

Desarrollo de una metodología para la gestión de inventarios de flora

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RESUMEN

Dentro de las características de los jardines zoológicos, se detectó que no se cuenta con un inventario de toda la flora, ni mucho menos de la que requiere más cuidados, de igual manera, no se conoce su correcta ubicación y/o distribución, lo que propicia un inadecuado control y mantenimiento de la misma. Para ello, se diseñó e implementó una metodología que guiará mediante un procedimiento adecuado, la definición, creación y uso de los inventarios para el Centro Ecológico de Sonora, el cual permitirá el manejo eficiente de sus recursos. Se analizaron y estudiaron diferentes autores con distintos procedimientos, se generó una propuesta que se pueda implementar en éste y en otros centros. Se debe de considerar que para este tipo de proyectos se requieren equipos de georreferenciación profesionales los cuales eviten el desfase de las coordenadas y una incorrecta ubicación de las especies. Como resultado, se obtuvo un inventario de muestra de la flora considerada por el centro como de interés y una herramienta tecnológica de apoyo, brindándoles acceso a información actualizada de las plantas registradas para el personal y los visitantes.

Palabras clave: Gestión de Inventarios, Herramientas TI, Flora Endémica, Tecnologías Móviles, Mantenimiento de Flora

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Development of a Methodology for the Management of Inventories of Flora

ABSTRACT

Within the characteristics of the zoological gardens, it was detected that there is no inventory of all the flora, much less those that require the most care, likewise, their correct location and/or distribution is not known, which leads to inadequate control and maintenance of it. To this end, a methodology was designed and implemented that will guide, through an appropriate procedure, the definition, creation and use of inventories for the Ecological Center of Sonora, which will allow the efficient management of its resources. Different authors were analyzed and studied with different procedures, a proposal that could be implemented in this and other centers was generated. It must be considered that it is required professional georeferencing equipment for this type of projects, which avoids the coordinates difference and the incorrect location of the species. As a result, a sample inventory of the flora considered by the center to be of interest and a supporting technological tool was obtained, providing access to updated information on the registered plants for staff and visitors.

Key words: Inventory Management, IT Tools, Endemic Flora, Mobile Technologies, Flora Maintenance





Introduction

The maintenance of flora in zoological gardens has evolved over time due to the necessity to make the plant species available for as long as possible, which is why different types of methodologies, techniques, tools or methods have been sought to ensure that maintenance departments can manage these resources and carry out periodic tasks in a more practical way, avoiding deficiencies, managing to preserve the tourist attraction of the organization.

A correct flora inventory management involves a methodology of decision-making and actions at different levels from the companies, it is necessary to implement measures that allow this inventory management to be controlled, in the same way, based on the management, the activities must be determined to affect maintenance, in order to take advantage of natural resources in a controlled and supervised manner as a proven alternative to improve the standard living of the species that leads to an important source of income.

This document consists of six sections, the first section presents a brief introduction to the reader towards the objective of this work. Secondly the environment of this study is exposed, and it is explained how the problem has been reflected in the organization. In addition to this, the analysis strategy where the theoretical foundations are located and clarifies concepts such as inventory management, database, flora location, taxonomy and some other existing strategies are mentioned regarding the capture and management of information through the use of the GPS; Likewise, it is shown in the "Methodology" section the steps to follow, clearly, in case it is required to replicate in another organization. Continuing with the "Implementation" segment related to the execution of the methodology in the specific case of the CES, the operation of the technological tool that was implemented was incorporated. Finally, in the results and conclusions,



an interpretation and an explanation of the relationship between the results and the objectives sought in the investigation are included.

OBJETIVE

This research proposes the design and implementation of a methodology for inventory management, which was applied to a state recreational center named “*Centro Ecológico de Sonora*” (CES) using mobile technologies, which will first have updated information on the location and/or distribution of the endemic flora of the place, whose information may be visually/virtually represented on a map, key information will also be shown, for each of the plants within the CES and complementary information such as common names, season of pruning, seed harvest season, medicinal properties of each of these, etc.

PROBLEM

The CES aims to promote and disseminate people's culture regarding care for the environment. Over the years, the CES has worked uninterruptedly, remaining open to the public and showing species of flora and fauna within its 2.8 km of route, in which there are some information points deteriorated by inclement weather. However, according to the interview with the person in charge of the environmental education area of the CES, since 2014, the maintenance of the existing endemic flora has been partial; hence, the tourist attraction of the park has declined due to the increasingly notorious state of deterioration, caused by the lack of attention from the personnel and lack of resources; many of the flora species died due to their incapability to sustain themselves, animals were given higher priority.

Currently there is no control of the information on the existing flora, nor how it is distributed within the entire park route. This means that the maintenance managers have an absence or total lack





of care for the plants, because they are unaware of their location within the park, and only those that are in plain sight are better maintained, causing the loss of some species inside the park. It should be noted that the city of Hermosillo, Sonora is located in an area considered to be desertic and the average temperature in the summer months is of 40 ° C, and the rest of the month's temperatures have a range between 20 - 40 degrees [1].

ANALYSIS

According to the previously addressed problem, loss of plants, it is necessary to describe some terms that will allow understanding to the investigation. The main ones are described below for the best interpretation of this article. *Inventory management system*. It is made of multiple stages that are intertwined to achieve its objective; for example: receipt of materials, registration of entries and exits from the warehouse, storage of materials, distribution of materials, preparation of forecasts, planning of purchases and analysis of demand [2].

The implementation of these systems helps the organizations to optimize costs and improve economic efficiency by allowing them to face fluctuations in demand, maintain inventories in optimal and excellent conditions, resulting in an increase in customer service levels [3]. Another important aspect of inventory management is the optimization of resources, as it saves effort and staff time [4].

Database system. It is a collection of programs that run on a computer and help the user collect, change, protect, and manage information [5]. Within these there are relational database systems (RDBMS or simply RDB), which are a common type of database that stores data in tables, so it can be used in relation to other stored data sets. Most of the databases used by businesses



these days are of this type, as opposed to a flat file or hierarchical database. Likewise, most of the IT systems and applications on the market are based on a relational DBMS [6]. Database management tools use different languages to access them, you can predefine your database schema based on your requirements and set rules to govern the data relationships between your fields [7].

Plant taxonomy. It is the science that explores, describes, names, and classifies all living organisms. This is one of the first scientific disciplines that emerged thousands of years ago, in the 15th-16th centuries. plant taxonomy benefited from the Great Navigations, the invention of the printing press, the creation of botanical gardens, and the use of the drying technique to preserve plant specimens [8]. The taxonomy focuses on integrative approaches to multiple traits, considering all the potentially useful sources of information provided by the various fields of biology.

The nested levels in a classification of organisms are usually not only named, but also classified, that is, a set of hierarchical terms, such as genus, family, and class, are applied to reflect the hierarchical structure of the classification. So, in this way, complete classification is a hierarchy of names denoting hypotheses about taxa. After completing a classification and selecting an appropriate number of higher taxa to name, they are then ranked into classes, families, and genera, and this system of categories is well known as the Linnaean hierarchy or Linnaean categories [9].

GPS. It is a satellite-based radionavigation global positioning technology to determine a location on the earth's surface with a high degree of precision, depending on weather conditions [10].





Nowadays there are a large number of this technology, for example, those used in cars [11], to mark the route to follow and reach a certain destination used in smart mobile phones, [12] to capture and share the location in real time, and those that are used professionally [13]. We will focus on smart mobile devices and some professional models.

RTK GNSS. The Global Navigation Satellite System (GNSS) is a satellite-based positioning, navigation and timing device (PNT) [14]. After the 1990s, based on Real Time Kinematic (RTK) Satellite Navigation technology became the preferred technique in the world and is still used in various applications such as monitoring, security systems, early warning and mapping and application engineering. GNSS provides several kinematic and post-processing methods of positioning solutions. Different real-time kinematic GNSS methods have been used to determine the position of any point on the globe. The differential GNSS method has been used since the 1980s, though more for navigation applications, using pseudo range data with submeter position accuracy [15].

GNSS systems can offer fast and accurate point measurements in a wide environment as well as providing accuracy close to 10 cm–20 cm and, with proper use and some form of correction data, these devices can provide high accuracy near (1 – 2 cm horizontal and 3 – 4 cm vertical) in their coordinates. All GNSS systems, however, have certain notable limitations. To be most effective, they need a clear sky so that the satellite signals are not blocked or attenuated by intermediate obstacles [16].

Trimble R4. is a tool that uses the global navigation satellite system (GNSS) and that uses RTK configurations, which aims to provide an ideal solution for surveyors who need the use of proven



GPS technology easy to use and that gives results in the most difficult and demanding conditions, it is capable of using georeferencing data and recording it within its system. Their GNSS operations are only as good as their correction source, being this a lightweight, convenient, cordless, and easy-to-use solution that provides everything you need to perform basic survey projects in demanding conditions [17].



Figure 1. Trimble R4 tool used for the collection of flora locations

Google My Maps con GPS. Google My Maps with GPS is a web-based application where custom maps can be created by adding favorite locations and can be used for navigation and other purposes on the go. This application alone does not offer much research utility, but when combined with GPS it has several benefits [10]. It is an easy-to-use tool and offers the ability to zoom in or zoom out to show the map. It offers a lot of additional information about many places in the world, such as routes to get to different places from any current location and it is possible





to print, send or link the maps, this type of tool is capable of taking advantage of the GPS of smartphones allowing the users of the application to be guided through different routes by the geolocation of the flora in collaboration with a map in line [18].

Google Earth with GPS. Google Earth Engine (GEE) is a cloud computing platform designed to store and process large data sets, turning it into a database manager for analysis and decision making. This database includes information from satellites, as well as vector data sets based on Geographic Information Systems (GIS), social, demographic, meteorological, digital elevation, and climate data layers, that allows users to find various locations such as streets, avenues, businesses and expand them in a very realistic and detailed way. The way to move around the tool on the screen is easy and simple, with simple and manageable dashboards without much prior knowledge. This tool can be combined with the use of a GPS for mapping areas and creating inventories by feeding it with data of interest and exporting it to be used in other tools that later capture this data in a shared way on different smart mobile devices [19].

Mobile devices with GPS. GPS came into use with the creation of "location-based services," which allowed smartphones to access personalized spatial data in real time over computer networks [20]. Modern devices have receivers for these signals and usually an assisted GPS system [21]. This tool works in combination with the mobile phone network and satellite signals to quickly determine locations, avoiding the acquisition time that traditional GPS requires before a location can be given [22], unfortunately this device lacks precision [23]; [24]; [25]. The use of cell tower signals clearly only works in places with radio coverage. When the data generation capabilities of smart devices are combined with GPS, georeferenced information can be



obtained, with which it is possible to create maps of many environmental factors such as those of the flora of a specific region.

Another approach is the use of satellite-based augmentation systems (SBAS), which sends correction data through these. At least 10 satellites are needed for the location to be accurate, also if the weather conditions are not the correct such as cloudy, mountainous terrain, realistic environments including nearby buildings and forests generally lead to significant deviations and sudden jumps in GPS positioning as these signals could be altered by shifting the location up to 10 meters [26]; [27].

As mentioned before, with the use of GPS, the Internet and the integrated camera of a smartphone it is possible to roughly geotag a plant (due to the characteristics discussed above). Once the photo is taken, it is verified and the image is geotagged with its details (longitude, latitude, capture date, pixels, image size, etc.) these can be stored in an online plants repository system. App users can check the lists of existing plants they want to explore and locate on the map by geo-location mapping [18].

METHODOLOGY

The methodology developed was created from the analysis of several studies, and the best elements were chosen, with the purpose of integrating and concentrating the best of each of these in a single work.

Pacheco and Avila [28], show the steps to follow for the survey of plant locations in a park and the development of a web system for the management of green areas, in order to map existing





elements in parks to control pruning and maintenance activities of these areas managing to optimize the resources and improve the planning of its execution.

For data collection, the methodology of Fajardo-Gutiérrez [29] was selected. Here, the information of the plants was collected from the consultation of herbariums and compilation of different botanical registries such a web portal. It was obtained a fundamental input for the development of taxonomic reviews of the flora and encouraging the participation of researchers in the generation of knowledge in taxonomy, ecology, ethnobotany, physiology, conservation, propagation, genetics and evolution of plants.

Additionally, the methodology of Ávila González and González Gallegos [30], was taken, they elaborate a list reflecting the different families and species of plants, as well as their category of protection; the plants in the list were ordered by large groups. Each of these groups followed an alphabetical sequence for the families, genera, species and specific taxa. For each taxon, the biological form (habit, habitat) was provided. New species, endemic to the area and new records are also indicated, thus achieving complete and detailed information on the plants.

The approach of Mesquita [31] was elementary to choose what type of plants to consider in the proposed inventory, which shows certain parameters to take into account in the collection of plants of interest, obtaining the most important information possible without leaving bias in the data collection. Since, in this study, field incursions are used to investigate the most abundant species in the area which were later identified by specialized personnel from the USON Herbarium, belonging to the University of Sonora, likewise, a specialized GPS device was used to map the plant specimens. Due to the great diversity of plant species scattered in the area, the

largest and most abundant species found were chosen. In the study, the inclusion criteria was being one of the plants of the 20 most abundant families.

The proposed methodology (figure 2) consists of five phases: 1) Analysis of existing data; 2) Elaboration of data schema; 3) Design of the data management methodology; 4) Implementation of methodology and finally 5) Evaluation.

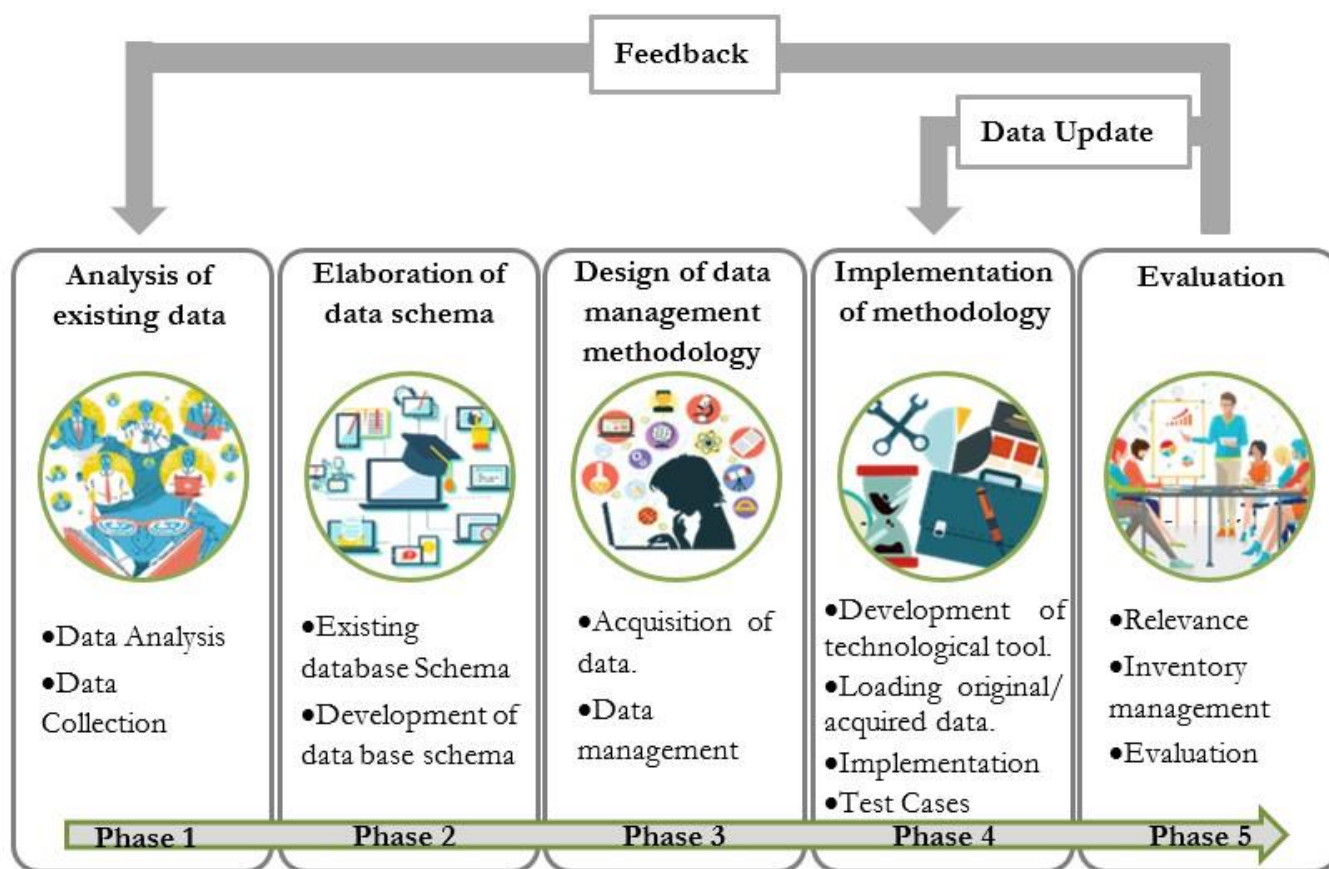


Figure 2. Diagram of the proposed methodology

All these phases are made up of a series of stages that were applied during the development of this research process. The first phase, called “Analysis of existing data”, had the purpose of





documenting, storing, and creating conclusions and ideas based on the available data. If the event that it is necessary to collect data, a survey process will be carried out using GPS tools.

This first phase is divided into two stages, the first stage, "Data Analysis", focuses on gathering and documenting all the existing data that the organism has on location, quantity, family, medicinal properties of plants, etc. to consider in the inventory; In stage 2, "Data collection", data was collected, complemented and documented with new real and updated data on location, quantity, family, medicinal properties of the plants to be considered in the inventory.

In the second phase, called 'Elaboration of data schema', two options were considered. In the first one, there is a database schema in the organization and it is intended to work with it, it will be updated, adapted or modified if necessary to meet the current needs; In the second option, there is no database schema in the organization, so it will be necessary to develop a schema that associates the data or concepts collected in the analysis and making them relate to each other and that comply with the specific requirements requested. In the CES, there was not one, so we proceeded to the "Development of database schema" stage, where a database system was chosen to help with the proposed objectives.

In the third phase, "Design of the Data Management Methodology", the aim is to connect the database to a technological tool that allows visualizing, adding, and updating the data if necessary. It consisted of two stages: "Acquisition of data" which identifies the best and simple way to acquire and store the information obtained in the previous phases, in this stage it is necessary to identify and choose the database where the data collected will be recorded and stored, as well as the technological tool in which they will be displayed, once this is fulfilled, the



database must be connected to the technological tool of choice in order for them to work together; For this, it is necessary to define the structure where the technological tool will be acquiring new data, If possible, the technological tool will allow adding new data needed to be updated to the database. The second stage, "Data Management", identified the best possible technological tool to manage and capture the information; a basic recognition of the proposed tool was carried out regarding the way in which it acquires the data.

In the fourth phase, "Implementation of the Methodology", the technological tool is defined with the characteristics and data of interest described in the previous phase, fully functional, for which 4 stages were considered, the first "Development of the technological tool" in which it is possible to create a tool from scratch or to adapt an existing technological tool that meets the defined criteria. Taking into account this tool, the second "Loading original / acquired data" database scheme is fed with the data obtained and, in the third stage "Implementation", the characteristics of the technological tool are presented in a real scenario. Finally, in "Test cases", a test scenario able to measure the functionality of the technological was used before and after it is presented to the end user.

In the last phase, "Evaluation", the results that cover the fulfillment of the initial objectives will be evaluated, as an example, the relevance of the information stored for the organization's personnel use, the better decision-making and management for the flora. This Phase consists of 3 stages, the first stage "Relevance", measures the satisfaction of the agency's staff and the general public through the use of indicators chosen for this purpose; in the second stage "Inventory Management", the generated inventory was evaluated on its function and satisfaction within the organization. Finally, the "Evaluation", which provides the results obtained by means of





the previous tools used. To resolve adjustments to the proposed data, two possible levels of adjustment and/or feedback of the methodology are presented; feedback (Structural) aims to make a general change in the data, both in structure and content for the inventory, while data update (Superficial) which is for minor changes in the data already existing within the database, such changes will be updated through the technological tool.

The follow-up of this methodology managed to solve the existing problem and remains as a basis of help for many students, researchers and/or workers who wish to carry out similar research or work in other entities or organizations with similar characteristics, not particularly being flora themed research.

IMPLEMENTATION

Interviews were conducted with CES managers and maintenance personnel in order to identify the existing problems. We proceeded to analyze and collect information, especially that available data about the plants of interest. One of the CES managers expressed that there is no documented information that could be provided at the beginning of the project, for which it was decided to carry out a survey of data; this was reflected in table 1, which includes the suggested characteristics that must be taken into account when carrying out a floristic inventory research. In this work, key information from the personnel in charge of the USON Herbarium of the University of Sonora and the representative of the Commission for Ecology and Sustainable Development of the State of Sonora (CEDES) was consulted.



Table 1. Characteristics to take into account in data collection.

Place / Characteristics	Herbario	CEDES
Flora type	Growth form: Trees, shrubs, lianas and succulents	Scientific name, Common name
	Duration (ephemeral and perennial)	Shrub, Tree, Cactaceae
	Flower colour	High, medium and low stratum (Arboreal, Shrub, herbaceous, ground cover)
	Type of fruit	Conservation Status
	Flowering season	
	Common / Scientific Name	
	Protection status according to NOM - 059	
Quantity per species	Habitat	
	Number for each species	The whole route
		From 5 to 10 meters to the sides of the route
	Trees and shrubs (cortex, stem, foliage)	Flower
Images of the species	Plant: Whole plant, approach to foliage, leaf arrangement, leaf shape, flower, flower shape, color	Whole tree
		Leaf details
		Fruit
		Cortex
Location	Coordinates (Certain Species)	Georeferenced
Medicinal properties	By type of disease / Respiratory, inflammation, etc.	Normal or medicinal use
	Used part of the plant, leaf, stems, roots. etc.	General uses
	Preparation mode	
Maintenance	Maintenance time	Pruning season
	Relief tree irrigation	Relief tree irrigation
	Removal of non-native plants	
	Seed harvest Season	

The database manager used to store data chosen was Google Earth, due to the ease and compatibility of working directly with a wide variety of geolocation technology tools. In addition to





this, within this manager, there is the possibility of sharing the database created based on the information fed through the export of keyhole markup language (KML) files, which are commonly used to store geographic data and all content related to it; A KML file exported through Google Earth which contains the design of the structure and hierarchy of the data shown as an example in table 2.

Table 2 shows the general information on both common and scientific names, families, medicinal properties, etc. of the flora that was collected in the survey of locations; The main function of this table is to provide information to the agency about the different protection status of the species belonging to it, especially those that have a "Threatened" status to support the preservation, seed harvest and irrigation to these species for their extension of life and reproduction within the park.

Subsequently, the technological tool Google My Maps was used, which is an environment where a map was designed and created, based on the data imported from the Google Earth database.

Table 2. Sample of the characteristics of the 4 most common plants in the area

Id	5	20	24	66
Common name	Palo Verde	Pitahaya	Guayacan	Mezquite
Scientific name	<i>Parkinsonia Microphylla</i>	<i>Stenocereus Thurberi</i>	<i>Guaiacum Coulteri</i>	<i>Prosopis Glandulosa</i>
Family	Fabaceae	Cactaceae	Zygophyllaceae	Fabaceae
Medicinal use	Traditionally the leaves, flowers and seeds in infusion are considered medicinal and have anti-fever, sudorific, anti-malarial and restorative properties. Also, with the leaves and cortex a syrup is made against cough and fever.	For diabetes, sap is squeezed into a glass, water is added and taken as drinking water; for animal bites, sores and wounds, a slice of the stem is heated over the embers and placed tied with a bandage on the injured part, for viper bites, two to three stem ends are cut, left to rest for 10-15 minutes, they are cut in half and put on the bite; pieces of stem are heated, wrapped in a cloth and placed on the painful part of the body.	Guayacan as a medicinal plant is used for colds, kidney and rheumatic conditions; fever. Pain from and/or contusions from objects.	Treatments for diabetes, digestive diseases, system parasites, eruptive diseases, adjuvant in cases of general malaise, kidney stones and cancer.
State of conservation	LC	LC	A	LC
Pruning Season	Systematic pruning of its lower branches (When Necessary)	N/A	Anytime (preferred spring)	It depends on the condition of the tree (It is possible to remove long, dead and damaged branches).
Seed Harvest Time	Between May and June	June - July	Spring Season	July - September
Relief tree irrigation	If necessary	N/A	If necessary	If necessary
LAT	29.0190983	29.01937525	29.01946335	29.01744225
LON	-110.9479236	-110.9488933	-110.9489928	-110.9504463



Once the previous steps have been carried out, as a requirement you must have an email account from the Google service provider, in order to link the new map with the CES; on the map, you can see the complete information, which can also be managed by the associated personnel, being able to upload new images to the defined plants, edit the existing information, edit the points, change their design, color and even search for the plants of interest. The final map obtained is shown in figure 3.

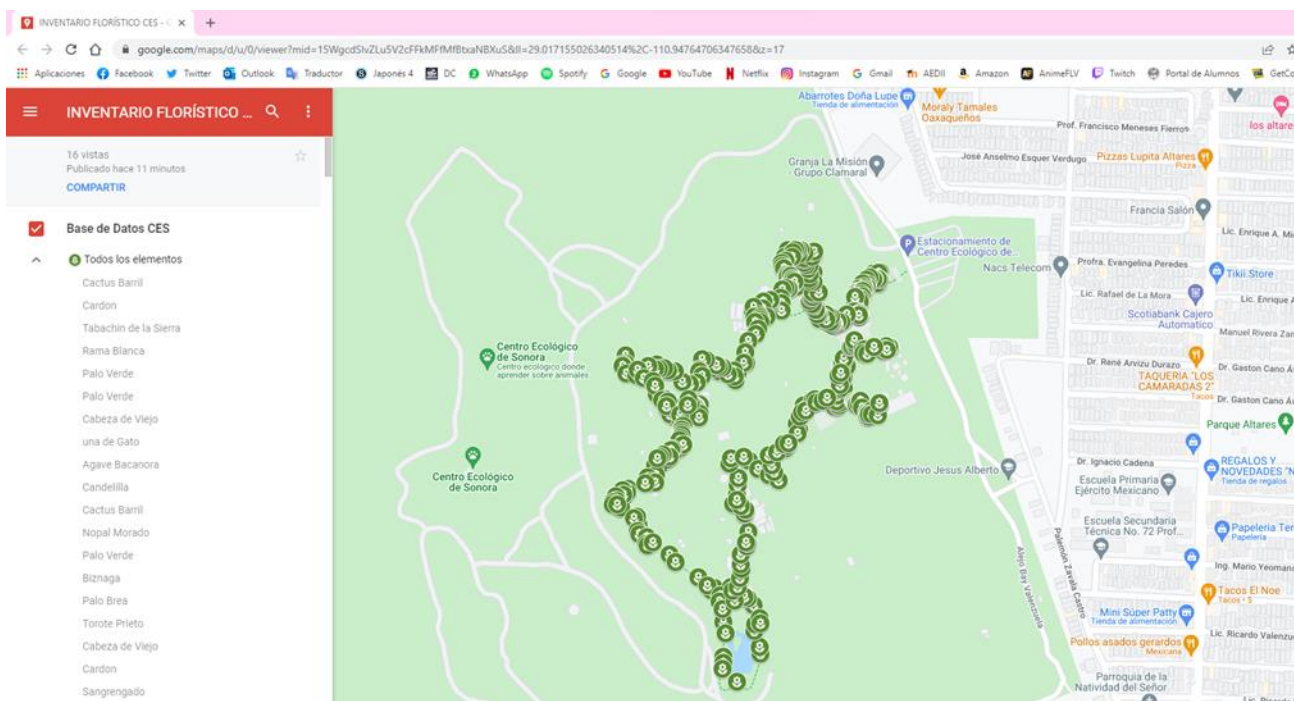


Figure 3. Floristic inventory of the Ecological Center of Sonora projected in Google Maps

Tool

This map allows the user to have the possibility of visualizing the entire inventory of the flora belonging to the CES distributed throughout the tourist trail, if you want to know the characteristics of a specific one, just zoom in and click on the plant of interest.

The final step is to share it with different users so that they can view it through the “Google Maps” mobile application. To achieve this task, the Google My Maps tool presents the option to share the map, which by using this option creates a link in the form of a link which gives access to its visualization.

In figure 4, a representation of the map is shown through access from a desktop computer, the visitor has the possibility of viewing the entire inventory of the plants belonging to the CES and how they are distributed throughout the route, the characteristics of a specific one stored in the database of the selected plant will be reflected on the left side.

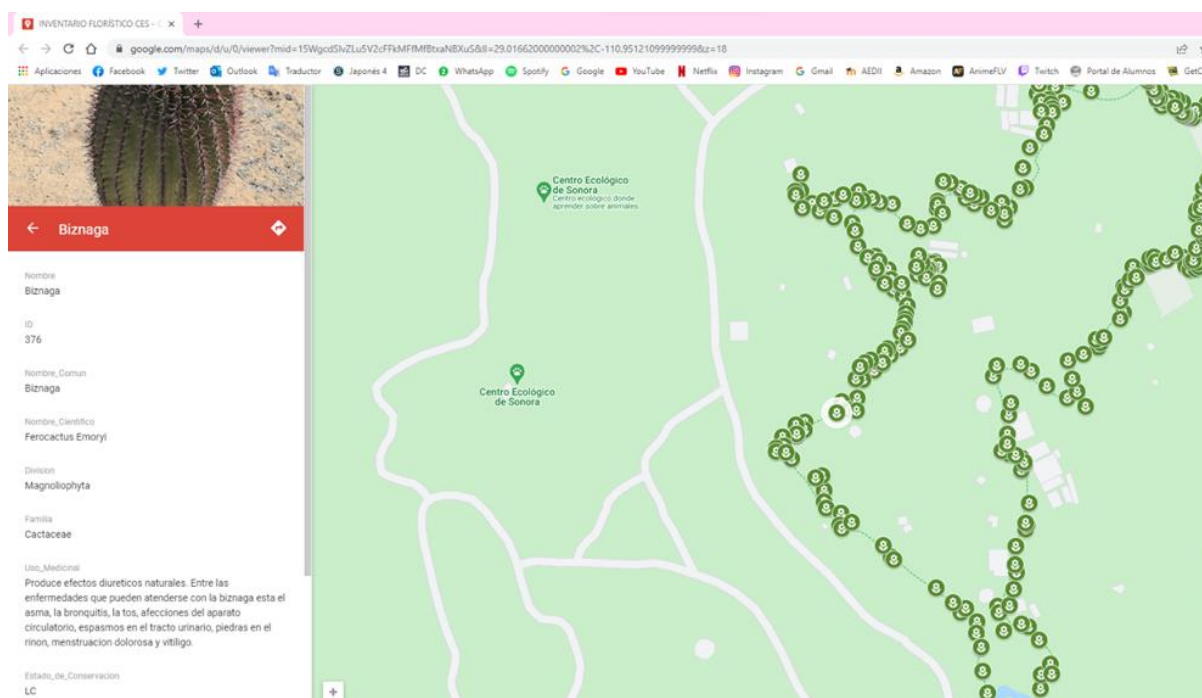


Figure 4. Characteristics of the plant of interest when are selected on the map





This tool also provides the search option if you need to perform a specific search for a species, this way you can write the name of the plant of interest, where similar to the inventory display, a left sidebar will be displayed showing the obtained results by the tool.

Finally, the generated link from Google My Maps was tested and verified on desktop computers, tablets and smartphones to verify that everything worked correctly, emphasis was placed on mobile devices, since today they are essential and practical. In this particular case, the map can be viewed by any visitor to the organization, who has a mobile device that has the Google Maps application. This device is easy to take to the different sites in the park and it is possible to consult the floristic inventory at any time you want or have any questions with the different species of plants scattered throughout the route.

RESULTS AND CONCLUSIONS

The research was developed due to the need of the Ecological Center of Sonora to have a better control of the location and maintenance of the endemic plants belonging to it, a methodology for inventory management that allowed the easy location of endemic flora of the region located along the entire main route of the center was designed and implemented in such way that the information included helps to make the right decisions, visualize the information as a complement to easy access both for the CES staff and for the general public. To improve the tourist attraction through the technological tool Google Maps and through the Google Earth database manager (both 100% compatible, adaptable, and efficient to the methodology). The use of common technological tools that everyone could access was considered not to complicate the process of this methodology.



The analysis of the location and/or distribution of the existing endemic flora and scattered along the route, it was obtained thanks to the use of a high-precision GPS tool provided by the University of Sonora, as well as the help of trained personnel for its' proper utilization; all this allowed us to obtain the locations of the flora through its coordinates with millimeter error margins.

Some important quantitative results were obtained, such as the number of registered species, the number of species with "Threatened" protection status, the location of the plants by means of coordinates and, qualitative information such as the different families to which each species belongs, its scientific and common name, in addition to the different medicinal properties that each plant has.

The social benefit obtained has been reflected in the results of a survey applied to the general public using the Likert scale, where out of 98 people interviewed, a total of 82 people find the information very interesting, 14 find it interesting but may present some vulnerability or dissatisfaction in the information embodied and 2 people are in the midpoint between totally agree and totally disagree regarding the interestingness of the information, which indicates that these people are dissatisfied with some characteristics. An advertising canvas was placed in the CES to encourage those interested in biological or medicinal areas when making a visit to view live and put into practice the learning of the native flora of the region. Through the implementation of this inventory, QR codes to access the map download and the map evaluation survey with the information obtained were generated.





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