 TB, for rasters and storage of media files. |
| **Mappia Publisher** | - Only free plans. | - Not applicable. |

14

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Universidad Politécnica Salesiana, Ecuador.

**Table 4.** Visualization and edition tools for each plugin.

| Plugins | | QGIS2Web | QGIS Cloud | GIS Cloud Publisher | Mappia Publisher |
|---|---|:---:|:---:|:---:|:---:|
| Zoom in/out | Visualization Tools | ✓ | ✓ | ✓ | ✓ |
| Geolocation | | ✓ | ✓ | ✓ | - |
| Distance Measure | | ✓ | ✓ | ✓ | ✓ |
| Areas Measure | | - | ✓ | ✓ | ✓ |
| Position Measure | | - | ✓ | ✓ | - |
| GMS coodinates measure | | - | ✓ | - | - |
| Search Bar | | ✓ | ✓ | ✓ | ✓ |
| Reset bearing to north | | ✓ | - | - | - |
| On/Off Layers | | - | ✓ | ✓ | ✓ |
| On/Off Base Maps | | - | ✓ | ✓ | - |
| Add/Remove Layer | | - | - | ✓ | - |
| Update Layer | | - | - | - | ✓ |
| Share Layer | | - | - | - | ✓ |
| Duplicate Layer | | - | - | - | ✓ |
| Export Layer | | - | - | - | ✓ |
| Zoom to Layer | | - | ✓ | ✓ | ✓ |
| Popups | | ✓ | ✓ | ✓ | - |
| Hide Popups | | - | - | - | ✓ |
| Zoom Selection by area | | - | - | ✓ | ✓ |
| Modify Map Scale | | - | ✓ | - | - |
| Projection Information | | - | ✓ | ✓ | - |
| Google Street Map Viewer | | - | - | ✓ | - |
| Print | | - | - | ✓ | - |
| Help Tool | | - | - | ✓ | ✓ |
| Web map Legend | | - | ✓ | - | ✓ |
| Metadata | | - | - | - | ✓ |
| On/Off Map Interactions | | - | - | - | ✓ |
| Save web map | Edition Tools | - | - | ✓ | - |
| Add Selected Layers | | - | - | ✓ | - |
| Remove Layer | | - | - | ✓ | - |
| Join Layers | | - | - | ✓ | - |
| Spatial Selection/Invert | | - | - | ✓ | - |
| Spatial Filter | | - | - | ✓ | - |
| Import Excel tables | | - | - | ✓ | - |
| Add Bookmarks | | - | - | ✓ | - |
| Email Selected Layers | | - | - | ✓ | - |
| Analyse Areas | | - | - | ✓ | - |
| Analyse Buffers | | - | - | ✓ | - |
| Point Proximity Relation | | - | - | ✓ | - |
| Heat Maps | | - | - | ✓ | - |
| Files Managemnt | | - | - | ✓ | - |
| Database | | - | - | ✓ | - |
| Data Source | | - | - | ✓ | - |
| Forms Management | | - | - | ✓ | - |
| Projection and Join Assistent | | - | - | ✓ | - |
| Geocoder | | - | - | ✓ | - |

LA GRANJA: *Revista de Ciencias de la Vida*
Universidad Politécnica Salesiana, Ecuador.

15

**Table 5.** General functionalities of each plugin.

| General funcionalities | QGIS2Web | QGIS Cloud | GIS Cloud Publisher | Mappia Publisher |
|---|---|---|---|---|
| Opensource/ Completely Free | ✓ | - | - | ✓ |
| Opensource/Partially Free | - | ✓ | ✓ | - |
| Tutorials | ✓ | ✓ | ✓ | ✓ |
| Acessibility | ✓ | ✓ | ✓ | ✓ |
| Storage | ✓ | ✓ | ✓ | ✓ |
| Independency | - | ✓ | ✓ | ✓ |
| Competition | - | ✓ | ✓ | - |
| Visualization Tools | ✓ | ✓ | ✓ | ✓ |
| Edition Tools | - | - | ✓ | - |
| Extra Web Page | - | ✓ | ✓ | ✓ |
| SSL Security | - | ✓ | ✓ | - |
| Cloud | - | ✓ | ✓ | - |
| Mobile Application | - | ✓ | ✓ | - |

**Table 6.** Processing times (in seconds) for each Web Map.

| Plugins | QGIS2Web | | | QGIS Cloud | GIS Cloud Publisher | Mappia Publisher |
|---|---|---|---|---|---|---|
| | *Leaflet* | *OpenLayers* | *MapBox* | | | |
| Processing Time (s) | 5 | 5 | 5 | 25 | 52 | 7800 |

# 4 Discussion

Tables 2 to 5 present the comparison between the four plugins at several aspects: advantages/ disadvantages; plans; visualization and edition tools; and general functionalities. The information presented in these tables will help to support the user decision when the objective is to create a Web Map using QGIS software. In general, the four plugins have several advantages in terms of accessibility by supplying tutorials and online support, and providing a set of visualization tools. Some of these plugins provide accessibility for users with no experience in QGIS. This feature is undoubtedly an advantage for a user who is new in this environment. The four plugins provide tutorials and help videos. All the plugins provide visualization tools. However, only the GIS Cloud Publisher provides viewing and editing tools within the Web Map. In terms of storage, each plugin provides a variety of storage according to each one's functionality. QGIS2Web provides more storage than the others.

Mappia Publisher provides 2GB of web storage. GIS Cloud Publisher provides up to 100MB storage in the user's free account cloud and can reach up to 1GB if the user subscribes the plan. The QGIS Cloud plugin provides 50MB of cloud storage on the user's free account and can reach up to 1GB if the user subscribes the plan. In terms of data security, QGIS Cloud and GIS Cloud Publisher use secure SSL connection. These plugins offer the user extra security so that no one can access their Web Maps without their permission. Mappia Publisher uses the security provided by the *GitHub* page and QGIS2Web is not composed by any type of security plan.

The four plugins work within QGIS software, however there are some plugins that use web pages to provide extra functionality such as QGIS Cloud, GIS Cloud Publisher and Mappia Publisher. Unfortunately, QGIS2Web does not have a web page, so it requires a different program to publish the Web Map on the internet. This type of plugins facilita-

16

LA GRANJA: *Revista de Ciencias de la Vida*
Universidad Politécnica Salesiana, Ecuador.

tes the connection between the internet and QGIS software, as well as provide an opportunity for new GIS users. The plugins attract a new audience for QGIS and offer an overview for all users.

Although the QGIS plugins to create Web Maps cannot compete with proprietary platforms, such as ArcGIS Online, one of the most used platforms, they can provide an extremely quick and effective way of collaborative mapping and it can be a good first step for many GIS users. The ArcGIS Online, part of the Esri Geospatial Cloud (ArcGIS, 2021), is a proprietary platform and it allows to connect people, locations, and data through interactive maps.

According to the information collected and presented in the Tables 2 to 5, some future recommendations can be considered: i) create the possibility to add edition tools in QGIS2Web, QGIS Cloud and Mappia Publisher; ii) add a mobile application to the plugins since it is crucial to give access to the Web Map through mobile devices; iii) the Mappia Publisher plugin requires more time to process the data and this should be minimized, so the optimization of the code to process the data is also crucial and; iv) the plugins that require external programs are more difficult to use, so these programs should be integrated in the plugins.

Currently, Web Maps are created and shared with everyone, so it is important to learn how to create Web Maps or even how to use them. The four plugins tested in this study are composed by several tutorials and support to work with them. Thus, any beginner or advanced user can be prepared to use these plugins. The open-source concept implies that a code can be updated at any time by anyone, being a great advantage to applications developed under open-source software and related with the creation of Web Maps, as part of a collaborative project.

## 5 Conclusions

This paper presented a comparison between four QGIS plugins considering their advantages, disadvantages, functionalities, subscription plans and the accessibility to create Web Maps. The existence of plugins under GIS open-source software provides the possibility to automatize procedures without requiring programming language. The plugins cho-

sen to test and compare allows to create Web Maps and it can be very useful to users without experience in programming language to create from scratch a simple Web Map. As QGIS provides several plugins to perform that steps, four of them, QGIS2Web, QGIS Cloud, GIS Cloud Publisher and Mappia Publisher were tested and compared. It was concluded that all the four plugins provide visualization tools, however the GIS Cloud Publisher provide more visualization tools than the others and also provides edition tools. In terms of subscription plans, only the QGIS2Web is completely free, however host the Web Maps in local server. From all the advantages and disadvantages, even with the subscription plan, the GIS Cloud Publisher proved to be a more robust plugin providing a set of visualization and edition tools to support the creation of a Web Map.

## Acknowledgments

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17

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18

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