Article

Online geospatial platform for the collection of the irrigation fee

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Abstract

In Mexico, there is an area of 6.5 million hectares under irrigation, made up of 3.3 million corresponding to 86 Irrigation Districts and the remaining 3.2 million to more than 40 thousand irrigation units. Due to the fact that in the country's irrigation districts the possession of land and the uses of soil and water are dynamic, it is necessary to have a continuous update of their user registers. The models of the Geographic Information System, at the parcel level of the irrigation districts of Mexico, constitute a valuable tool that needs to be capitalized in the use of different applications to improve the development of the activities that involve the attention of said districts. In this work, based on the update of the user registry and the cadastre in the GIS model of module 5 Tepatepec of the Irrigation District 03 Tula, Hidalgo, the system for collecting the irrigation service fee is integrated into a geospatial platform online. This will allow obtaining a register of users, cadastre, cultivated areas and pattern of crops in real time, updated through the process of charging the irrigation service fee.

Keywords: geographic information systems, real time, user registry.

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Introduction

Legislation from the first decades of the 20th century proposed a policy of handing over irrigation districts to users; policy that, in fact, was carried out as demonstrated in four cases analyzed (Irrigation District 01 Pabellon, Aguascalientes, 027 Ixmiquilpan Hidalgo, module I, first unit of the Irrigation District 09 Valle de Juarez, Chihuahua and the module V Santa Rosa of the Irrigation District 034 Zacatecas state). The self-managing organization of users continued until and after the transfer. The administration by the users of the surrendered districts continued until the legislation and transfer policy of the state administration to the users in the 1990s (Rodríguez and Palerm, 2007).

The National Water Commission, created in 1989, began a process of transferring management, operation, conservation and maintenance of territorial areas of the irrigation districts, defined as irrigation modules (generically called modules). The users of these modules were organized for their administration, in non-profit civil associations of users (ACU), to which the use and management of irrigation water was granted. By 1996, 372 civil associations of irrigation users had been formed to control water deliveries for more than 2.92 million hectares (Arredondo and Wilson, 2005).

Currently, this transfer is practically completed and the management and administration of the irrigation district modules is in charge of their users, according to the indicated operational scheme, under the close supervision of the National Water Commission (CNA), Velasco *et al*. (1994), mentions that the user registry is one of the fundamental documents of an irrigation district, from which the programs and actions that it carries out derive, and based on which the dimensions of the budgets, costs, fees, execution times, value and volume of production and water, surfaces, crops, etc. are established.

In 1969, in the Irrigation District 038 Río Mayo, Sonora, the feasibility of the application of electronic computation to the solution of routine calculation problems in various work areas of irrigation districts was examined (Chávez, 1974). Currently, in the country’s irrigation districts, the ‘user registry system’ is in operation in version 3, called SIPAD 3 (Gerencia de Distritos de Riego, 2004). In the country's irrigation districts, land ownership and land and water use are dynamic, which requires continuous updating of their user registers.

The National Water Law (LAN) published in December 1992, in its fourth title, chapter iv, article 30, section 8, mentions that ‘the National Water Commission at the national level and the basin organizations in the field of hydrological-administrative regions, will keep the public registry of water rights in which the registers of users of the irrigation districts will be registered, duly updated’ (LAN, 1992). Under this context, where the LAN mandates to have updated User Registers, it is necessary to use the border tools that allow this update. These tools are the Geographic Information System (GIS) models, online applications via the internet and automated systems for collecting the irrigation service fee.

A GIS is a set of tools that allow the processing of spatial data information used to make decisions about a certain space or specific area of the Earth or also to generally visualize a space according to the content of digital databases (Sosa and Martínez, 2009). In the same way, Otaya *et al*. (2006), define them as a hardware, software and procedures tool designed to facilitate the obtaining, management, manipulation, analysis, modeling and output of spatially referenced data, to solve complex planning and management problems.

According to Mejía *et al*. (2003), the development of a GIS for an irrigation district and the modules that make it up can allow, in a fast and reliable way: a) to have, process and analyze the geographic-statistical information generated during the development of the activities that make possible the operation of the irrigation district; b) update the user registry; c) update the inventory of hydro-agricultural infrastructure; d) integrate the GIS generated with the collection system of the irrigation district; and e) integrate the GIS with climate and operational information for real-time decision-making.

Arnab and Santanu (2018), mention that the current generation of commercial GIS cannot facilitate decision-making in real time without significant modifications or integration with external models. In general, the technology of digital geographies has found the representation of change over time extremely difficult to handle.

GIS today remains a technology for static data, which is a major impediment to its use in spatial modeling Palacios *et al*. (2002), mention that, in order to achieve the sustainable development of irrigated agriculture, it is necessary for the civil associations of users (ACU) to establish payment fees for irrigation services that allow them to be economically self-sufficient, because the price of irrigation water can achieve a number of important social and management goals.

According to (Palacios and Exebio, 1989) cited by Santos *et al*. (2000), in the irrigation districts of Mexico there are differences regarding the cost of the irrigation service and the way to recover it; There are basically two ways of charging: per irrigated area or per volume used. An intermediate modality is per hectare per irrigation, where the payment of the service is a function of the number of irrigations carried out in the surface unit during an agricultural cycle.

At present, various technological tools, software and hardware have been created, which integrated to facilitate technical and administrative management in the irrigation districts Mundo and Martínez (2002), created a computerized system for the management of water in irrigation systems by gravity in Mexico (SICODE) which is a computer system that integrates in a modular way the following programs: database, geographic information system, simulation of soil water balance (irrigation forecast, supported by automated meteorological stations), biological simulator and expert system. It was implemented in the irrigation district: 010 Culiacan in the State of Sinaloa, Mexico.

Sagols *et al*. (2007), developed the SIGTERNET system, which is a tool to build, maintain and consult Geographic Information Systems (GIS) under a client-server architecture accessible via the Internet Delipetrev *et al*. (2014), developed a web application prototype for water resources using the latest advances in information and communication technologies (ICT), open source software and web GIS. The web application has three web services for: (1) geospatial data management, presentation and storage; (2) water resource modeling support; and (3) optimization of water resources.

Rueda *et al*. (2018), collaboratively designed a Web-GIS platform with an interface and contents corresponding to spatial indicators capable of generating data that reveal the degree of naturalness, biodiversity and the effect of urban wetlands. In Mexico, during the years 2006 to 2012 GIS models were made at the plot level for 85 Irrigation Districts. This was a great effort as a Nation to generate a unique geographic platform worldwide. However, it has not crystallized into applications that allow better management of irrigation districts and modules.

Currently, in all the irrigation districts of the country, the register of users and cadastral plans are not updated, which implies that the systems for charging the irrigation service fee do not correspond to reality, with the administrative conflicts that this entails. Likewise, there are 3 ‘registries’ in each district: 1) the official registry of users that CONAGUA has; 2) the register of users that the ACU of the irrigation module has; and 3) the register of users with which the irrigation service fee is charged.

The coexistence of these 3 registers implies a serious problem for the adequate management of the irrigation districts and modules. Additionally, the report of agricultural statistics in the irrigation districts and modules presents serious inconsistencies due to not having sufficient technical personnel in charge of these activities.

In this work, the implementation of an online geospatial platform for the collection of the irrigation service fee is developed, where border tools are integrated to update the user registry, cadastral plans, as well as agricultural statistics, which will allow to improve the administration process of module 5 Tepatepec of the Irrigation District 03 Tula, Hidalgo, under the following hypothesis: it is possible to obtain the update of the register of users, cadastral plans and agricultural statistics in real time through the collection of the irrigation service fee if supported by the implementation of an online geospatial platform.

Materials and methods

The works were carried out in the Irrigation Module No. 5 called ‘users and producers’ unit Tepatepec, AC’ of the Irrigation District 003 Tula, Hidalgo. It is located between the parallels 20° 12’ and 20° 15’ of north latitude and the meridians 99° 01’ and 99° 08’ of west longitude. In Figure 1, the location of Irrigation Module No. 5 ‘users and producers unit Tepatepec, AC, in the state of Hidalgo is presented.

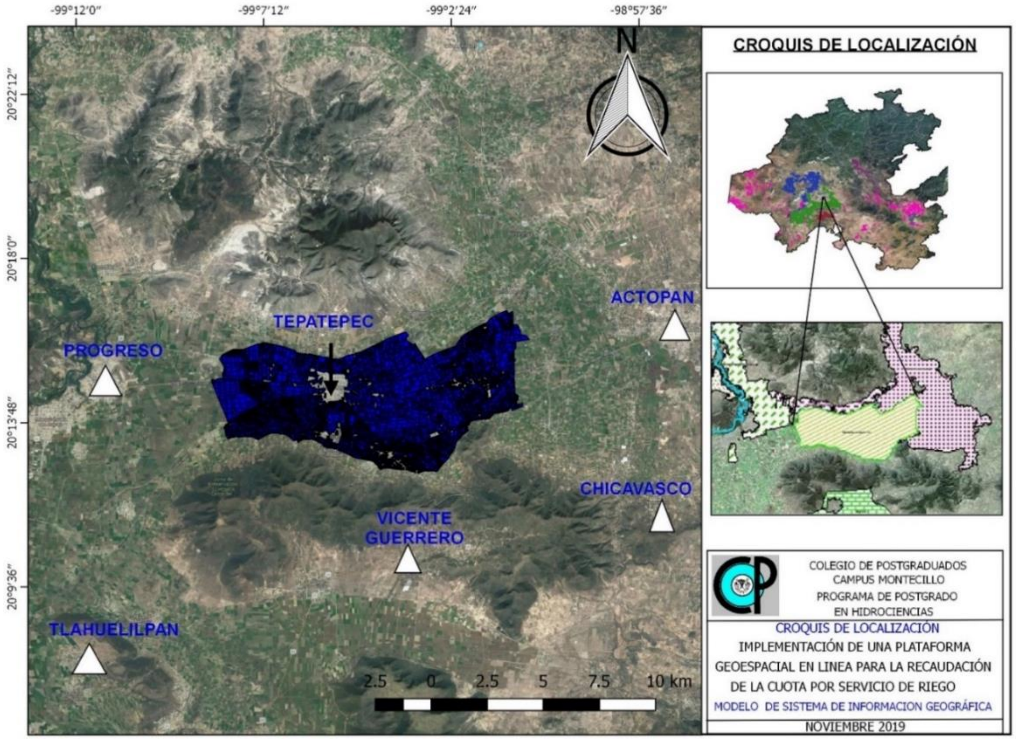

Figure 1. Location of the study area.

To carry out this work, the methodology shown in Figure 2 was developed.

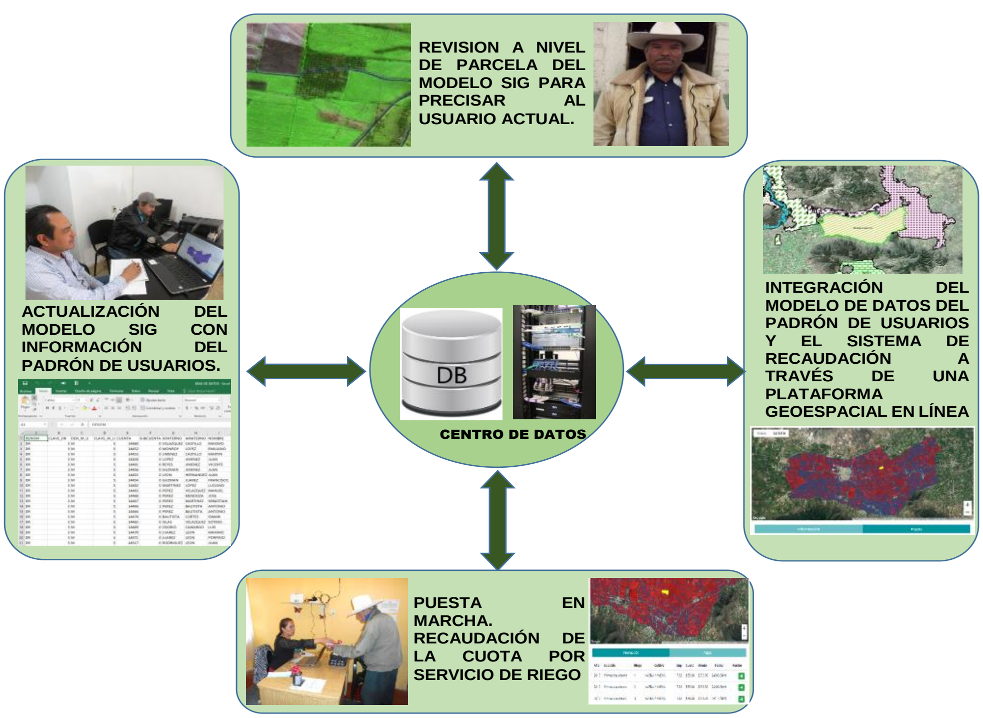

Figure 2. Methodology developed in the present work.

The description of each of the stages is presented below.

Plot-level review of the GIS model to pinpoint the current user

In a first review, the changes referring to irrigation surface, location of the plot and username were obtained between the database of the district users' register, irrigation module and the GIS model database using the number account. Accounts that were consistent in their information were deemed valid. Subsequently, the accounts in which there was inconsistent information in only some data or that were not in any of the three databases, were reviewed in the field. These plots were located in the field to collect the correct and updated information during the months of January to June 2019.

Updating of the GIS model with information from the user registry

The requirements for updating the GIS model were identified, based on the user register accounts provided and the information collected in the field at the plot level. Table 1 presents the classification of the needs to update the user registry as follows:

Table 1. Classification of the needs to update the user registry.

Update type	Account characteristics
User change	They are those parcels where the owner is no longer the one indicated in the database of the register of users of the geographic information system model.
Change of user and surface	They are those plots where both the owner and the surface underwent changes for which the update was required.
Surface change	Refers to parcels where the owner is the same but it was required to update the surface.
Accounts and subaccounts created	They are those parcels that are in the database of the register of users, however they had not yet been registered in the model of geographic information system.
Without changes	In these plots the information collected in the field and office does not undergo changes.

Finally, the GIS model was updated with the information on the respective changes both in the User Register database and in the subdivision (shapefile), as the case may be.

Integration of the user registry data model and the collection system through an online geospatial platform

The online geospatial platform means that the GIS model and the collection system are accessible through the Internet. To achieve this, two stages were followed, which are described below: In a first stage, we start from the database, which is the essential component of the GIS model because in it the content is organized and stored (vectors ‘shp’ and ‘dbf’ tables) of the applications that are part of the geospatial platform, in this case, the collection system. For this, it is vital to visualize the flows of the geoprocessing that illustrate the ideal scenario for the execution of the database from the conceptual, logical and physical model.

In this way, database management systems are the most appropriate tool, since it allows the storage and manipulation of vector geometric objects, transaction processing, referential integrity, stored procedures and standardization of the query language and advanced functionality (Bustos, 2012).

In order to design the spatial database, the following steps were followed: the functional requirements of the irrigation service fee collection system were defined. Conceptual design: to represent the geometric and topological information, the entity-based model was used, which conceives geographic objects embedded in space. Two components are distinguished in a geographic object: 1) a description; and 2) a spatial component, which corresponds to the shape and location of the object in space.

This view of the geographic information gathers within a spatial object points of the underlying space that share similar properties, that is, they have the same description. In order to distinguish one object from others, each object is assigned an identification. The complete entity set (identification, spatial object and common description constitutes a geographic object.

Logical design (data model mapping)

The database is implemented in PostgreSQL; from the mapping of the entity-based model and using the specific data model of the database management system (implementation data model), for this case the relational model was used.

Physical design

The storage structure of the files, their organization, indexes, and access paths are specified. Simultaneously, the application programs corresponding to the transactions are designed and implemented, in this case the collection system. Stage 2 depends, directly, on the structure of the data repository created in the first stage, duly documented, which dictates the guidelines to be followed to present the products on an online geospatial platform.

According to (Olaya, 2011) cited by (Nuñez, 2014), the advancement of local networks and the Internet ‘has allowed the geographic information contained in a GIS to be accessed using the client-server paradigm. For this, it is necessary to have components on the server side that distribute the information and components on the client side to access it’. In Figure 3, we can observe in a general way the simple architecture for a dynamic website, as is the case of the present work.

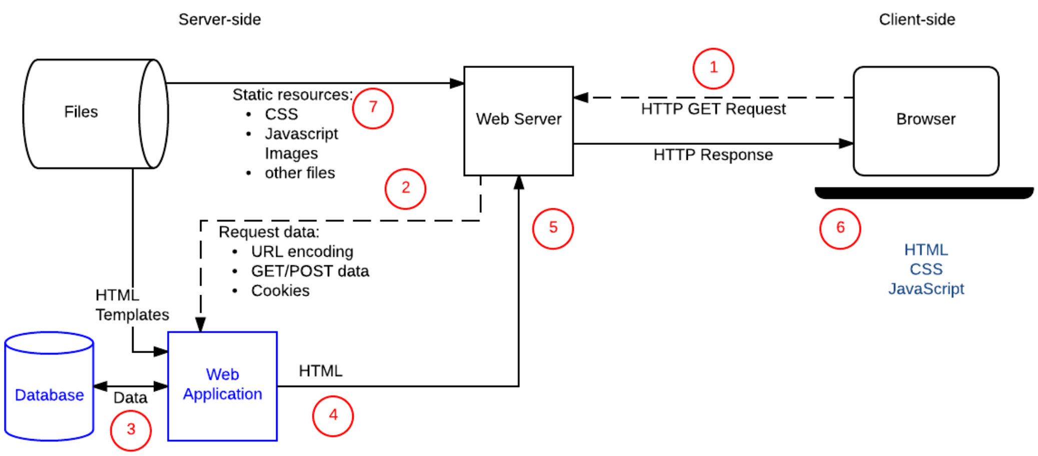

Figure 3. Simple architecture of a dynamic website (www.developer.mozilla.org).

In the same way, the online geospatial platform for the collection of the irrigation service fee will be linked to the spatial database through the GeoServer and GeoExplorer web applications, both tools grouped in the Web Server.

Start up. Collection of the irrigation service fee

Once we have generated the online geospatial platform, we proceed to start it up. In the module, your account has four collection offices arranged to serve the five irrigation sections. During the month of September 2019, the operation of the geospatial platform was explained to the staff of each collection office in order to collect the irrigation service fee. In Figure 4, the process to be followed to collect the irrigation service fee is presented.

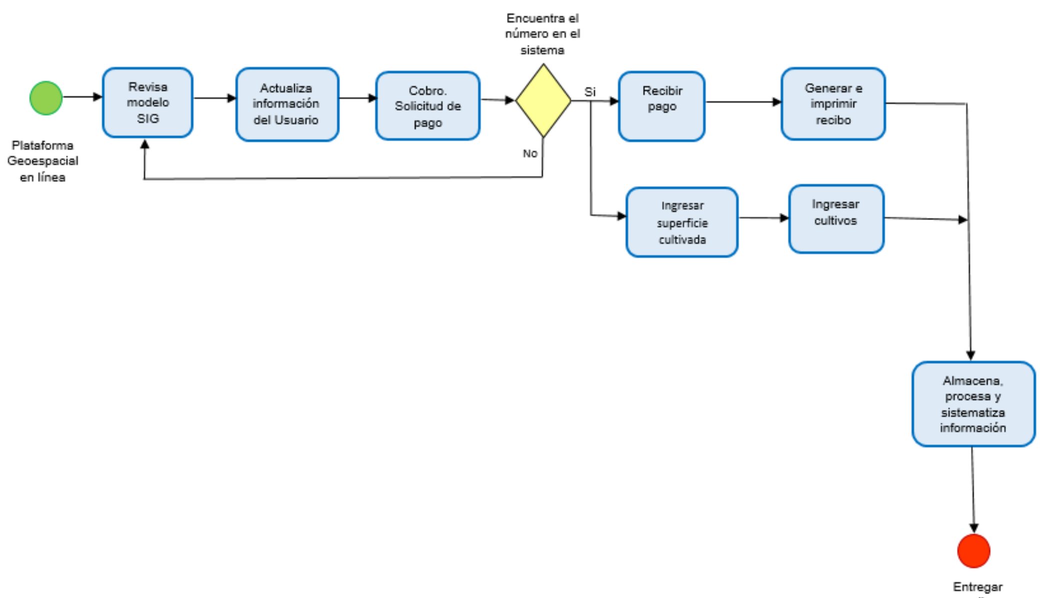

Figure 4. Collection process for the irrigation service fee.

The purpose of the start-up was to test the collection process implemented to detect possible inconsistencies between the relationship of the geographic entities, the attribute table and the collection table. The staff was instructed so that in the event that the account number is not found in the geospatial platform, we will be notified to proceed to review and update the user registry. Following the collection process, the necessary information is entered to be able to receive the payment and later generate and print the receipt which is delivered to the user. The information generated in the collection process is stored in the online geospatial platform to obtain the updated User Register, cadastral maps and agricultural statistical information in real time.

Results

Review and update of the GIS model

The GIS model corresponding to the information from the generated user registry database and the geographic entities was reviewed and updated. Table 2 shows the number of accounts reviewed and updated.

Table 2. Review and update of the user registry.

Update type	No. of accounts	(%)	Area (ha)
Without changes	3 131	62.10	3 355.57
User change	1 488	29.51	1 646.83
Accounts and subaccounts created	261	5.18	178.81
Surface change	104	2.06	100.72
Change of user and surface	58	1.15	68.29
Total	5 042	100	5 350.22

The user registry database amounts to 5 350.22 ha and 5 042 accounts, of which 37.9% of the user registry corresponding to 1 911 accounts was updated. The results of the review and update of the user registry accounts can be seen in Figure 5.

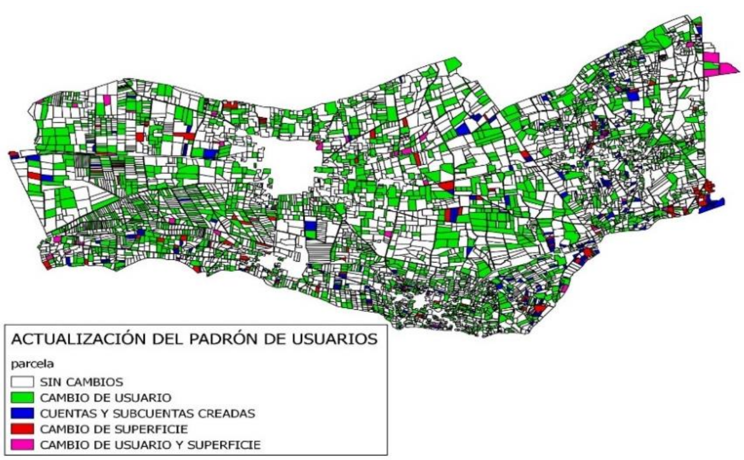

Figure 5. Graphic representation of the review and update of the user registry.

Integration of the user registry data model and the collection system through an online geospatial platform

The model of the user registry database was implemented in the PostgreSQL database engine, with the ability to manage the data from QGIS. Once the data repository is tested, the implementation of the online geospatial platform begins. Within this stage the connection with the database is developed, the edition of the geographic data to be uploaded to the network and the insertion within a geographic web environment for viewing on the internet. The GeoServer and GeoExplorer tools are used in this activity. In summary, the first is a map server for sharing, analyzing and editing geospatial data. While the second is an application for composing, styling, editing and publishing maps from the browser.

For the incorporation of the GIS model and the collection system on the Internet, GeoExplorer is used, which contains the necessary tools to hook the data directly to the web, without extensive programming or instructional implementation processes. The sequence to build the geospatial platform with the GIS model and the collection system is explained as follows: a) the GeoExplorer platform must connect to the GeoServer map server; b) add the layer to the map and connect to the Local GeoServer giving the go-ahead for publication; c) if you want to make changes to style, labels, colors with the style tool within the same page, the changes are made; and d) as a product, a geospatial platform is obtained that includes, in addition to the GIS model and the collection system, external coverage of googlemaps and openstreet maps, a tool for approaching, consulting, identifying, among others.

Once the GIS model and the collection system have been developed, a Web portal is built that serves as an online geospatial platform to carry out the process of collecting the fee for irrigation service and consulting information. In order to have greater control over access to information, an authentication form was created, in which it is necessary to have the corresponding username and password. Subsequently, you can see a viewer where the GIS model represented by geographic entities (polygons) is shown. In the background you can see the satellite image obtained from the Google server.

To be able to select a geographic entity (parcel), click on the center of the polygon and it will be painted yellow, at the same time that we select the geographic entity, at the bottom, the information loaded in the online geospatial platform appears, such as, producer data, crop data, channel network and other data, as can be seen in Figure 6.

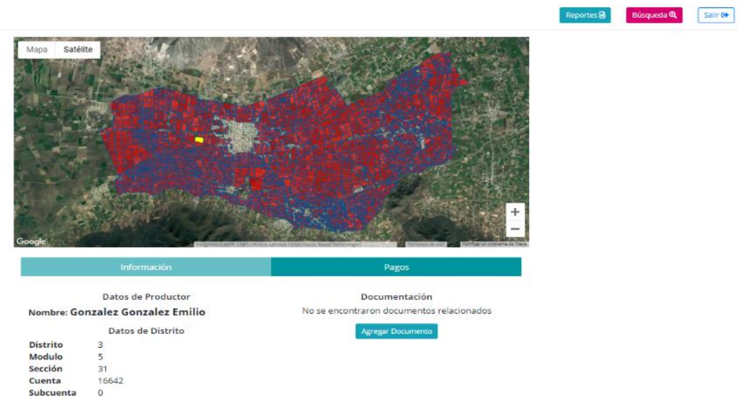

Figure 6. Online geospatial platform.

Start up. Collection of the irrigation service fee

To carry out the process of collecting the irrigation service fee, you start by selecting the search menu to locate the property. The search can be done by account or username. Subsequently, as can be seen in Figure 7, we select the search for the property by account and the name of the user is displayed. By clicking on select, the geospatial platform allows us to view the plot in the center of the GIS model. Once the search has been carried out and the account has been located, we proceed to collect the irrigation service fee. By selecting in the 'payments' menu, it displays the collection history and allows us to add a payment (Figure 8).

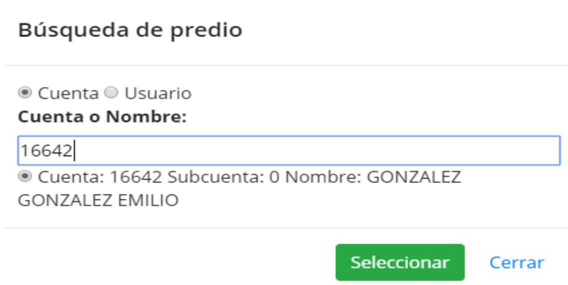

Figure 7. Selection of the property search by account.

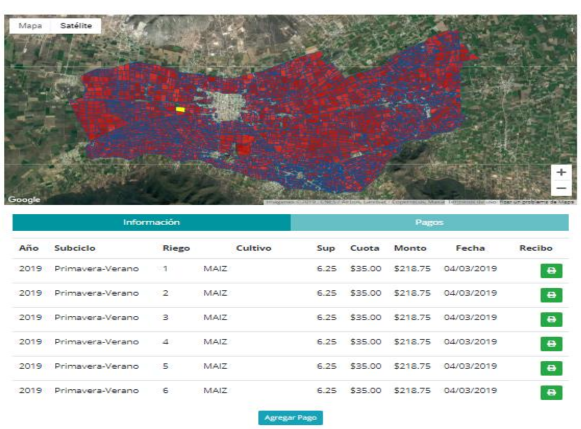

Figure 8. Visualization of the payment process (add payment).

Immediately, a pop-up window is displayed, in which to be able to make the payment, the indicated spaces must be filled. Subsequently, when clicking on the 'save' selection, the collection history is immediately displayed, where it is observed that the collection that was previously made has been loaded (Figure 9).

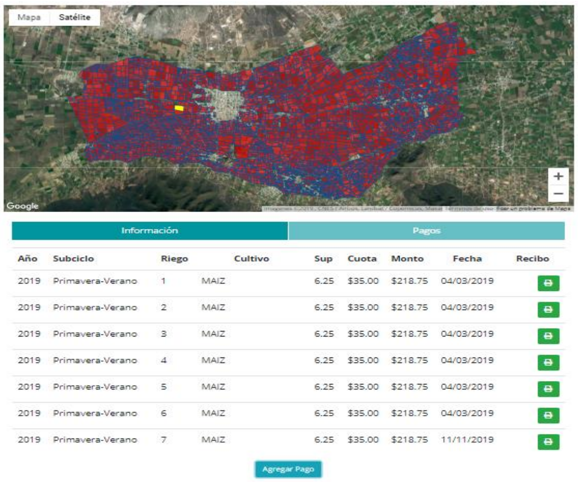

Figure 9. History of collection of the irrigation service fee.

Once the payment has been added, the corresponding receipt is generated for printing, as shown in Figure 10 and subsequently delivered to the user (Figure 12). Additionally, the property search can also be done by name, selecting the account that corresponds to the user, which we can see in Figure 11, then the same procedure described above is followed. Next, Figure 12 shows the launch of the online geospatial platform for the collection of the irrigation service fee.

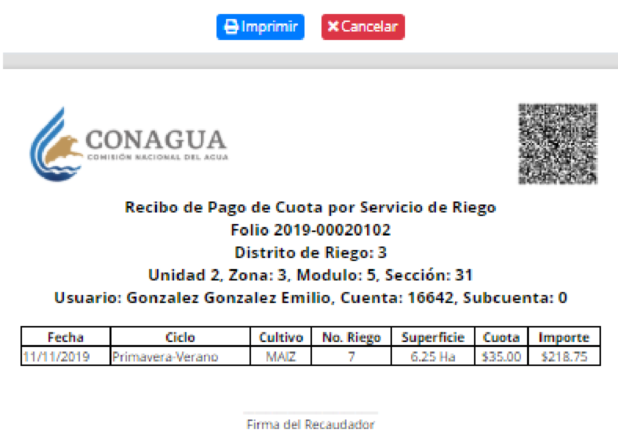

Figure 10. Generation of the payment receipt for the irrigation service fee.

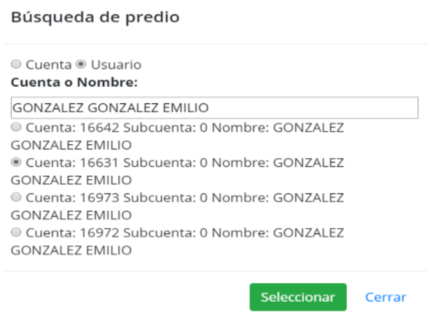

Figure 11. Property search by username.

Figure 12. Start-up and delivery of payment receipt (Tothie Office) 4.

Storage and management of available information

The geospatial platform stores the information which is available to obtain the updated register of users, cadastral plans and agricultural statistical information in real time. The cadastral plans and crop pattern information obtained from the implementation of the online geospatial platform are shown graphically below (Figure 13).

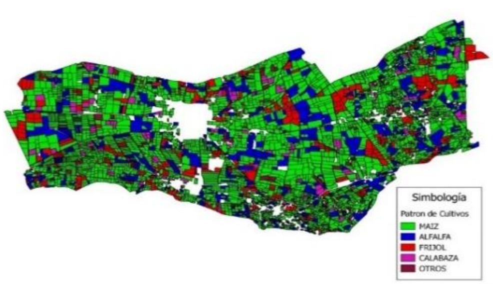

Figure 13. Crop pattern.

Table 3 shows the information corresponding to the pattern of crops with cultivated area derived from updating the user registry.

Table 3. Pattern of crops with cultivated area.

Crops	Cultivated area	(%)
Corn	3 611.25	67.5
Lucerne	936.29	17.5
Bean	481.52	9
Pumpkin	187.26	3.5
Others	133.9	2.5
Total	5 350.22	100

The crop pattern amounts to 5,350.22 hectares, it is observed that 67.5% corresponds to corn, 17.5% corresponds to lucerne, 9% to beans, 3.5% to pumpkin and 2.5% to others.

Conclusions

From the review of the user registry, it was obtained that 3 131 accounts did not present changes, 1 911 accounts were updated, of which: 1 488 accounts were updated due to user change, 104 accounts due to surface change, 58 accounts due to user change and surface area and 261 accounts and subaccounts were created. The above allowed the user registry to be updated as of August 2019. The GIS model and the collection system were made accessible through the Internet to collect the irrigation service fee on a geospatial platform.

The implementation of the online geospatial platform allows for a continuous process of updating the register of users, cadastral maps and agricultural statistics in real time through the collection of the irrigation service fee. Currently, the collection of the irrigation service fee is carried out in module 5 of the Irrigation District 003 Tula, Hidalgo, where the register of users is constantly updated and the cadastral plans are available up to date and information on the pattern of crops and cultivated areas in real time.

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